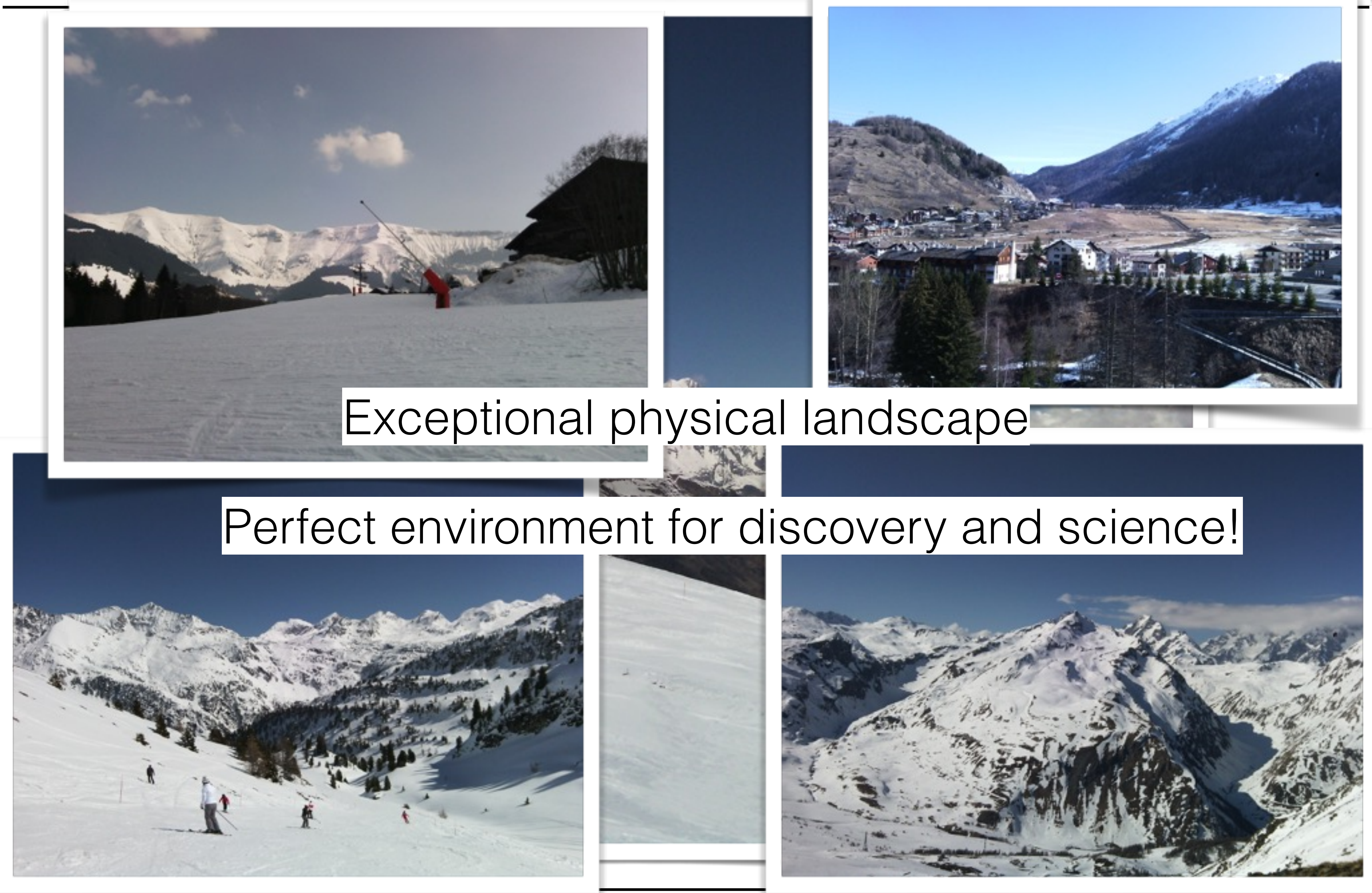
Highlights from 50th Rencontres de Moriond

Giacomo Ortona LLR-École Polytechnique

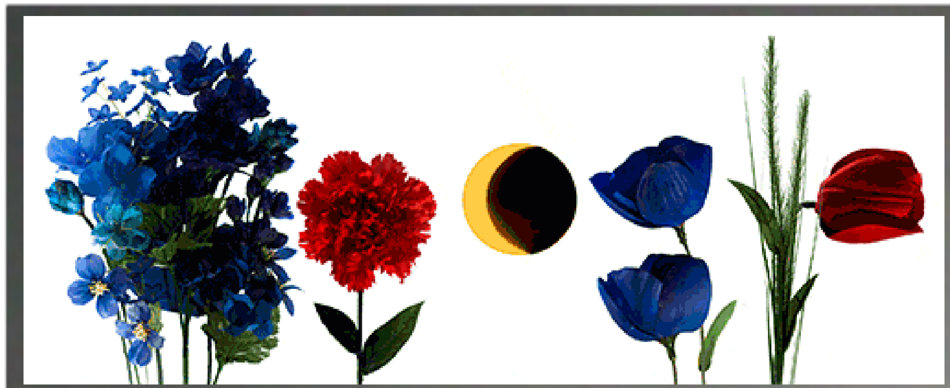
#1: sky, snow and scenery

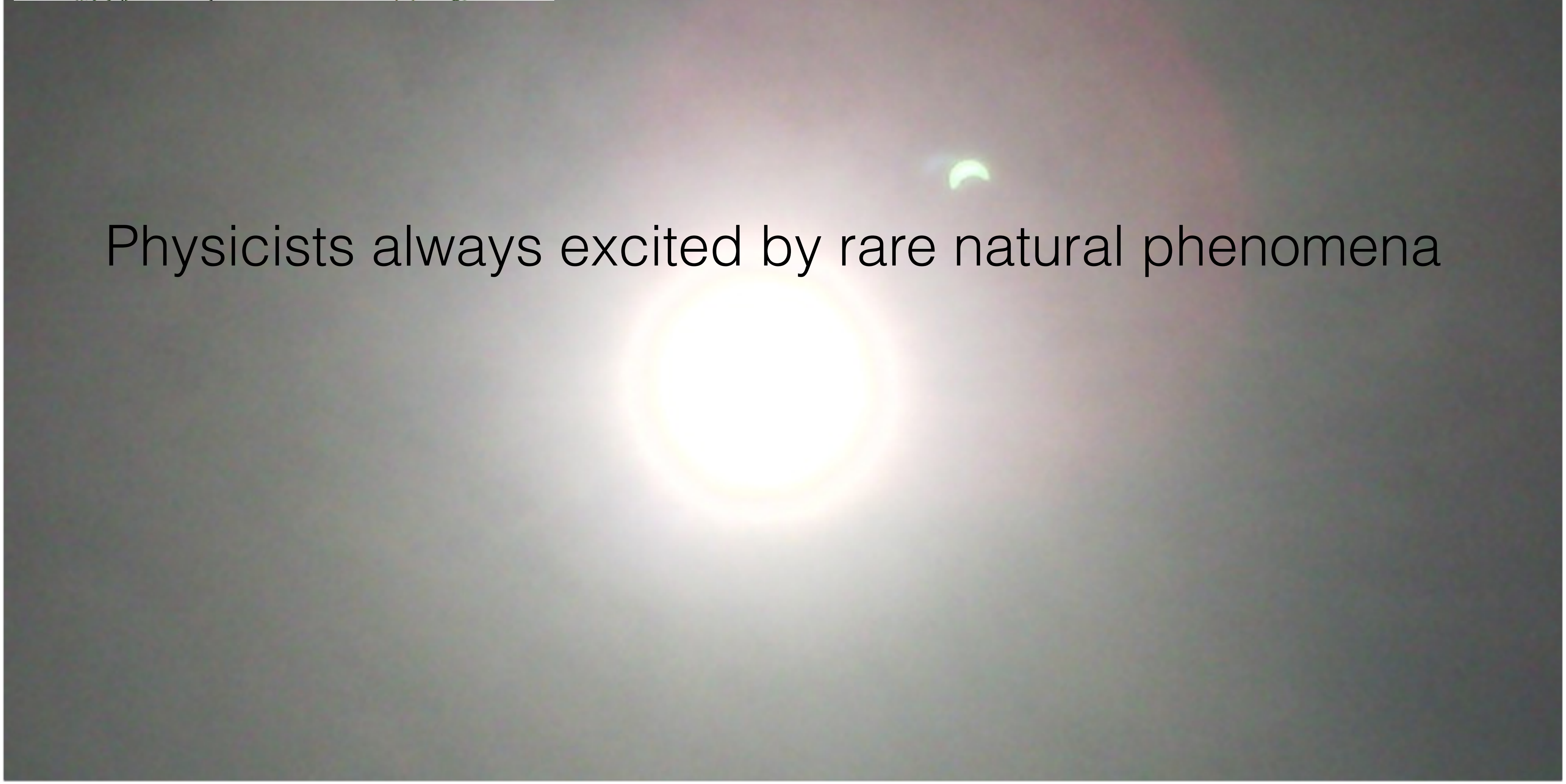


Exceptional physical landscape

Perfect environment for discovery and science!

#2: 20th March solar eclipse





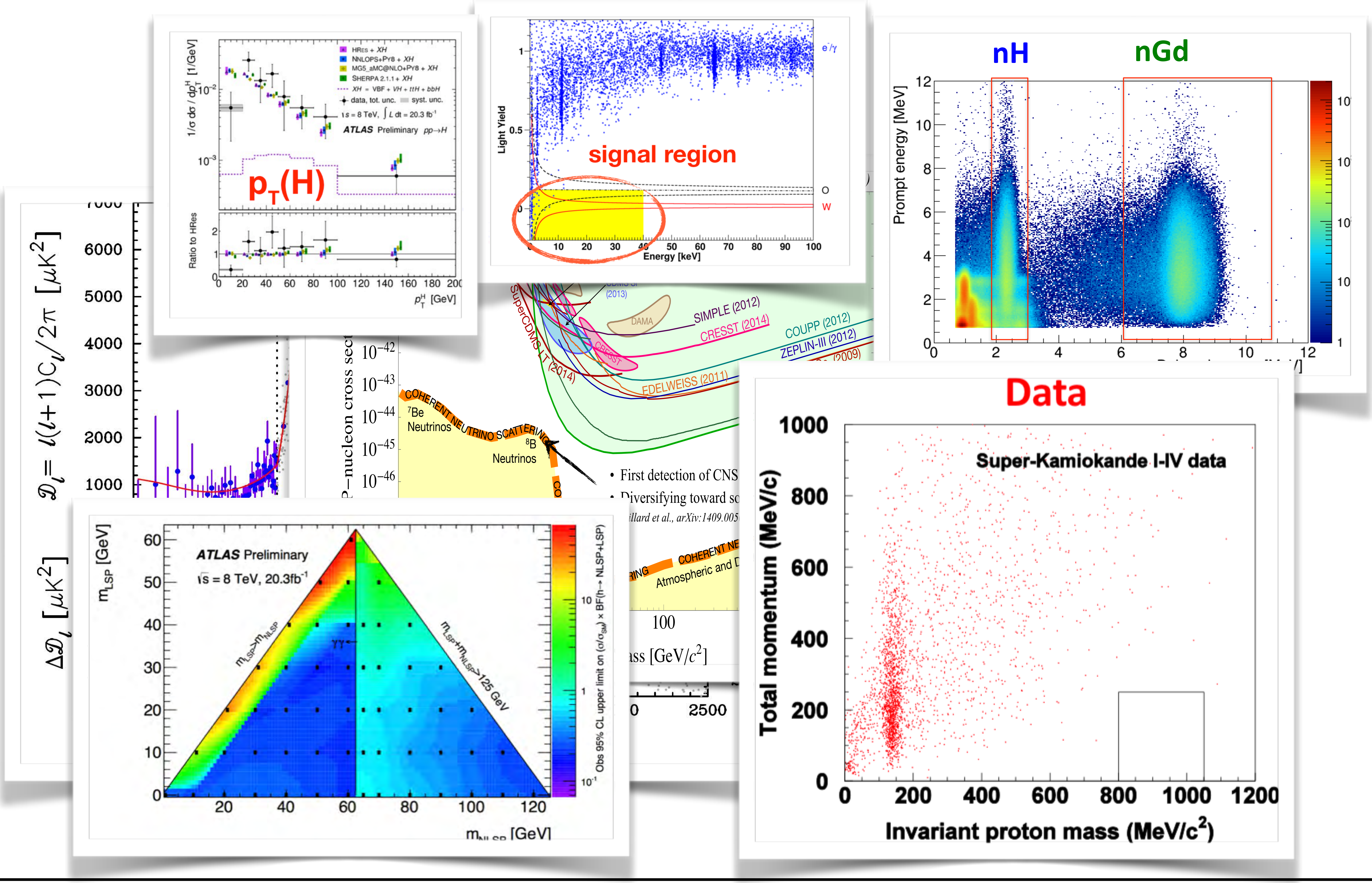
Physicists always excited by rare natural phenomena

#2: 20th March solar eclipse

Physicists always excited by rare natural phenomena

State-of-the art technology to observe it

#3: Plenty of exciting physics results



Disclaimers

- A wise person said: "Never do the summary talk at a conference where you can sky"
- The conference ended on saturday
  - These are my feelings and the results that most impressed me, without any deep afterthought
  - It doesn't pretend to be fully complete
  - All inaccuracies are my own
  - Much more experiment then theory
- The program was rich and interesting
  - Don't be upset if your favourite result is not here!

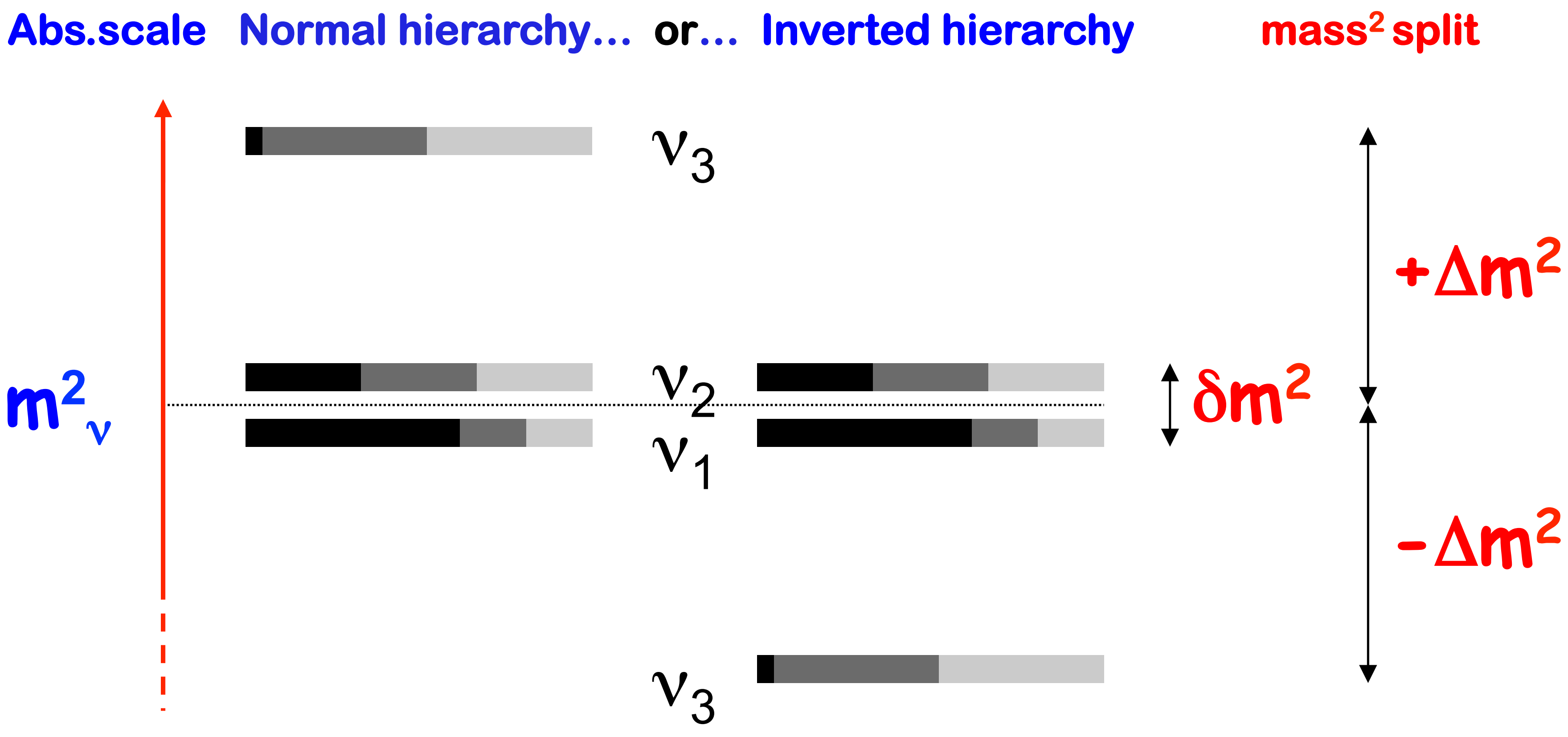
Outline

- Neutrinos
- Dark matter
- Scalar sector
- Standard Model
- BSM
- Top
- Heavy Flavours
- Miscellanea
- Prize winners: Higgs mass and LHCb $B \rightarrow K^{*}\mu\mu$

ν, status

$$\text{PMSN} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{bmatrix} \begin{bmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{bmatrix} \begin{bmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & e^{i\alpha/2} & 0 \\ 0 & 0 & e^{i\beta/2} \end{bmatrix}$$

[only if Majorana]



Terra Cognita:

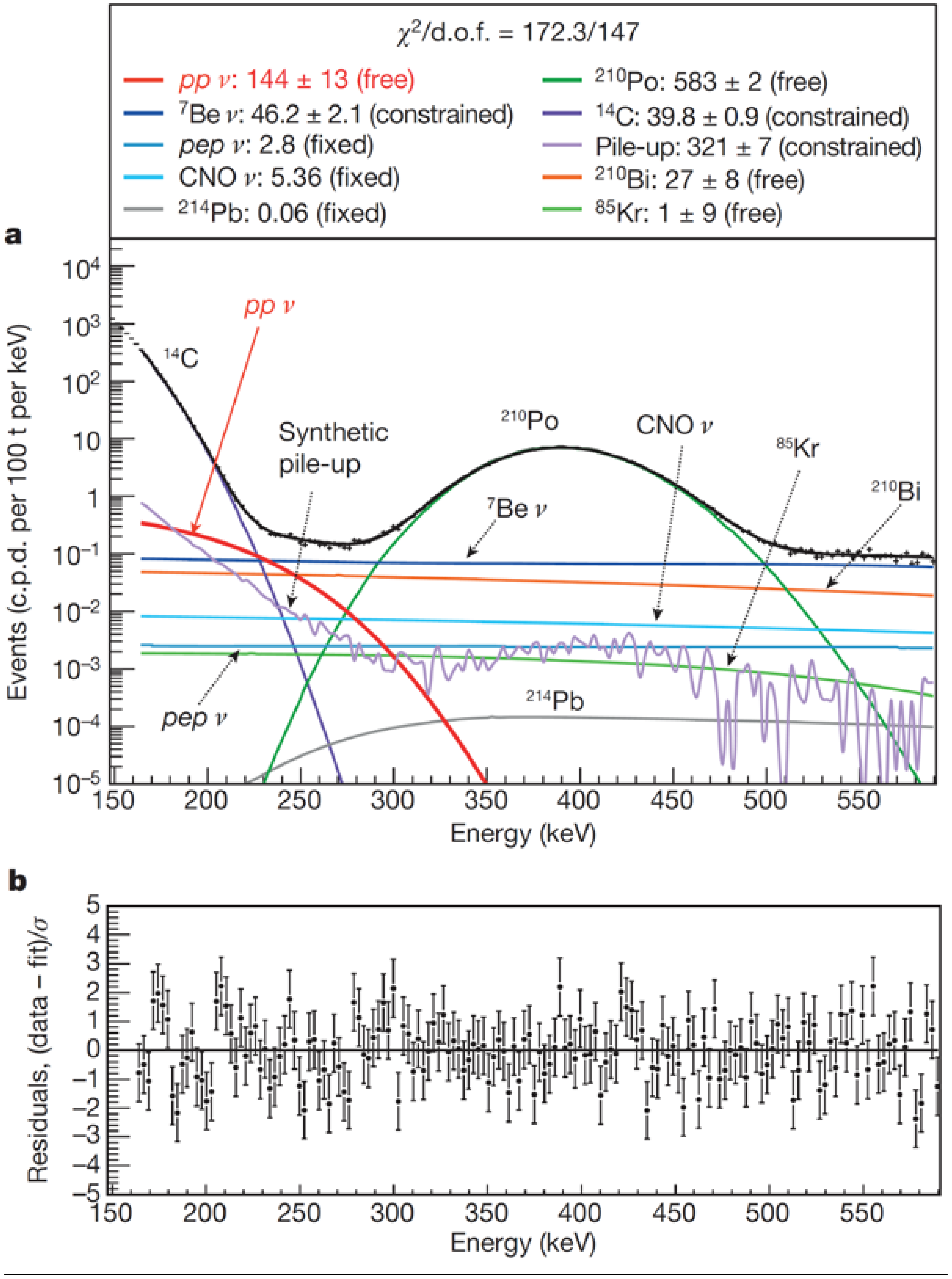
δm^2 ~ 8 x 10^{-5} eV^2
Δm^2 ~ 2 x 10^{-3} eV^2
$\sin^2\theta_{12}$ ~ 0.3
$\sin^2\theta_{23}$ ~ 0.5
$\sin^2\theta_{13}$ ~ 0.02

Terra Incognita:

δ (CP)
sign(Δm^2)
octant(θ_{23})
absolute mass scale
Dirac/Majorana nature

Results from ν experiments

- Borexino (Solar ν)
  - pp-ν rate = 144±13±10 cdp/100t
  - Φ_{pp}=6.6±0.7x10^{10}cm^{-2}s^{-1} (10σ)
  - νe→νe survival rate ~64%
- Daya-Bay (Reactor experiment)
  - $\sin^2 2\theta_{13} = 0.084^{+0.005}{}_{-0.005}$
  - $|\Delta m_{ee}{}^2|=2.44\ _{-0.11}{}^{+0.10}10^{-3}(eV^2)$
  - $10^{-3}eV^2<\Delta m_{41}{}^2<0.1eV^2$
- SuperKamiokande (Long Baseline)
  - $\tau_{p\rightarrow e\pi} > 1.4\times10^{34}$ years (90% CL)
- EXO200 ν-less β decay
  - No events $\tau_{1/2}\ 0\nu\beta\beta>1.1x10^{25}$yr



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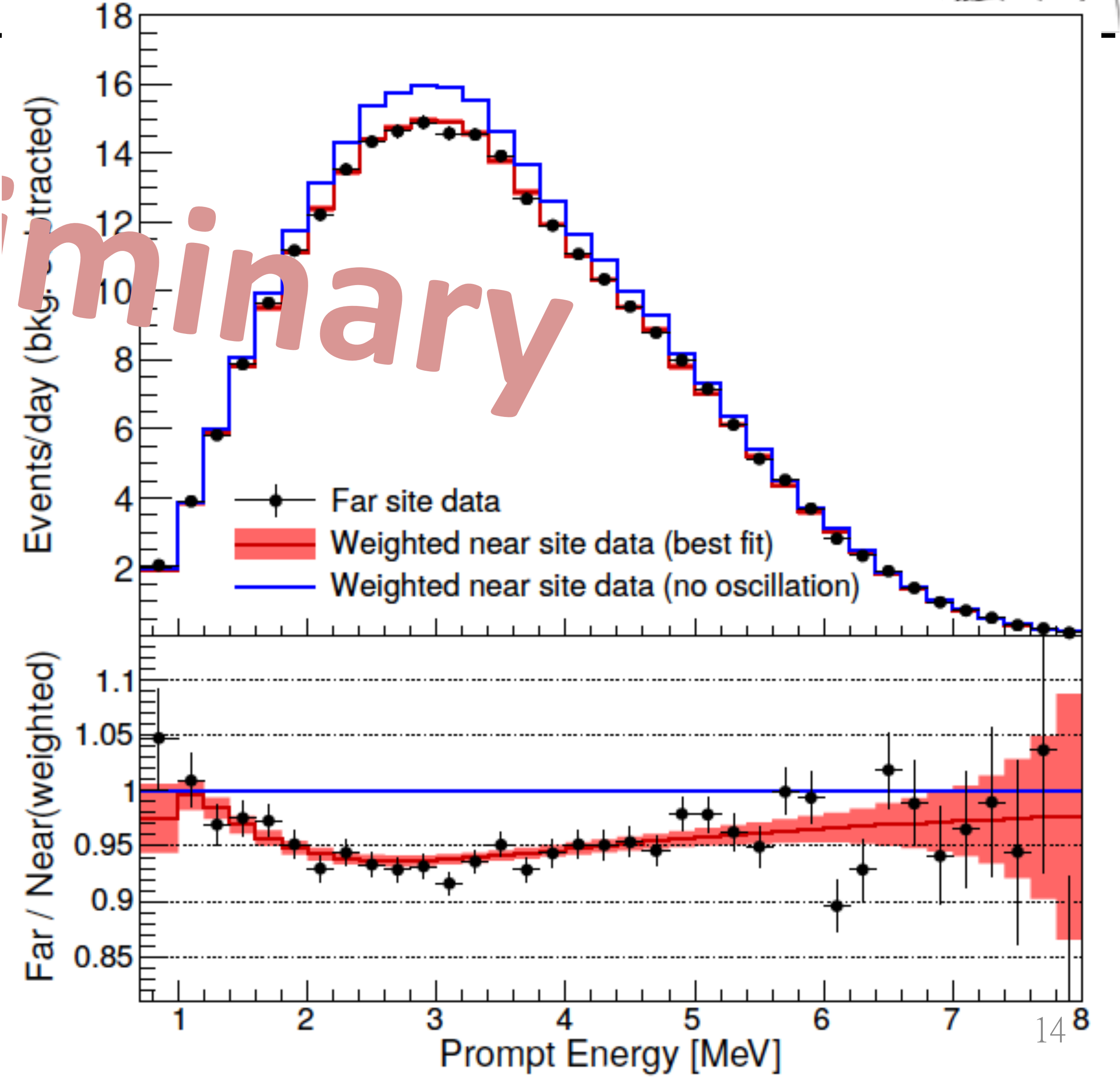

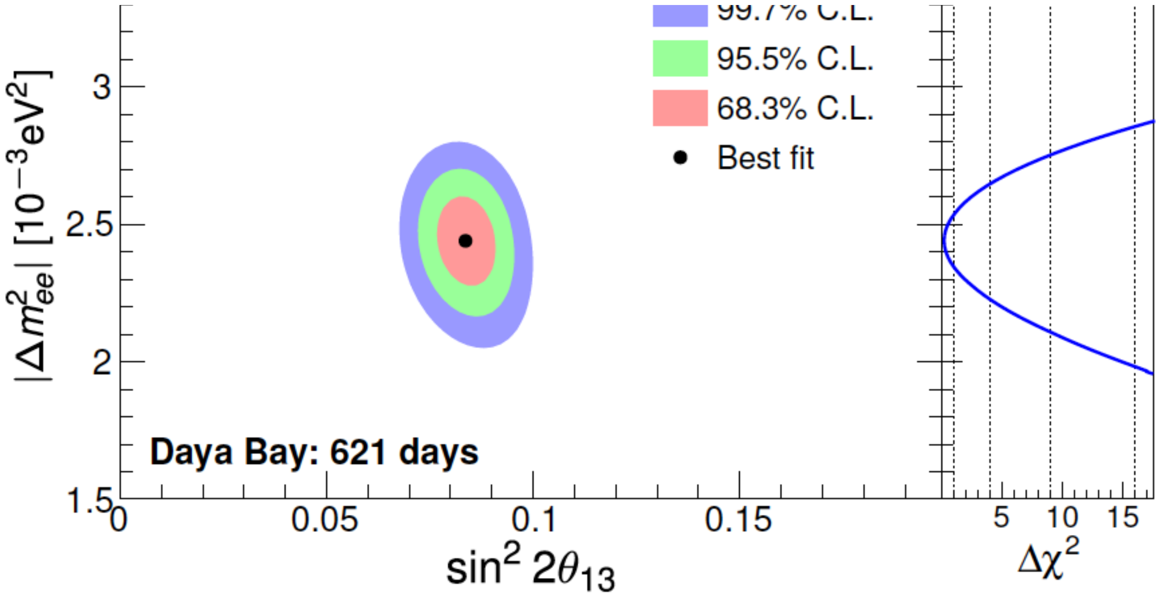

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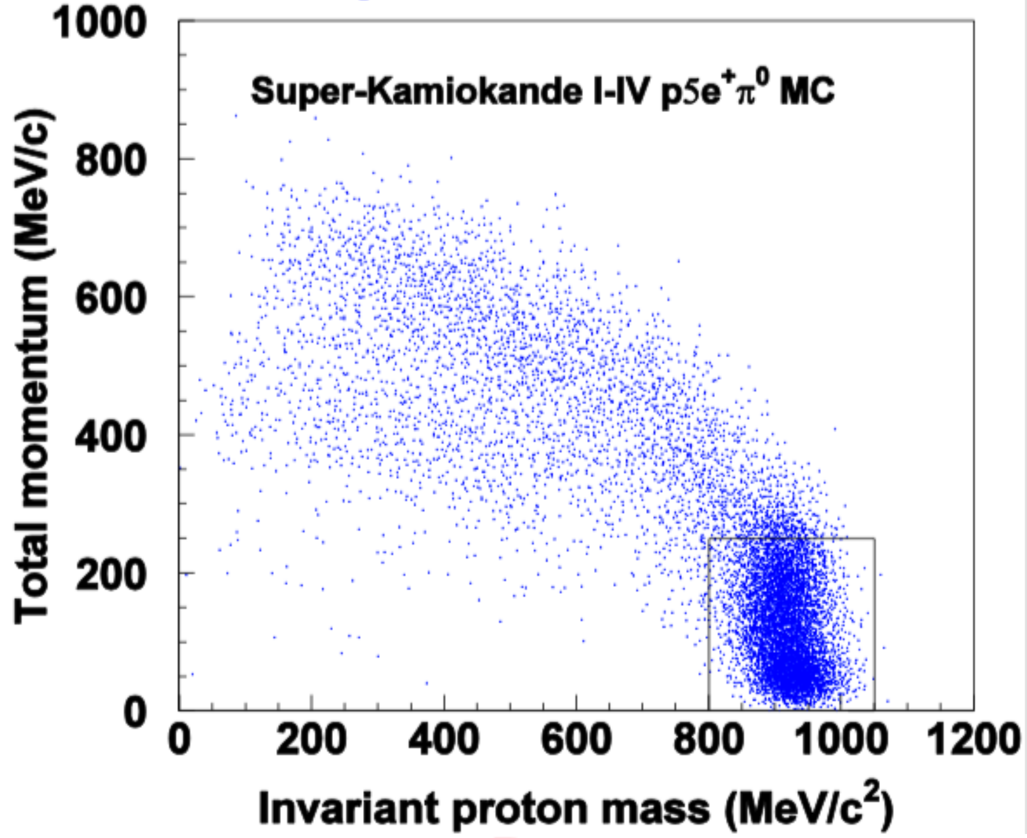
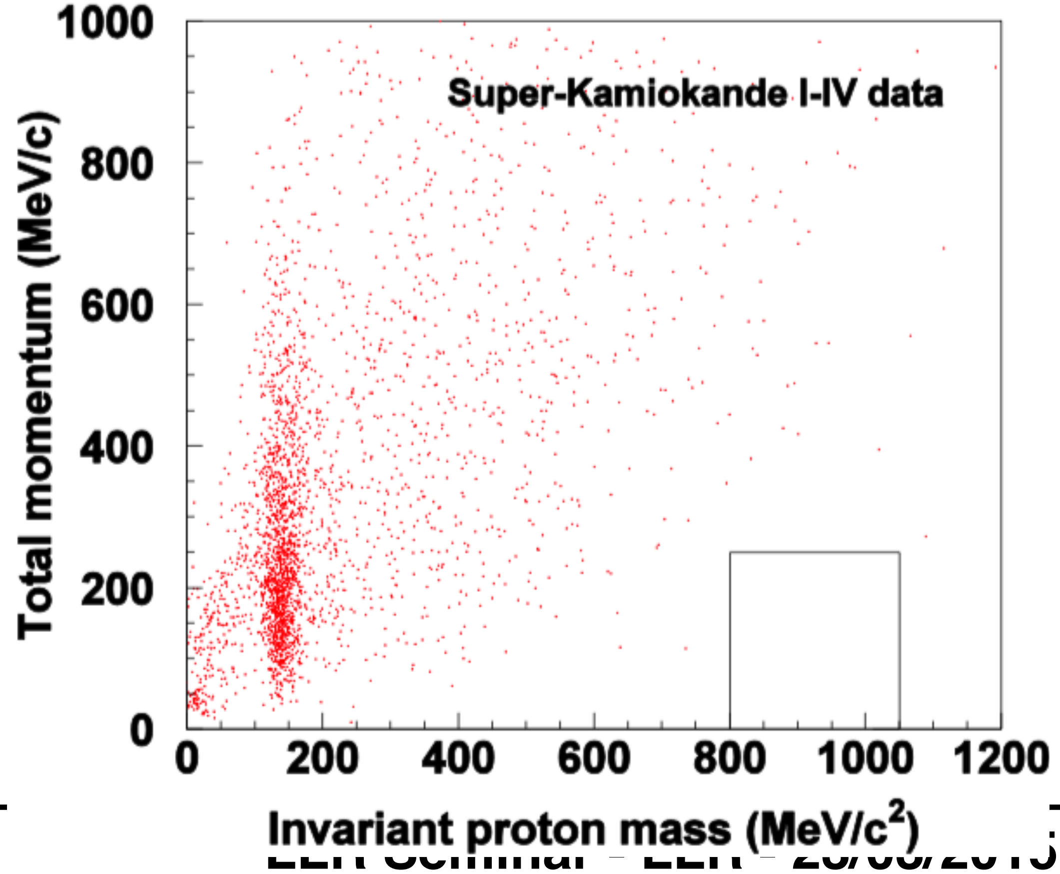
p→eπ⁰ MC



Data



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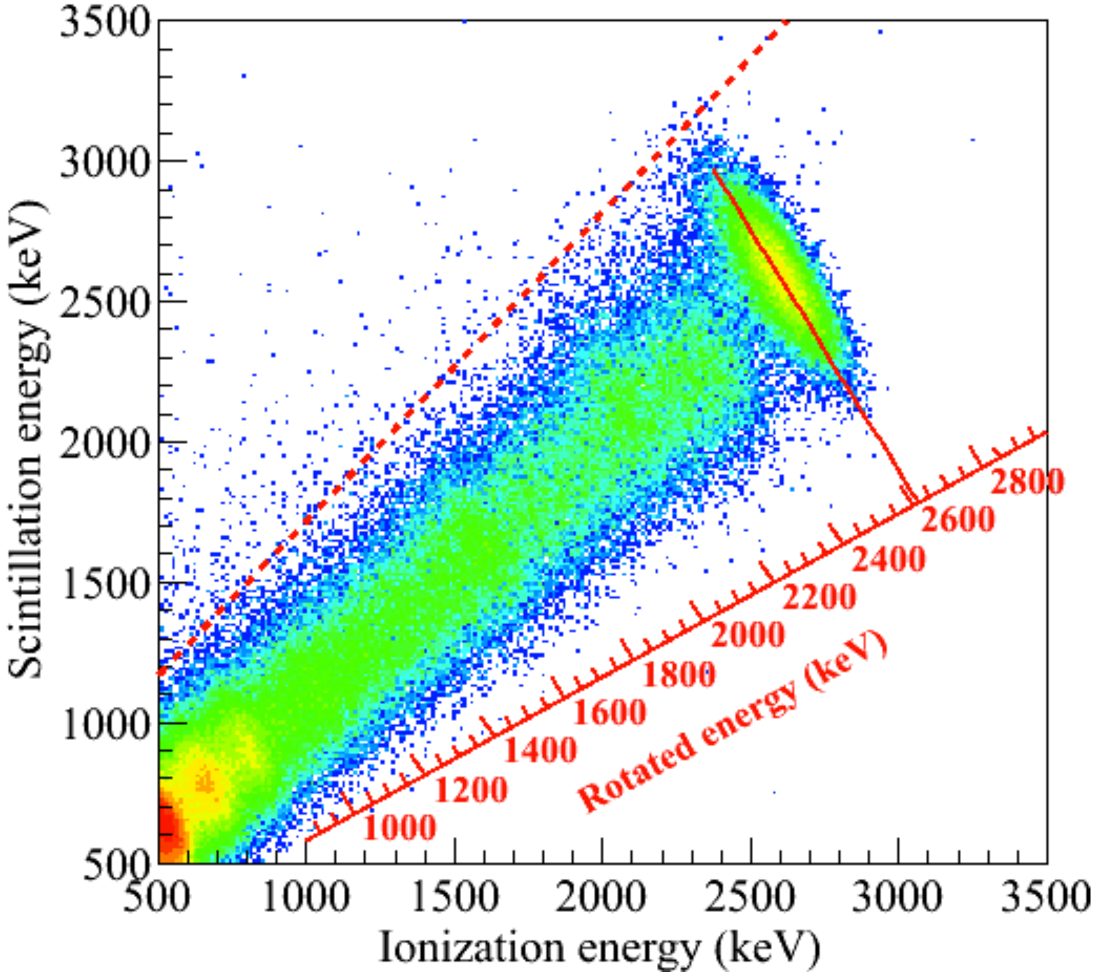
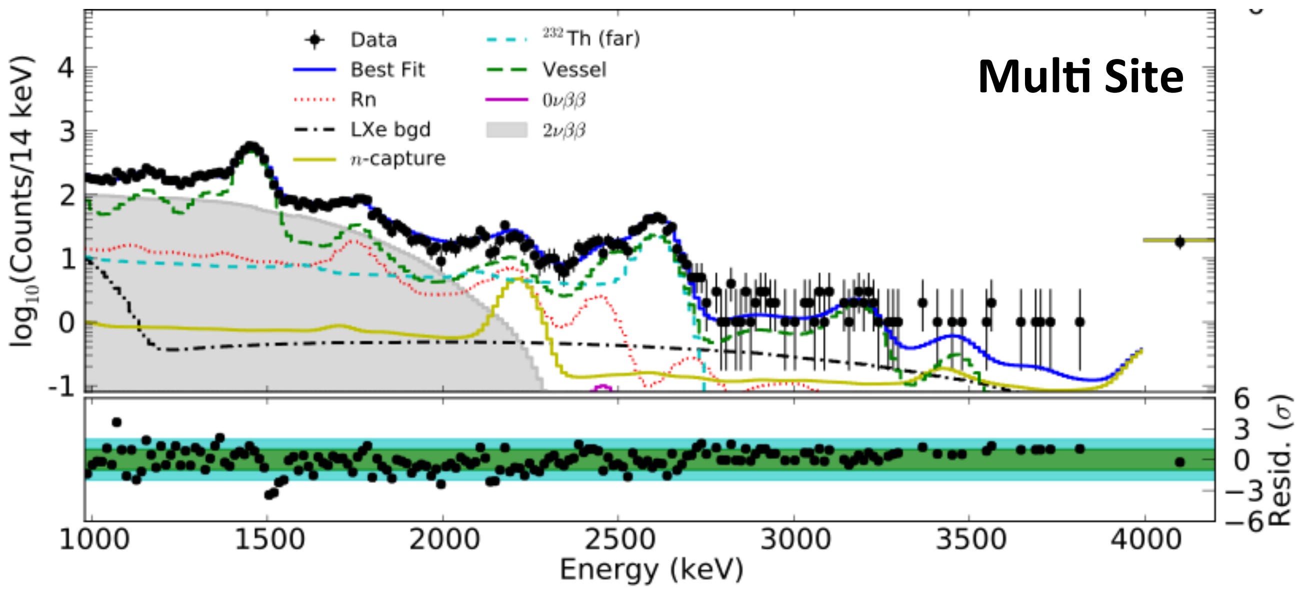
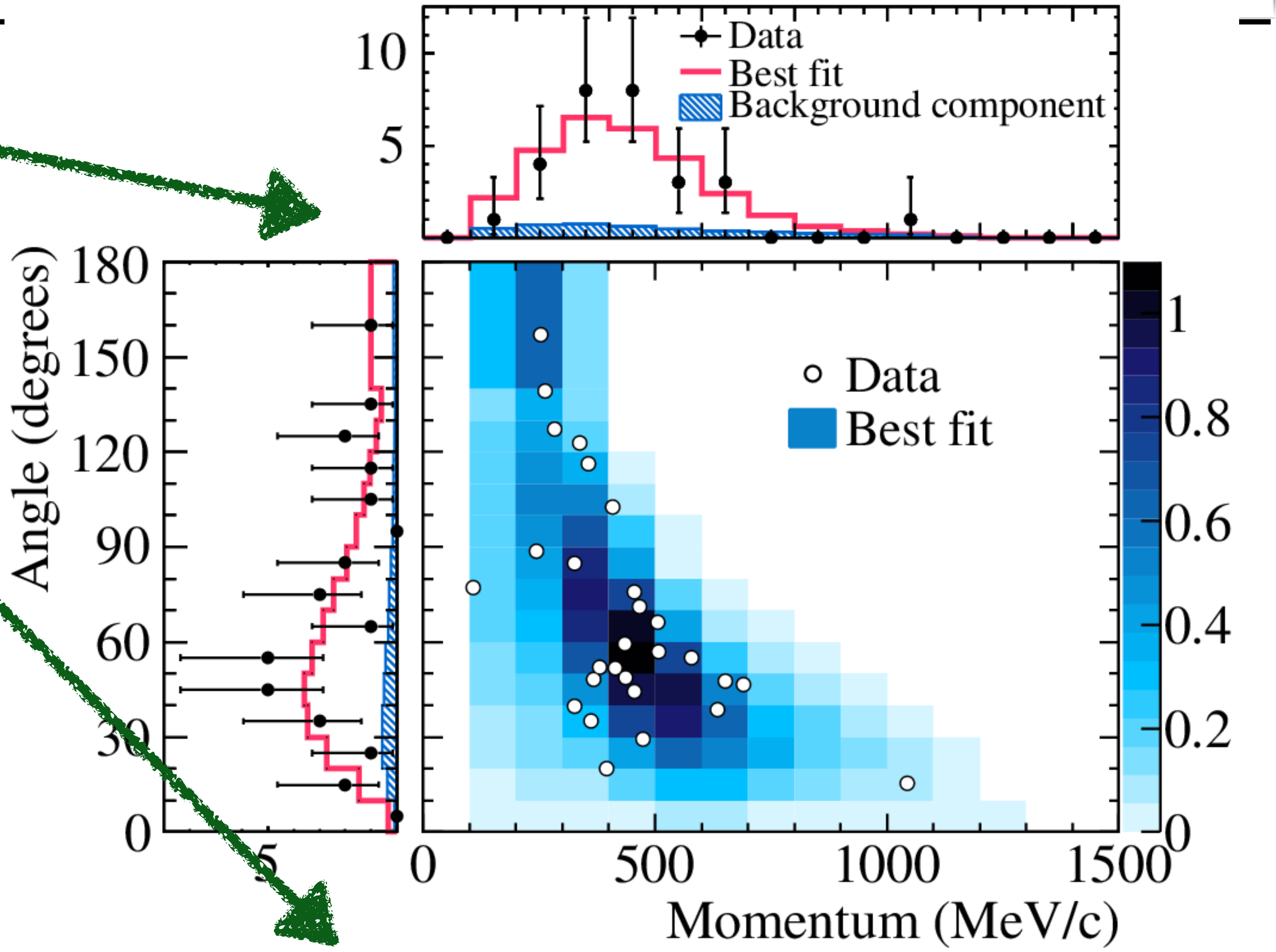
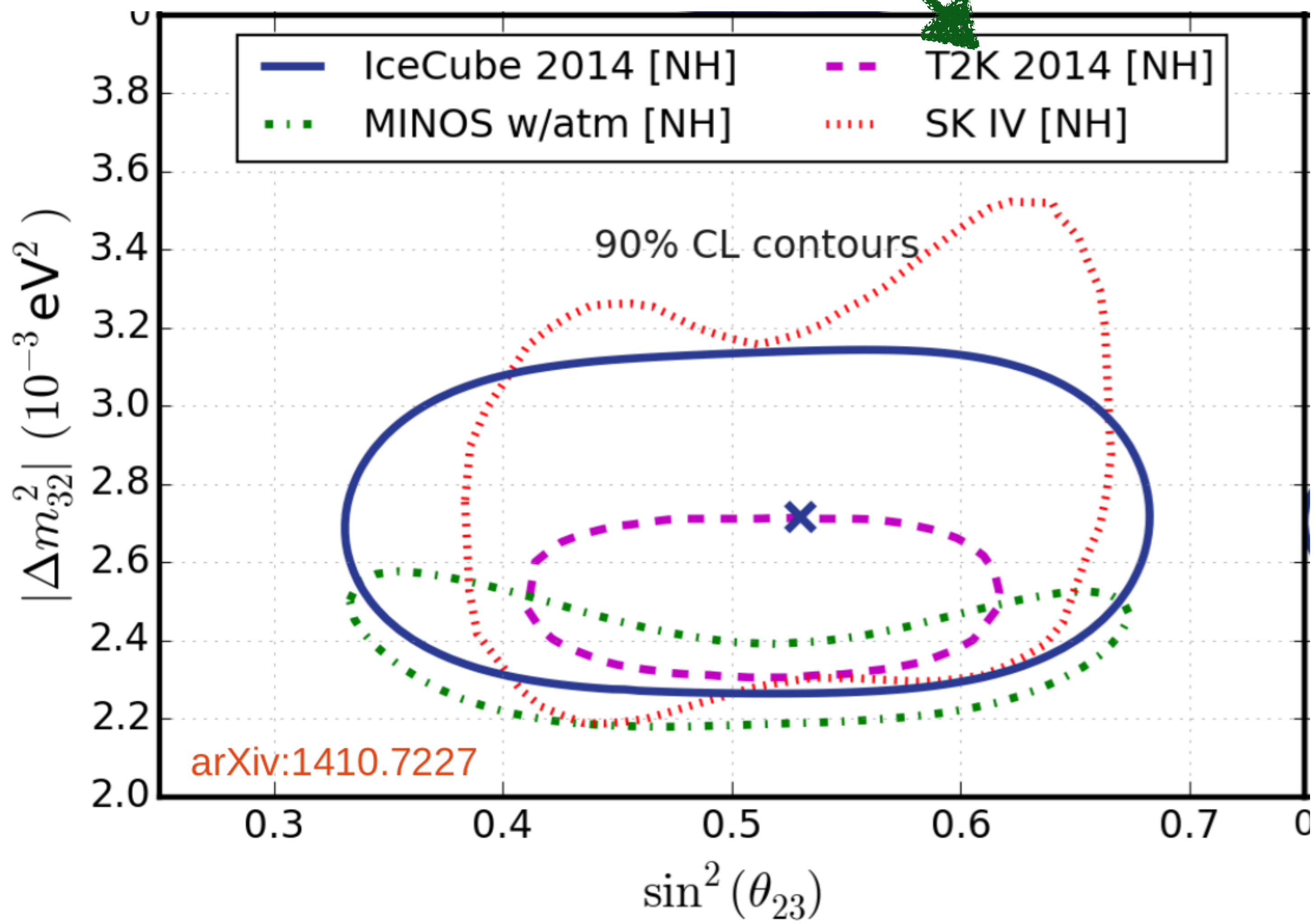




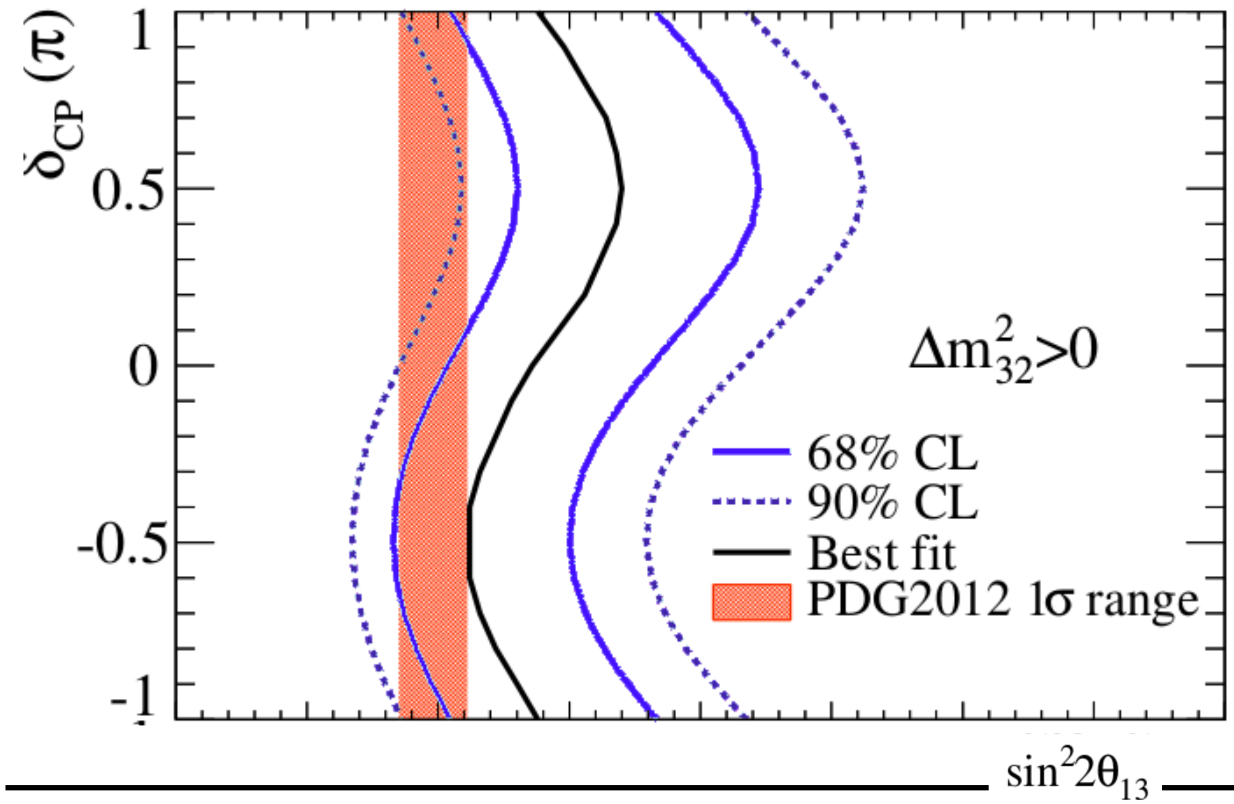
T2K

- Observation of $\nu_\mu \rightarrow \nu_e$ with 7.3σ significance
- No statistically significant measurement of δ_{CP}, but $-\pi/2$ looks favoured
- World best measurement of θ_{23} in ν_μ disappearance

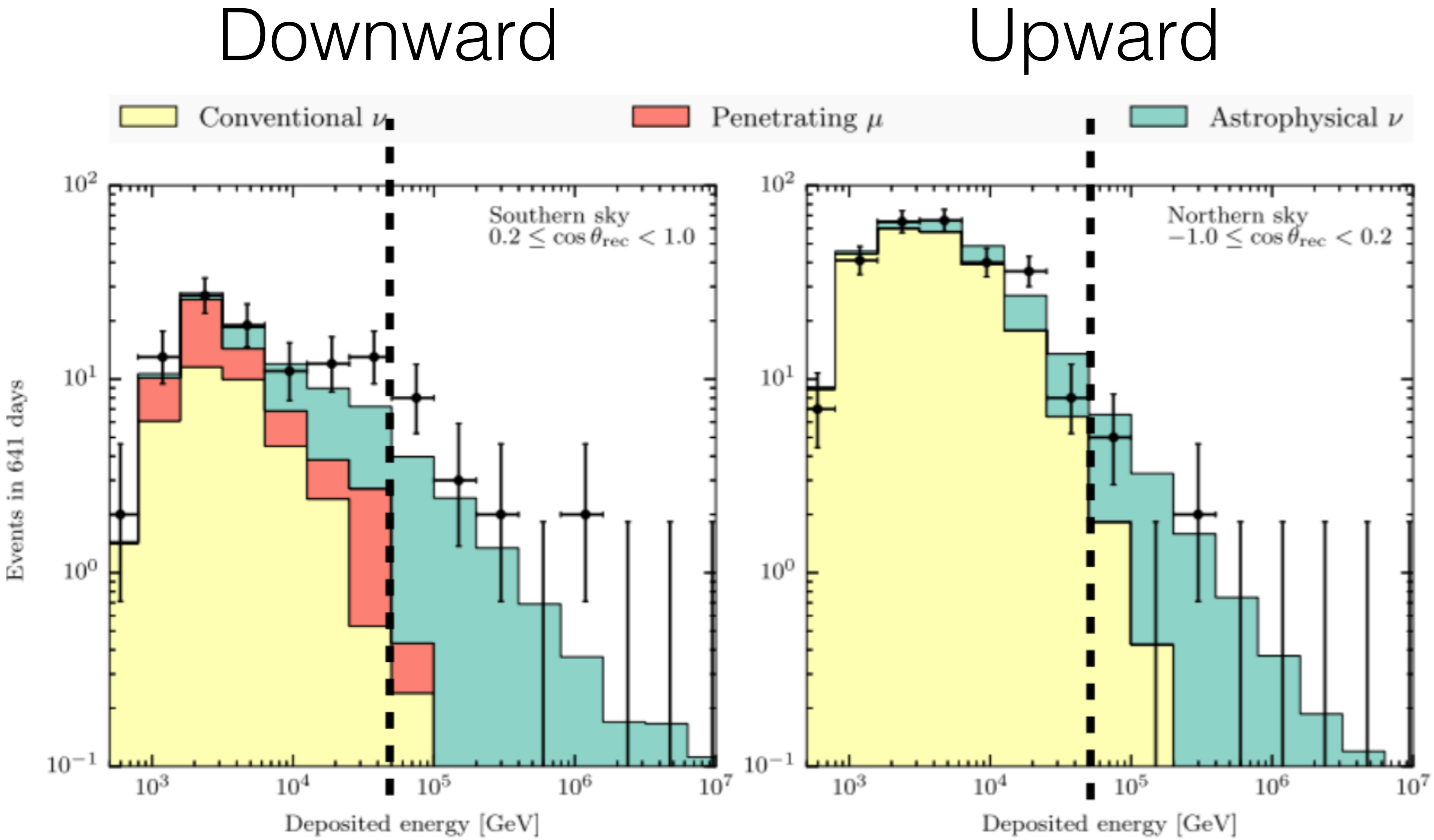




arXiv:1410.7227



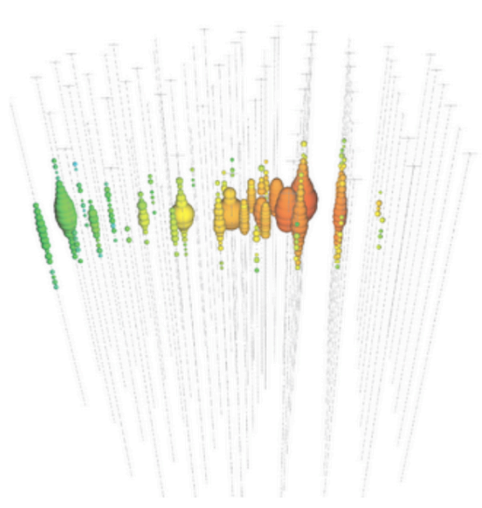
VHE ν in IceCube (I)



- Low energy part of the spectrum shows very good understanding of atmospheric ν bkg
- 37 HE candidates
- 5.7σ evidence for astrophysical ν origin

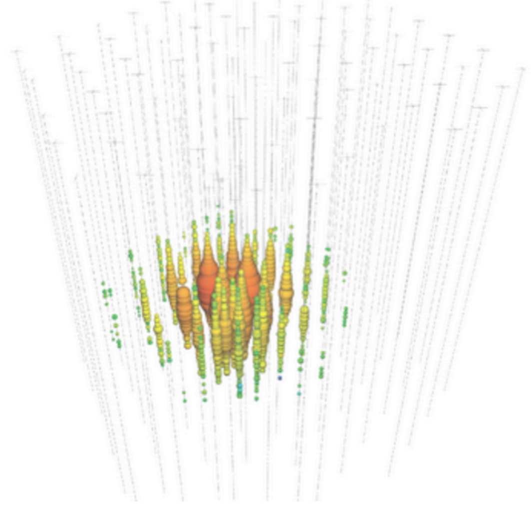
VHE ν in IceCube (II)

Muon track



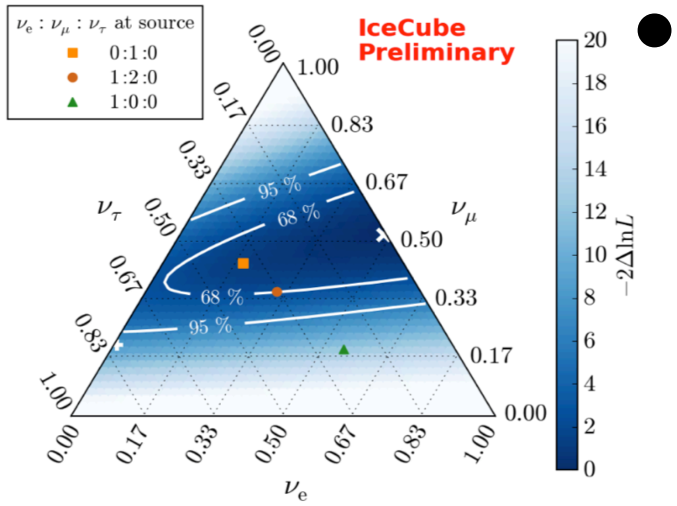
$\nu_\mu + N \rightarrow \mu^- + X$

Shower (cascade)

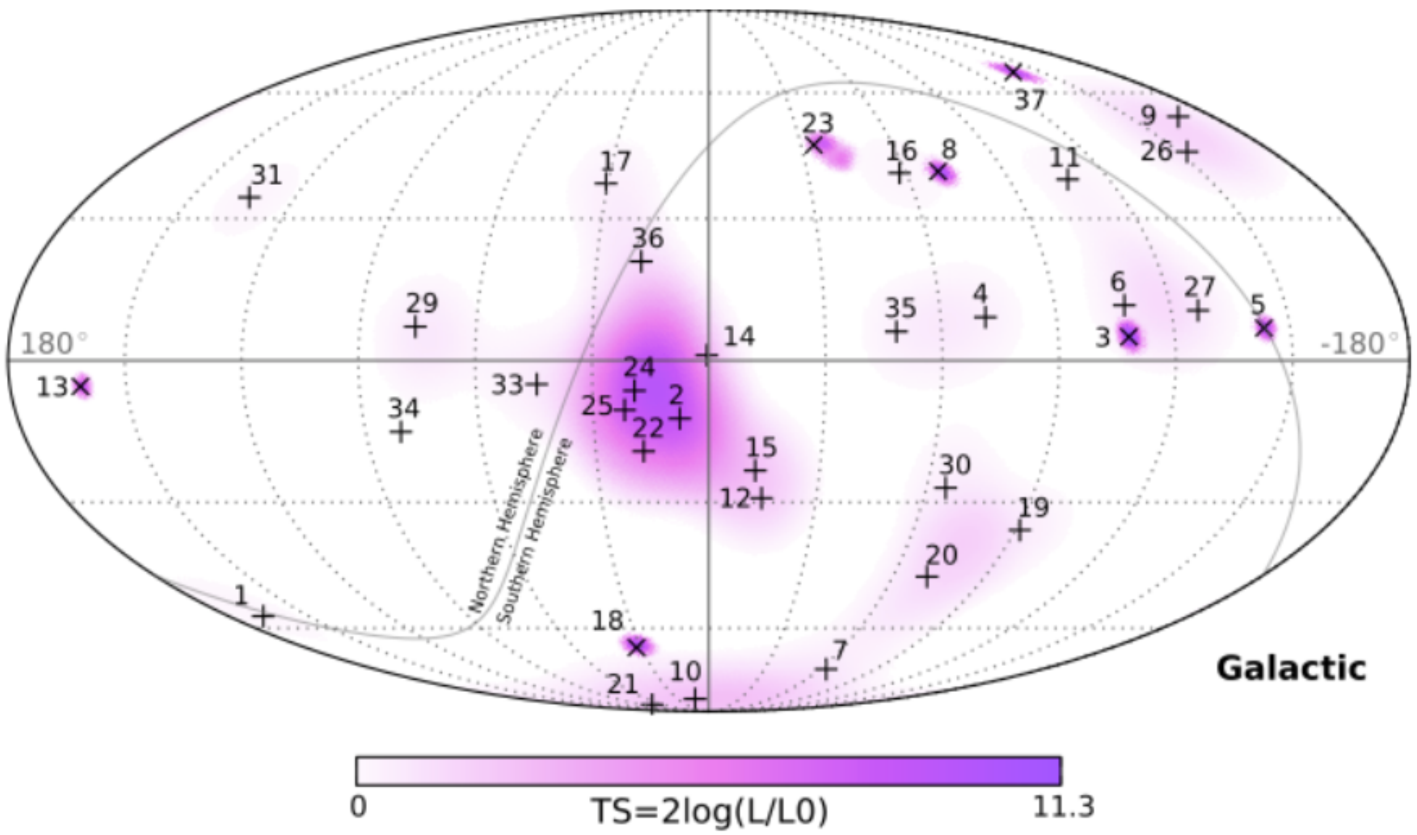


ν_μ (NC), ν_e, ν_τ

- Event topology give information on ν flavour
- 9 tracks, 28 showers
  - $N_{tracks} \approx$ expected N_{bkg}
  - Proposed an interpretation which leaves room for increased ν x-section

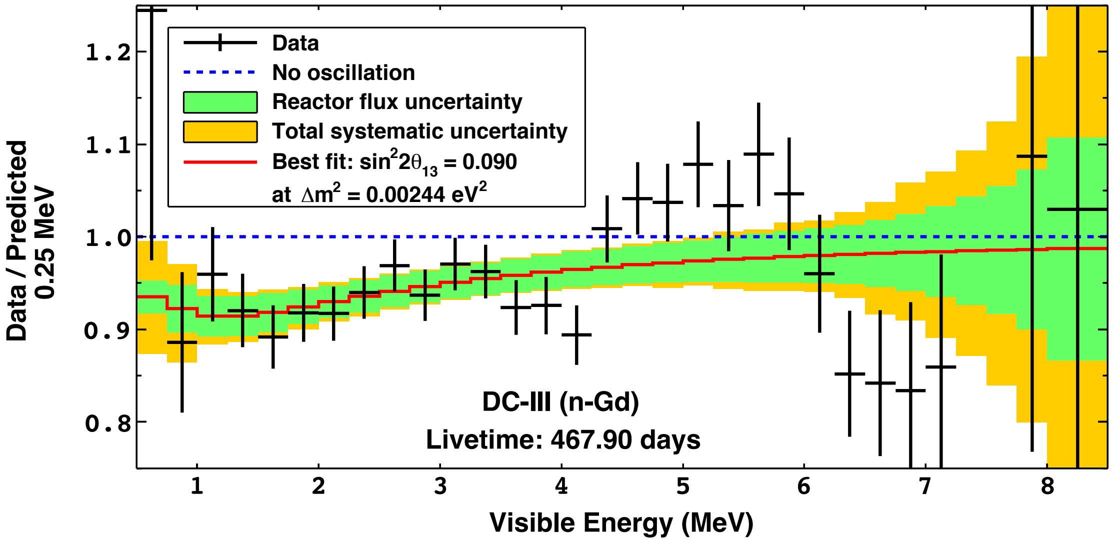


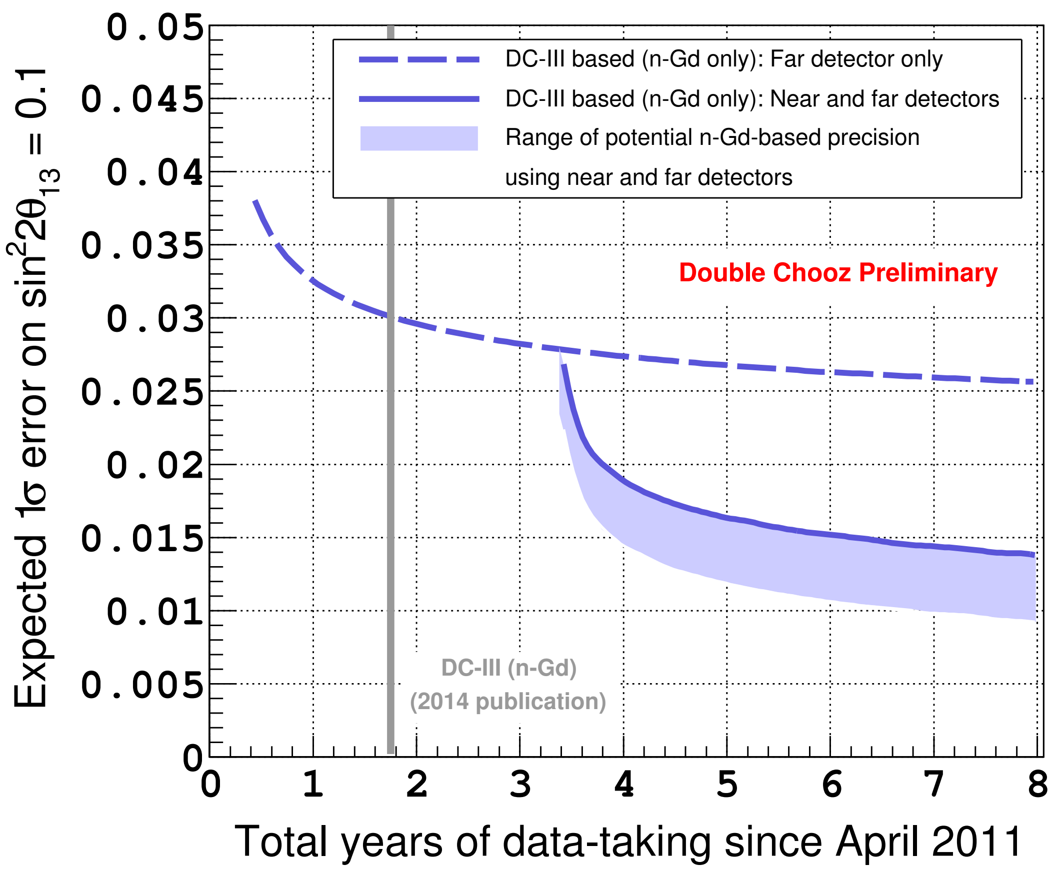
- Within uncertainties, data consistent with 1:1:1 flavour composition naïve expectation
  - But no agreement on what to expect
- No evidence for clustering



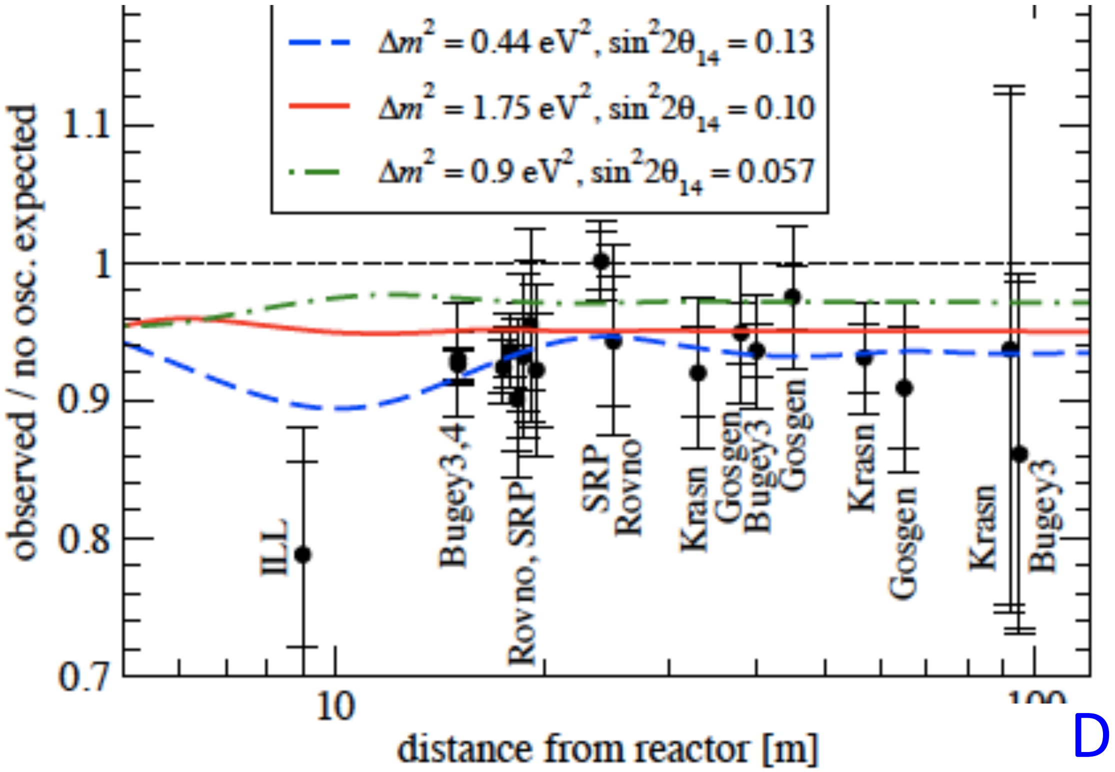
Double Chooz

- Located at Chooz, France
- Measure θ_{13} via $\nu_e\nu_e$ disappearence
- 8.3t Gd-doped liquid scintillator, with 18t undoped liquid scintillator to detect γ
- Detectors at nearly isoflux positions
    - Far: 1115/998m, Near: 465/351m from reactors
    - Reactors systematics errors >90% suppressed
- Near detector completed! Taking data since december
- After ~468 days of data (with far detector only):
    - $\sin^2 2\theta_{13}=0.090^{+0.032}_{-0.029}$





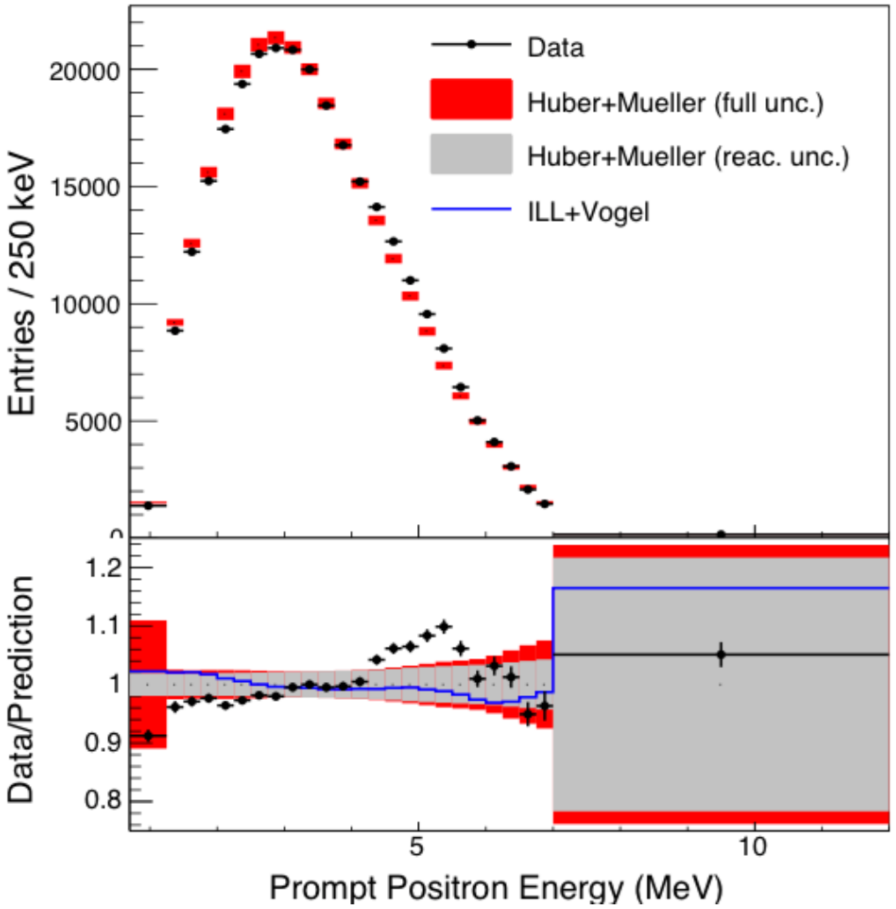
Reactor anti-ν anomaly (I)



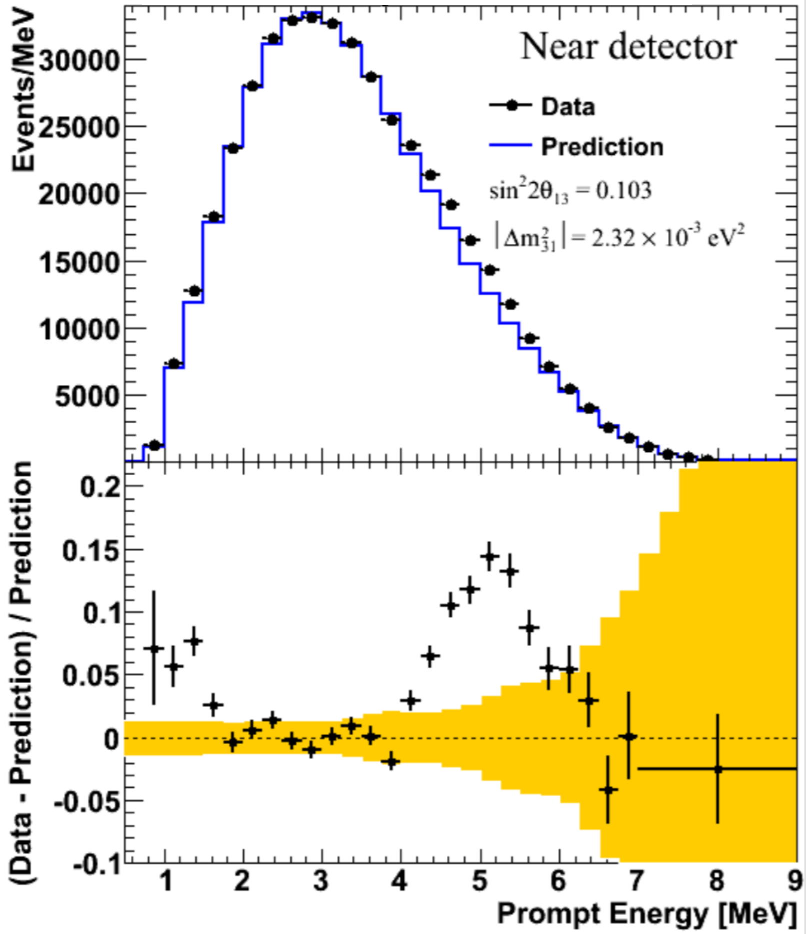
- Very difficult calculations
- Quoted syst. can be underestimated by ~2
- Need for new experiments
- Until new data, claims for ν_s on this basis should be rejected

- Observed/ Expected=0.94 (~3σ) deficit in anti-ν rate in short baseline reactor experiments

Daya Bay



RENO



Outline

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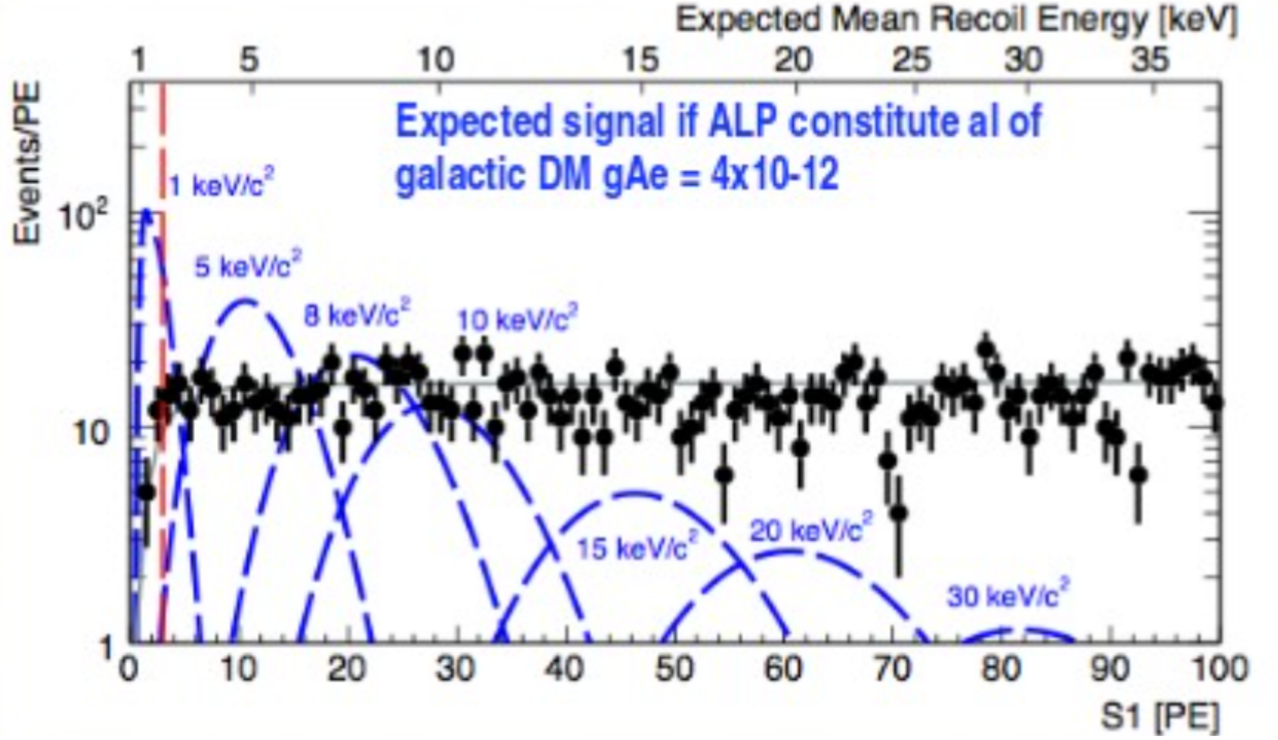
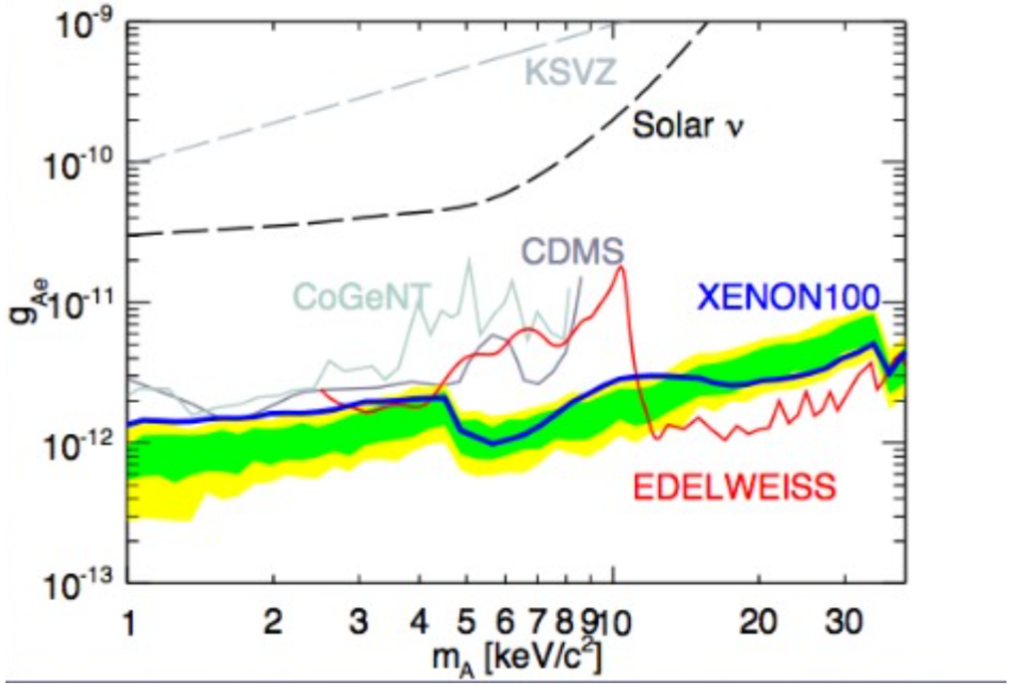
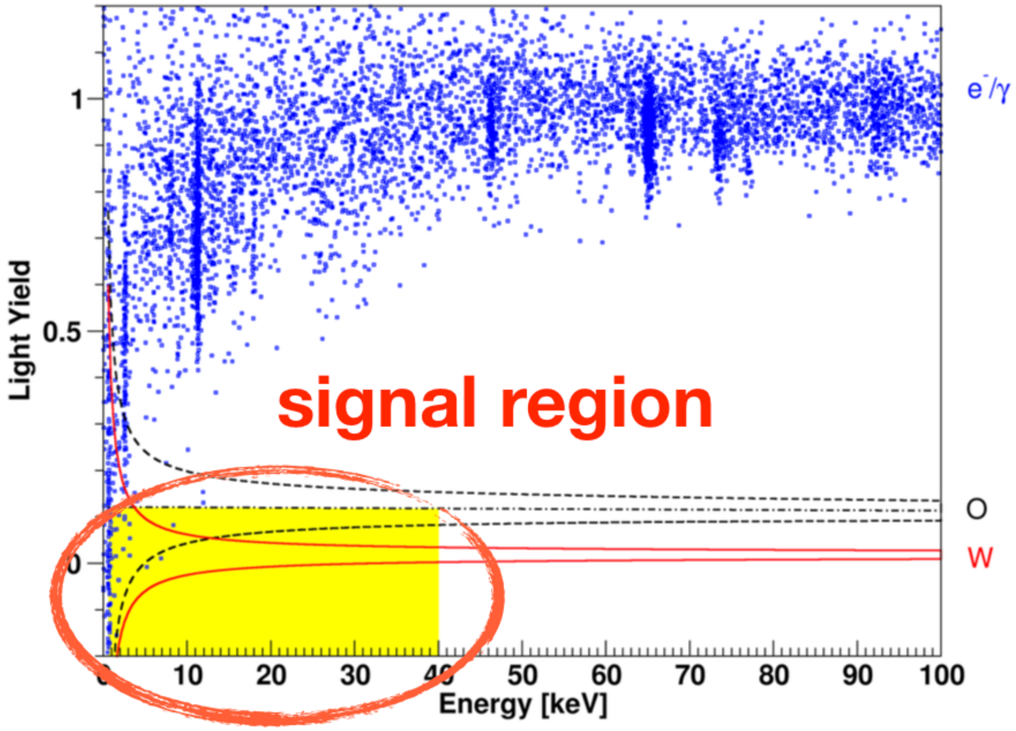
Direct searches for DM

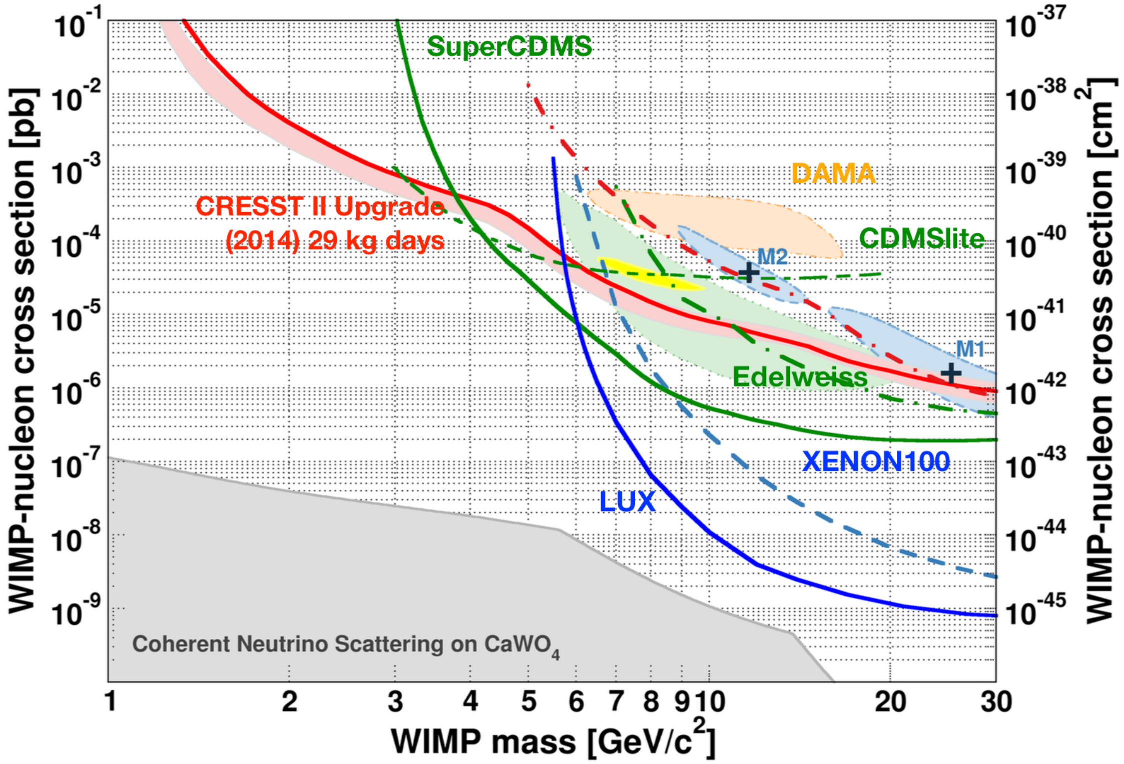
- XENON100 (62 kg target–scintillation light+ionization): Axion search





- CREST-II (phonons + scintillation) 600 eV threshold

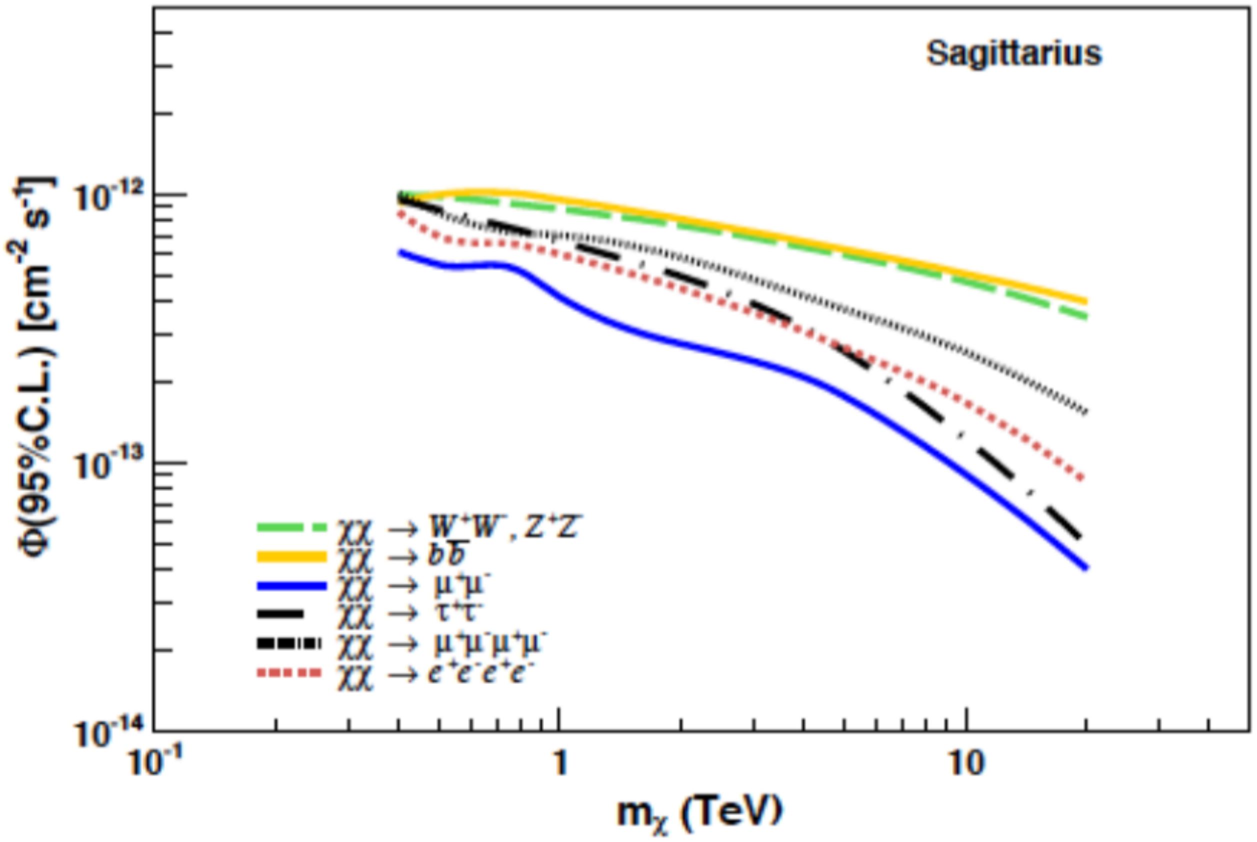




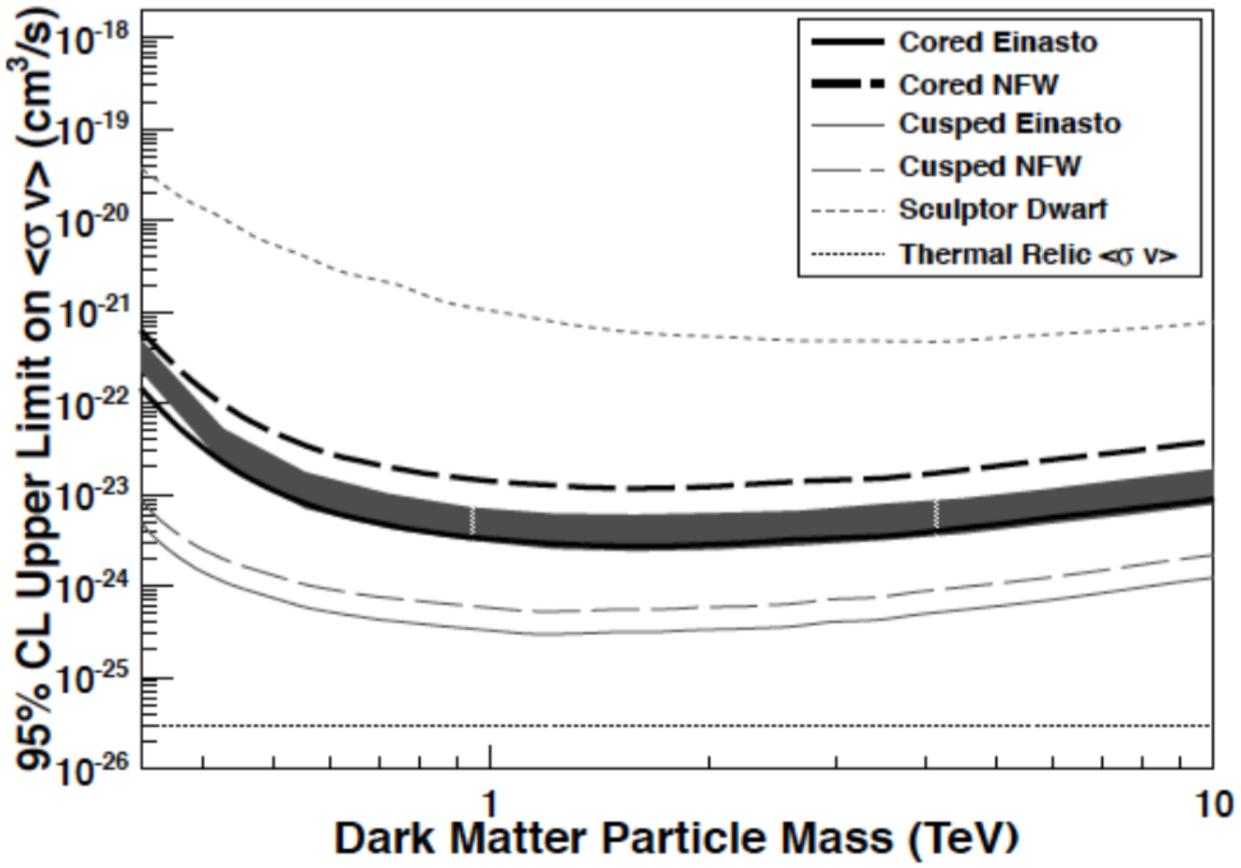
Indirect searches for DM

- Search for astrophysical sources of DM annihilation into SM particles
- Search targets: regions where large DM densities are expected
  - Dwarf galaxies, inner galactic halo
- Main results from HESS
  - 4x12m telescopes, 1x28m telescope
- No evidences so far even using updated DM models (flat in galactic core)

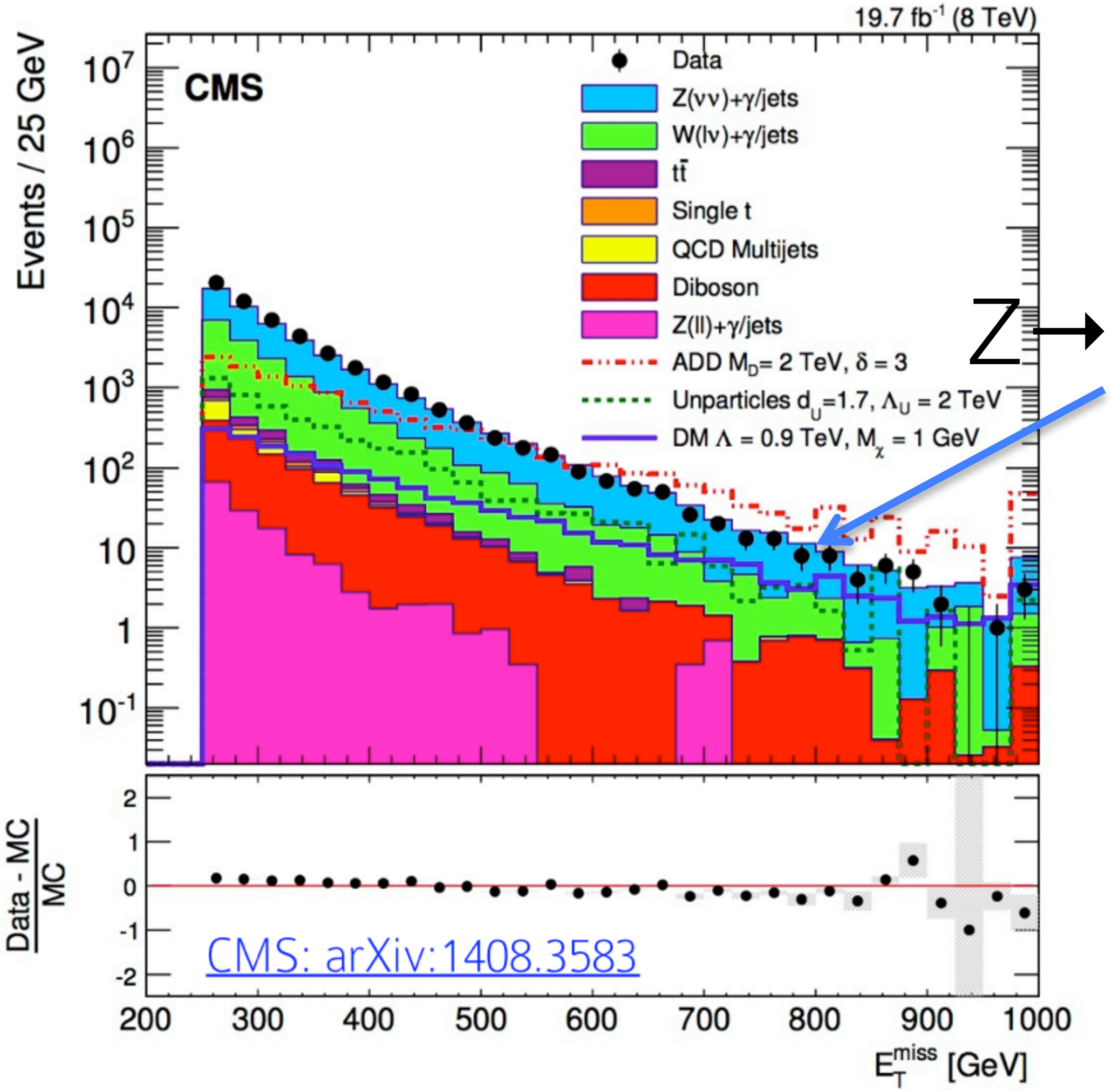
Dwarf galaxies



Inner galactic halo



Collider searches for DM



CMS: arXiv:1408.3583

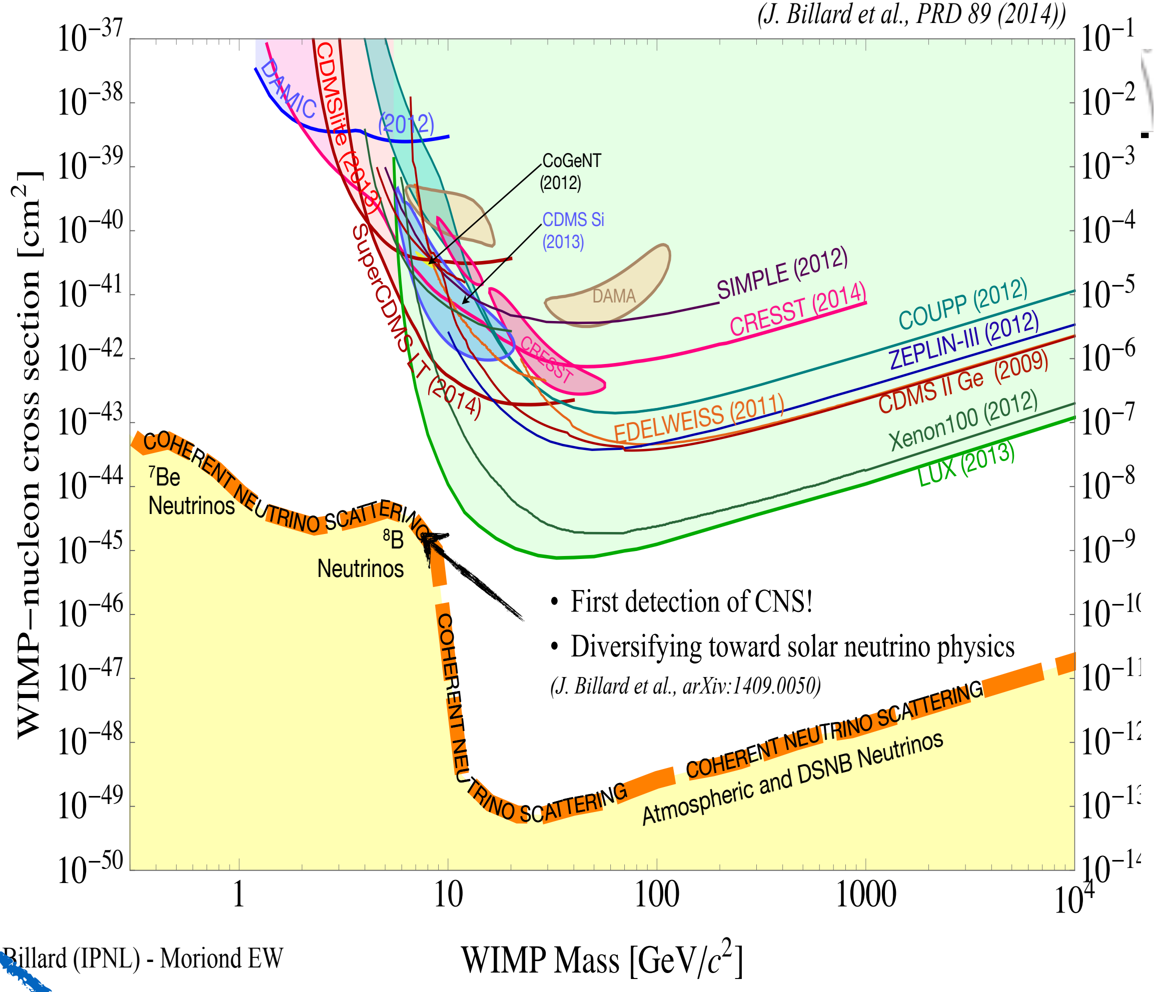
$Z \rightarrow \nu\nu + j$

- Effective operators fails at high energies!
- They can mislead to miss the MET signal
    - assumed growth of $\sigma \sim E^2/\Lambda^4$ In models where $1/\Lambda^2 \approx g^2/M^2$, such growth stops at the mediator mass
- What we really would see at the LHC is the heavy mediator mass

- Tipical signature: Large MET
- No evidence in any channel so far
- "We can find DM in the range $100\text{GeV}\times10^{\pm40}$ by 2012 or later" (putting dir/ind/coll searches together)

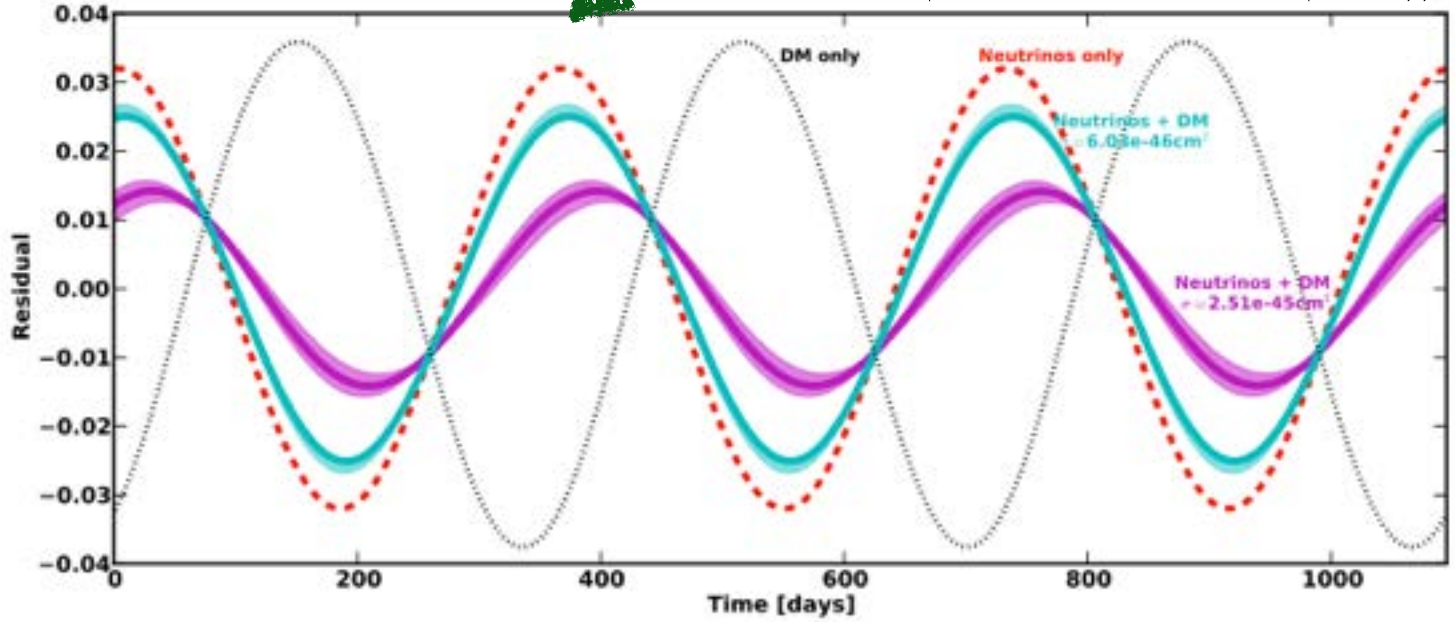
Breaking the ν floor

- WIMP and low-mass DM searches are quickly reaching the ν floor limit
- There's still hope that we can go through
  1. Reducing syst. unc. on fluxes
  2. Target complementarity
  3. Directional detection (cygnus vs sun)
  4. Annual modulation (wimp: june, ν: january)

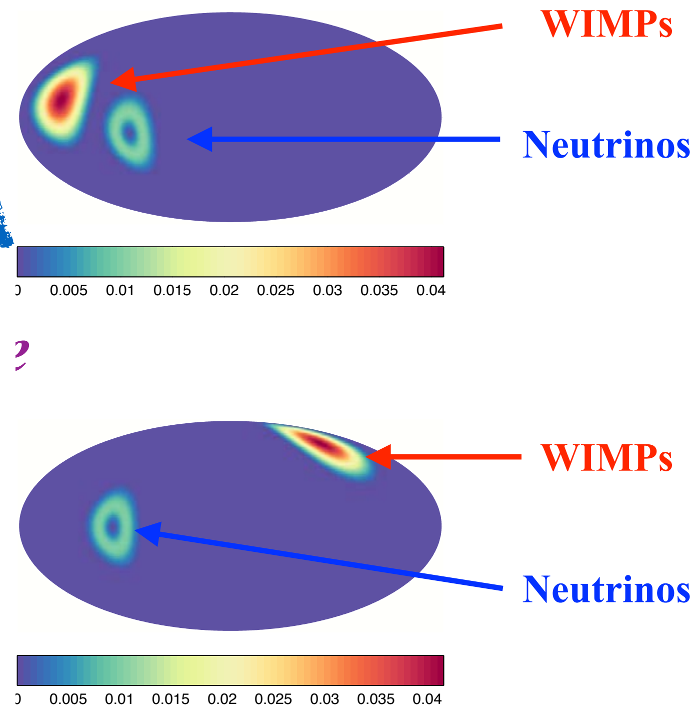


Julien Billard (IPNL) - Moriond EW

(J. H. Davis, JCAP (2015))



3.3 keV - 5 keV



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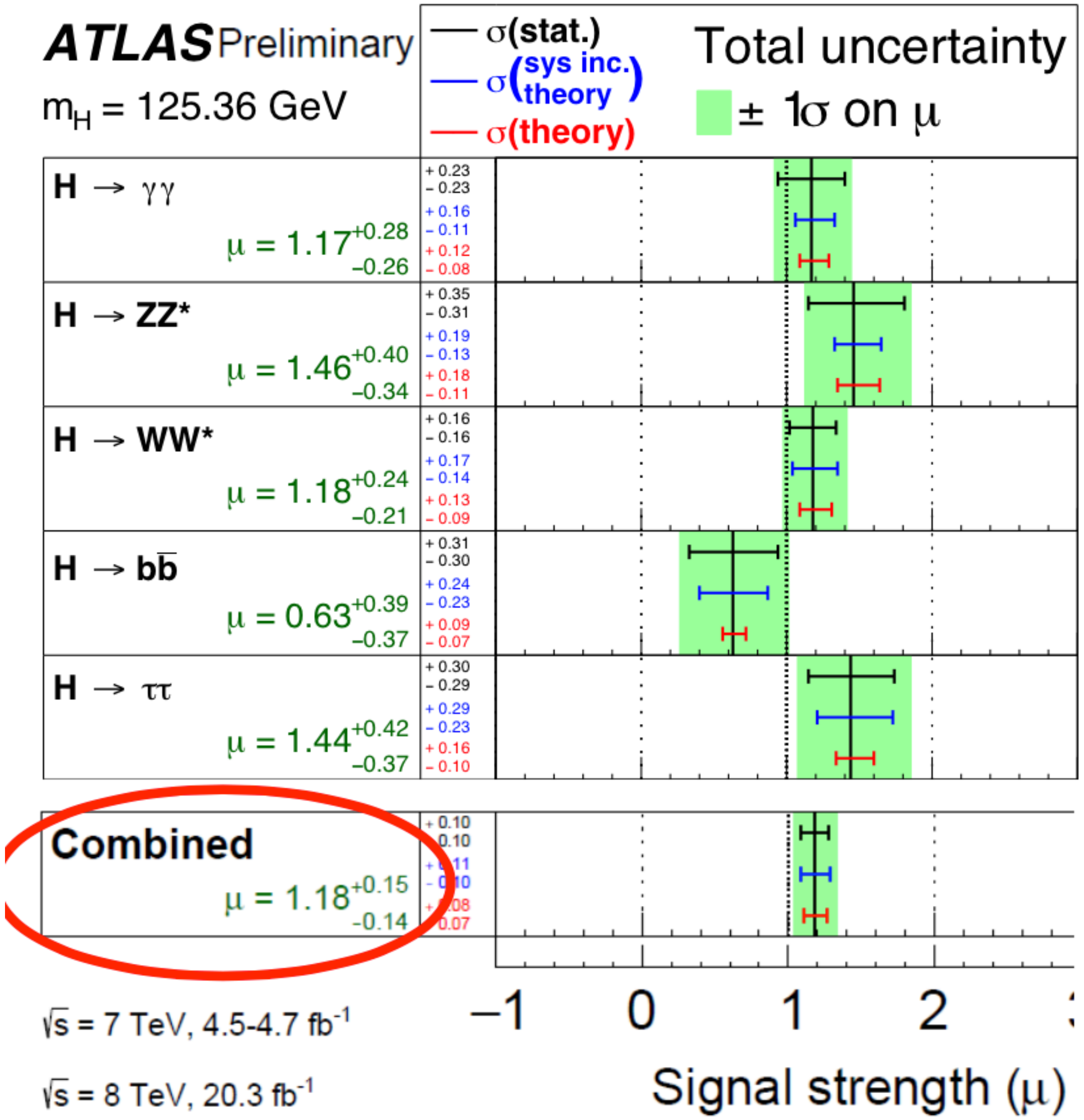
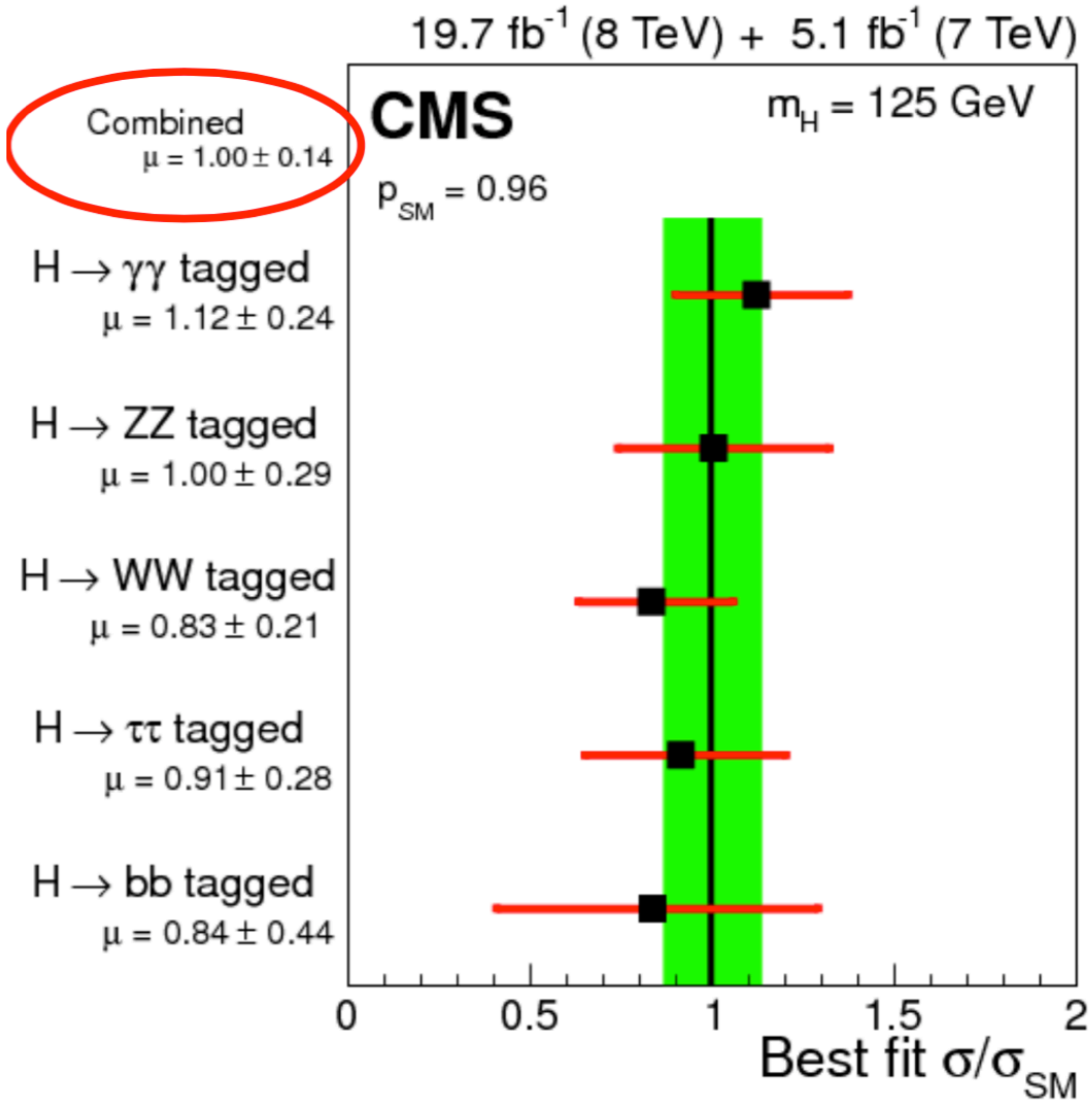
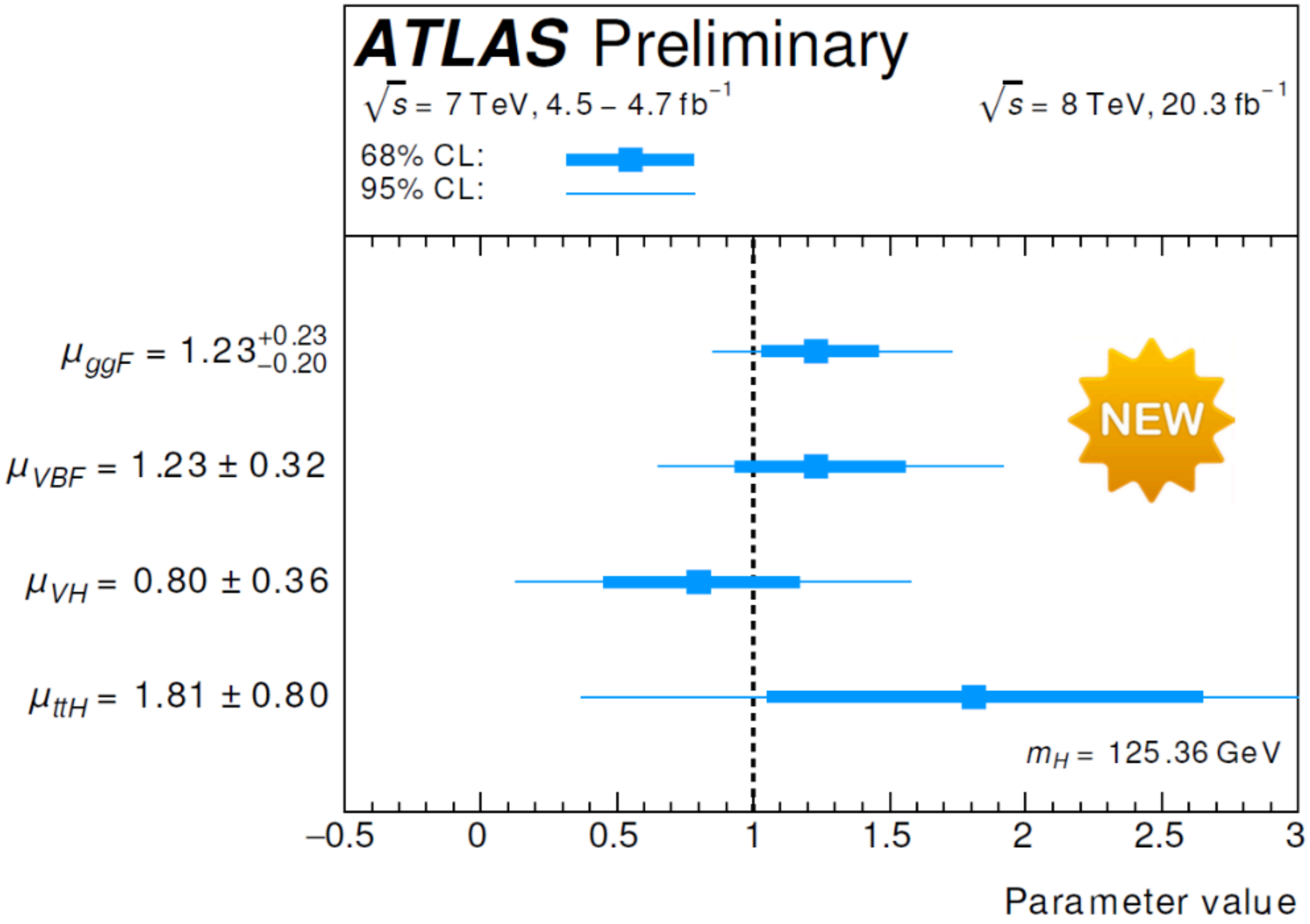
Higgs signal strengths (by decay)

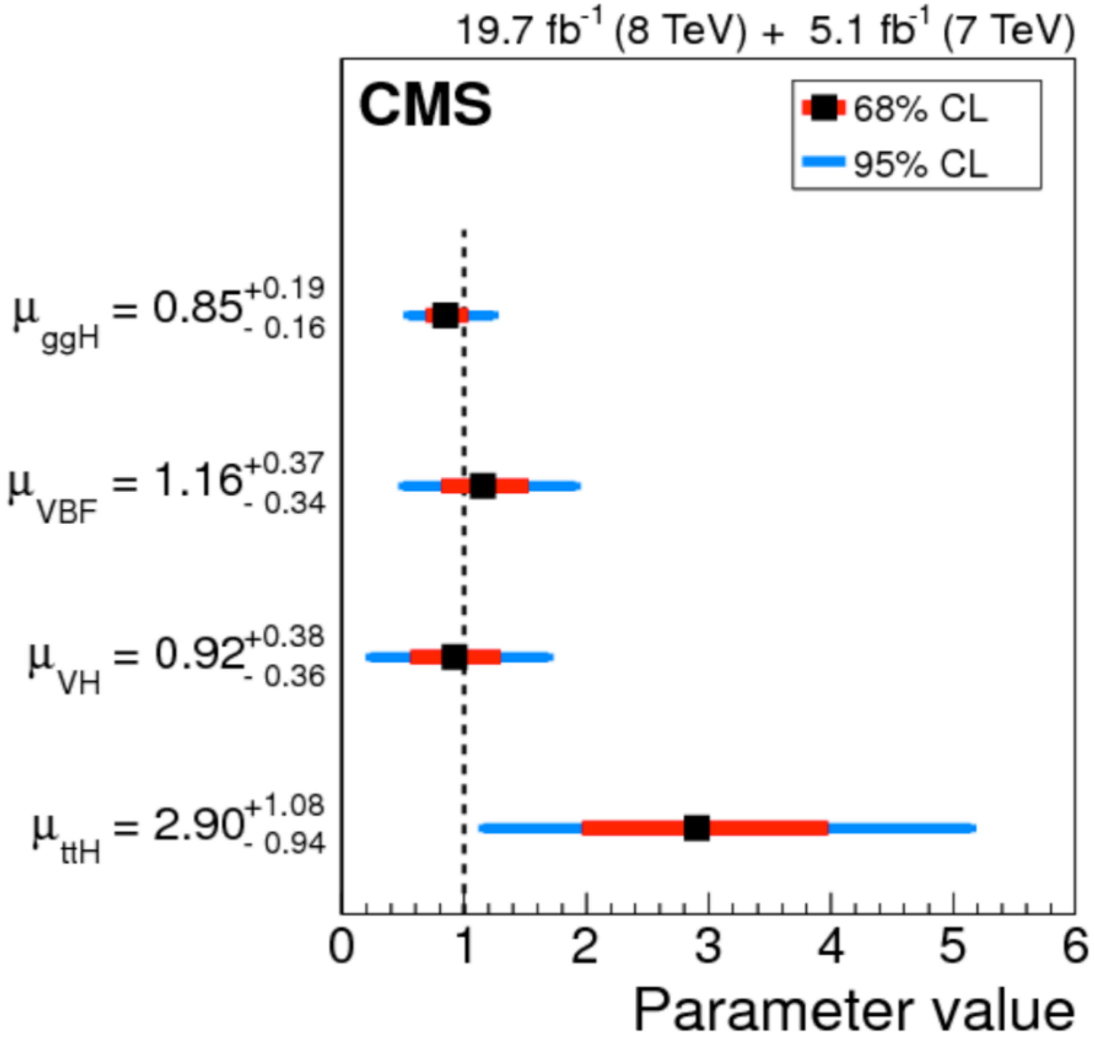




- Comparable results between ATLAS/CMS
- Right on top of the Standard Model

Higgs signal strengths (by production)

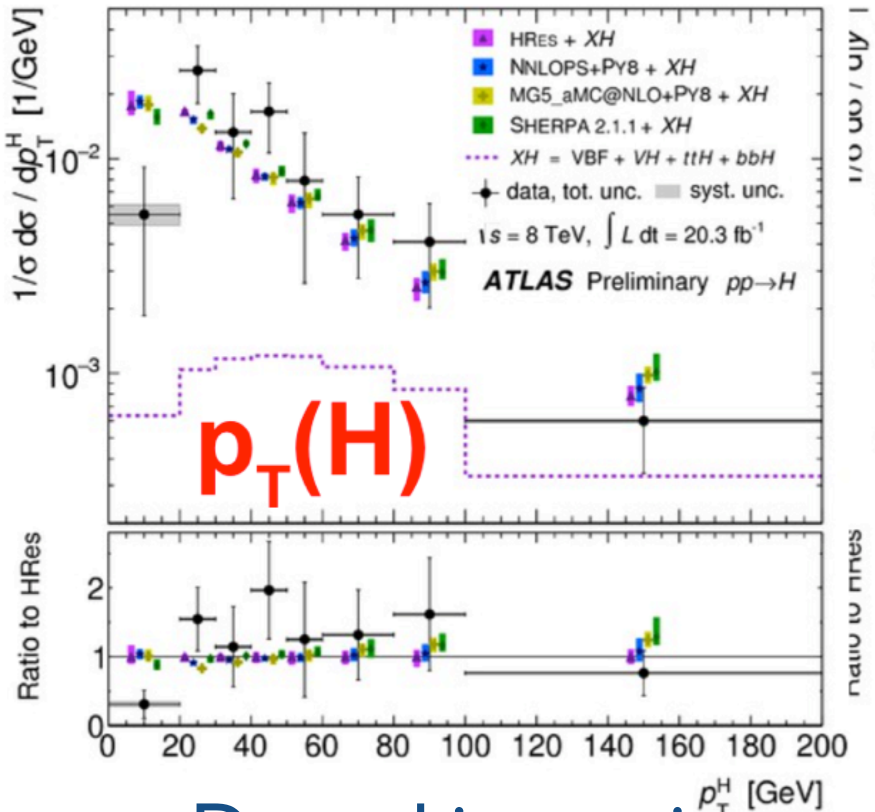


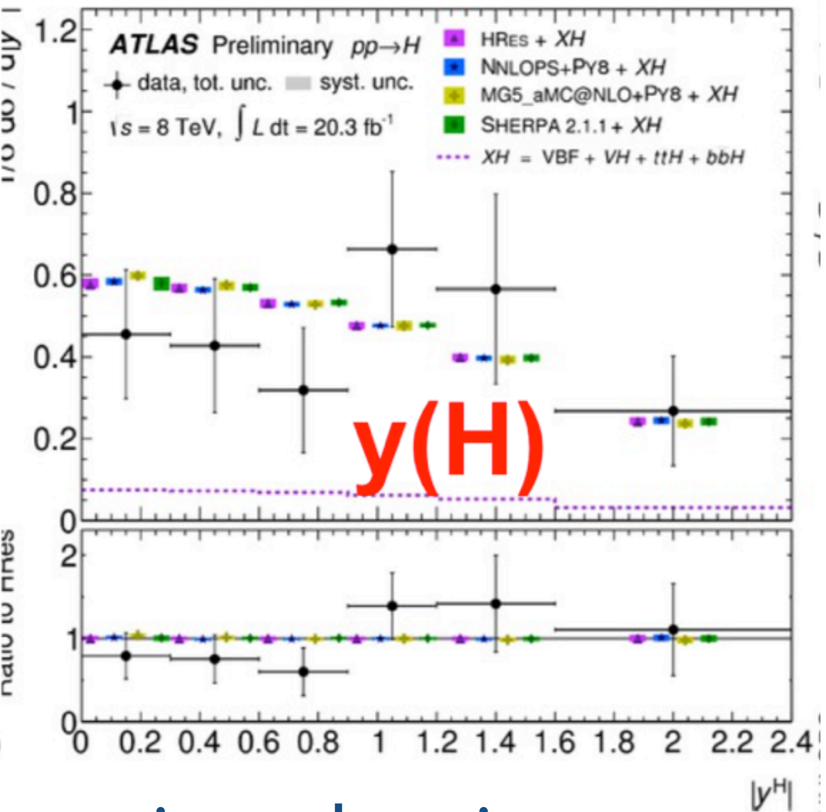


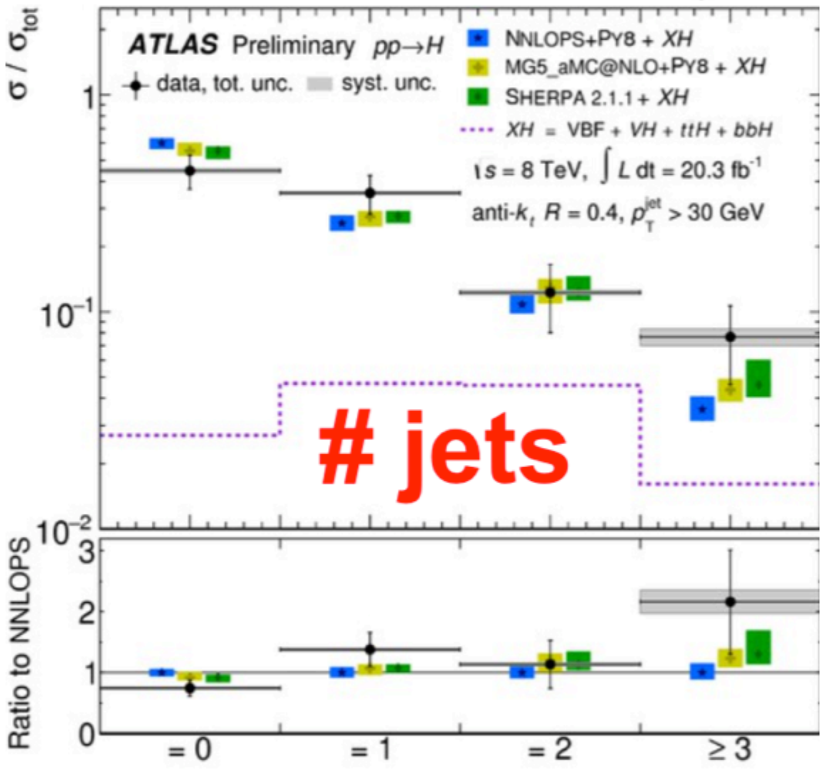
- Again consisten with SM
  - 2σ fluctuations are not unexpected
- Experiments can play in many way to check particular combination of ratios (e.g.VBF)…
- But the take-home message is that so far SM holds beautifully

Higgs Kinematics

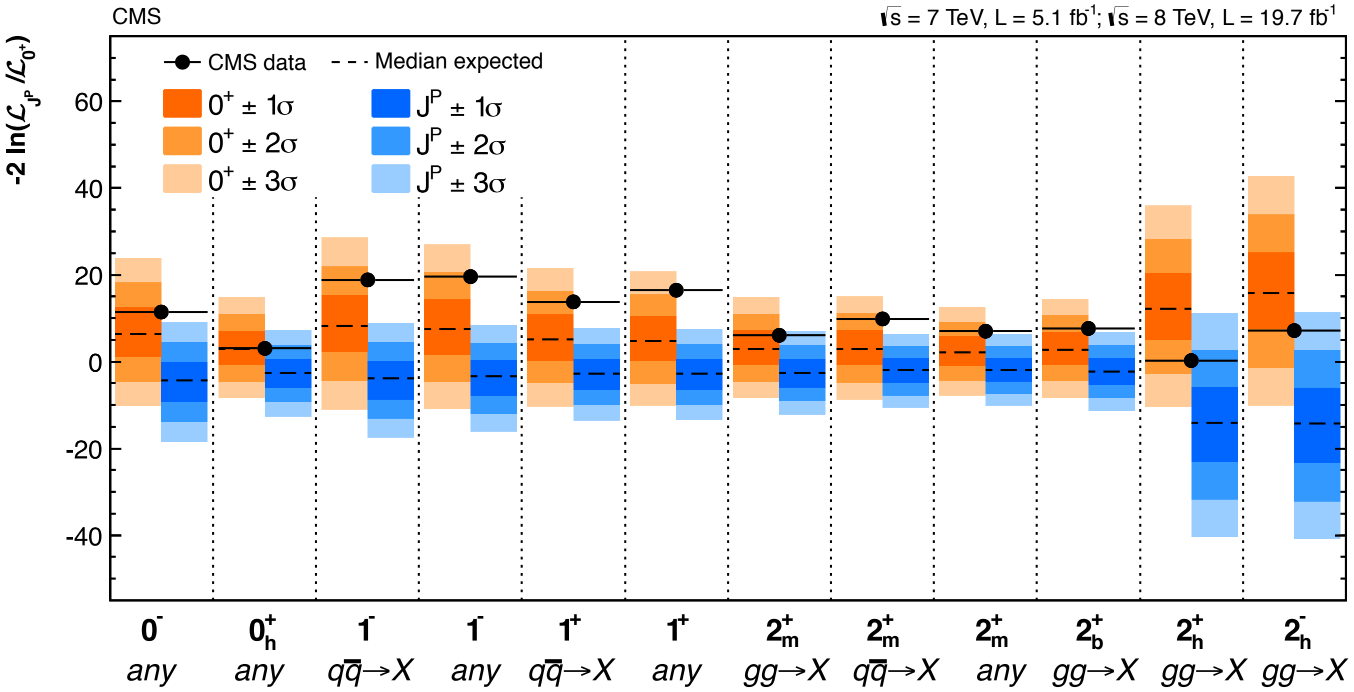
- Production kinematics

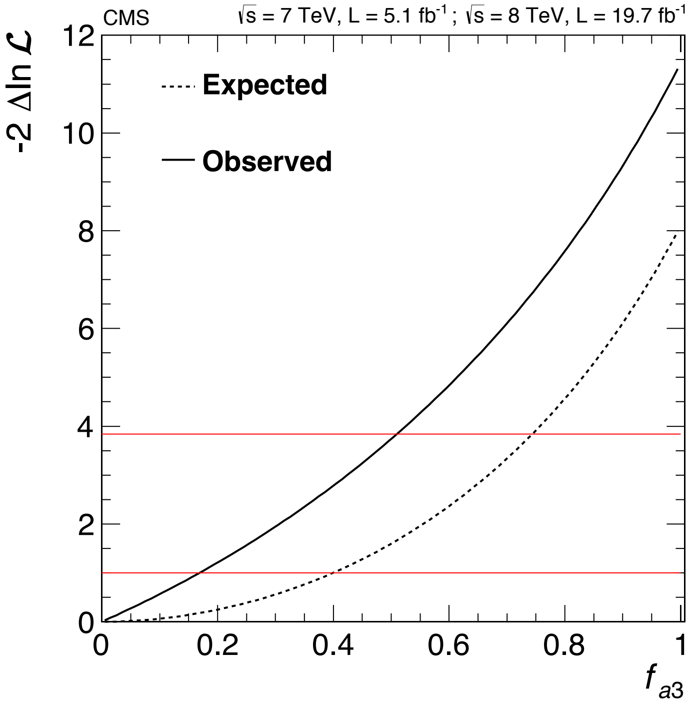






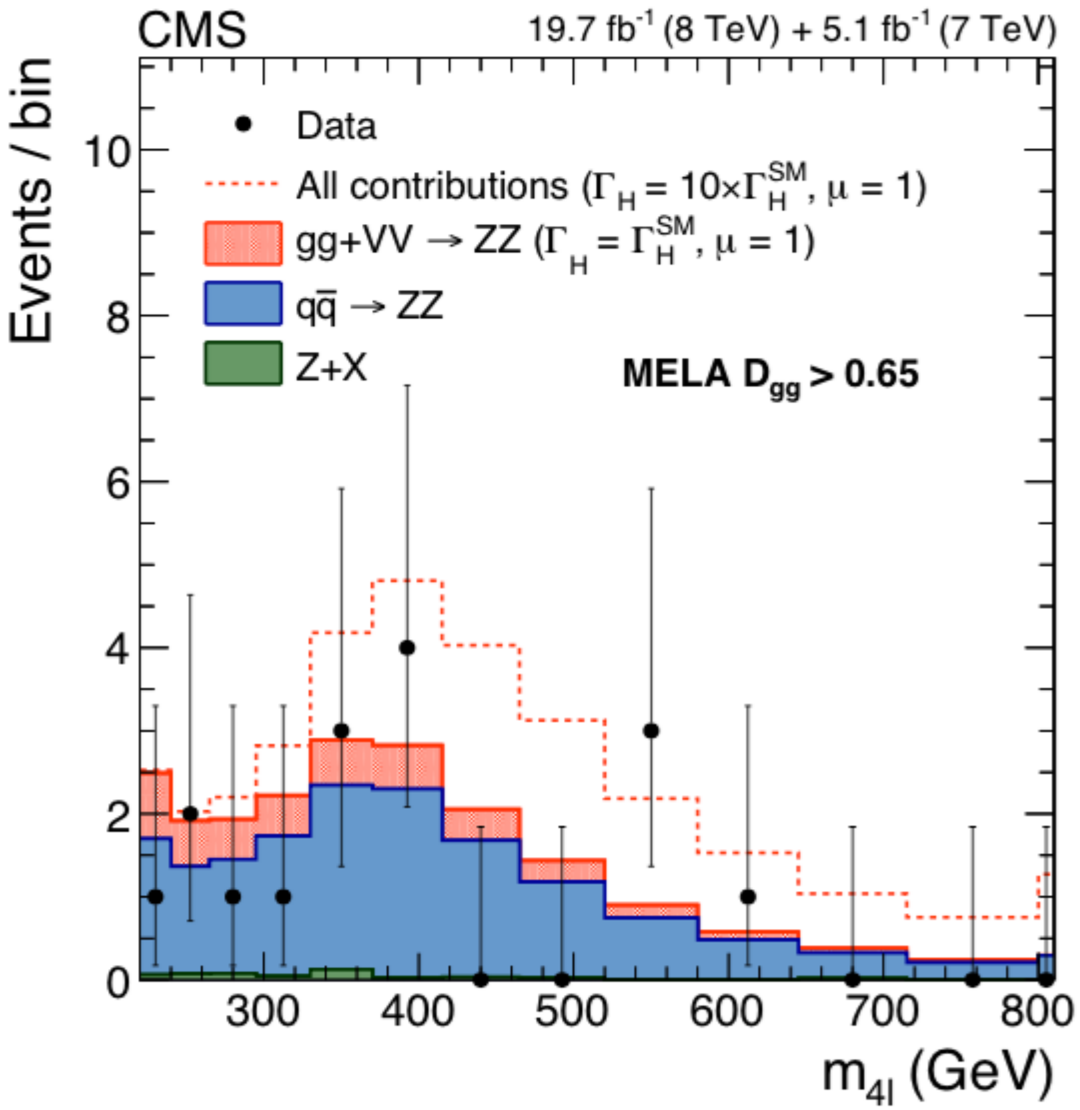
- Decay kinematics: test spin and parity

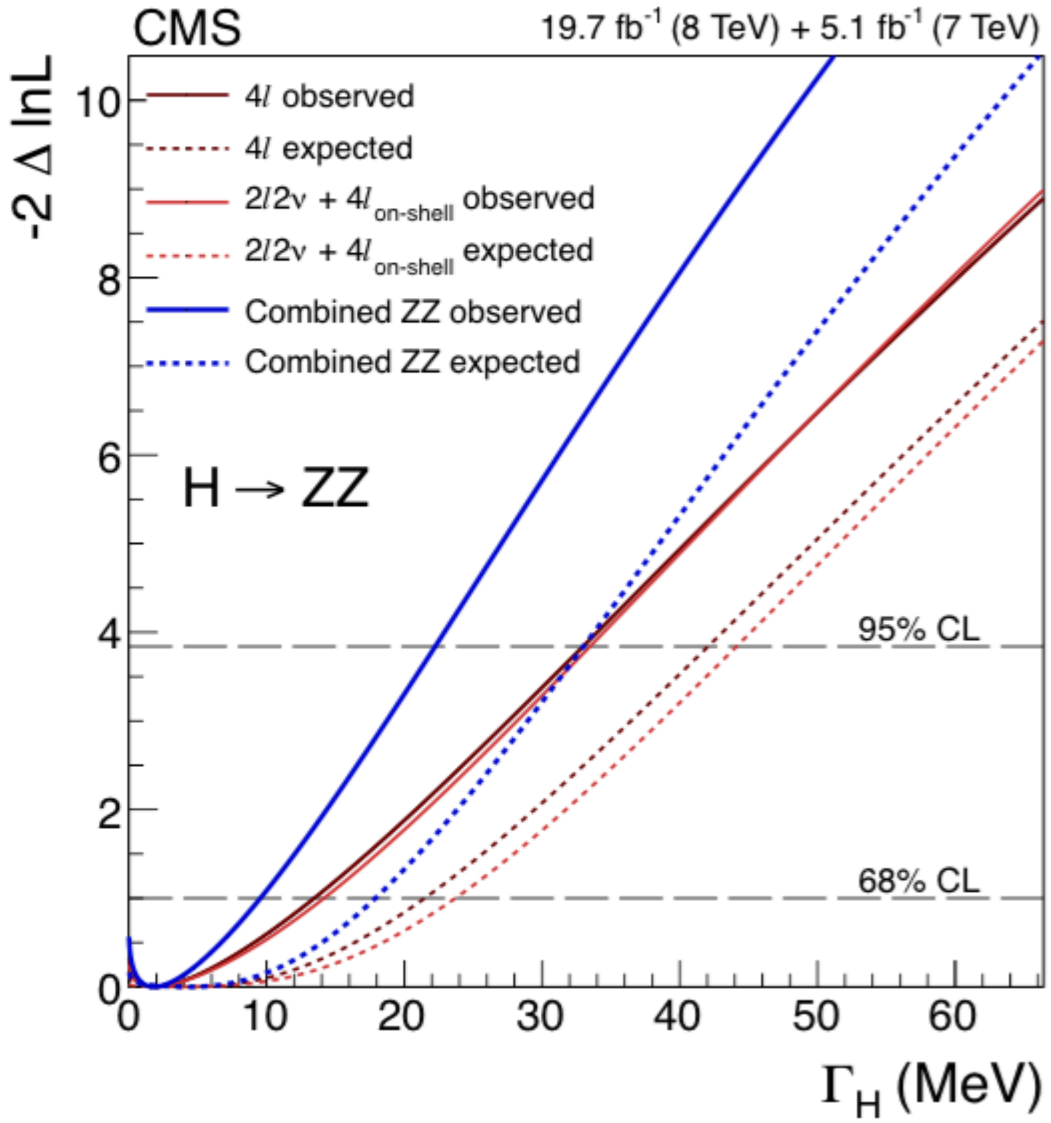




- Spin 1 and 2 variants ruled out at 95% CL
- Limits on possible admixtures of 0− or BSM

Higgs width

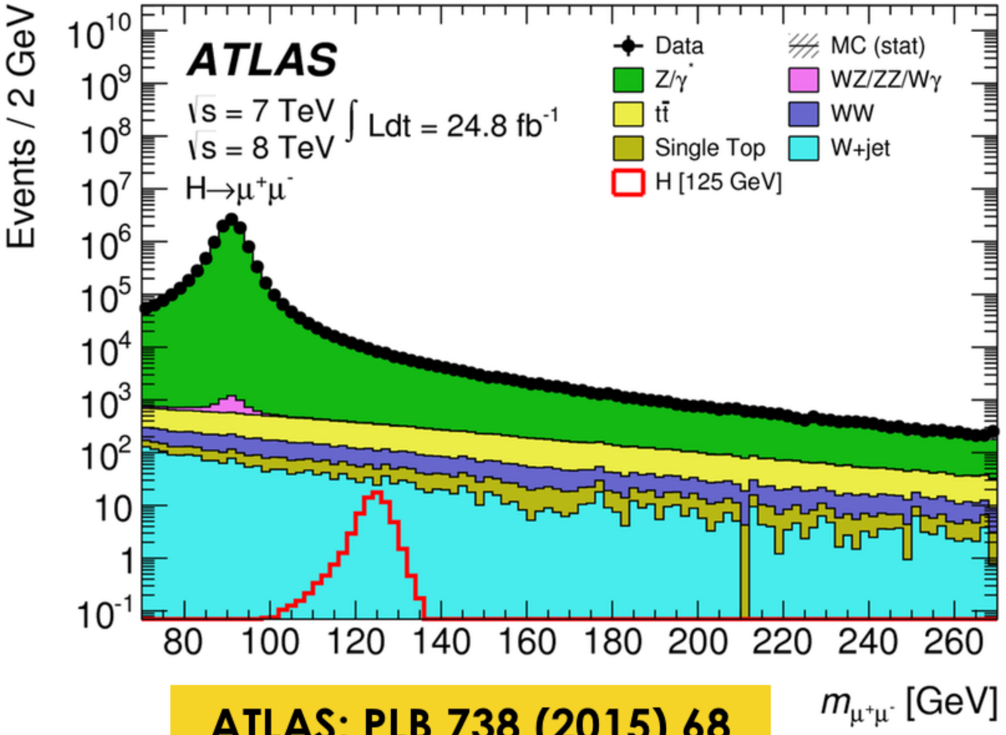




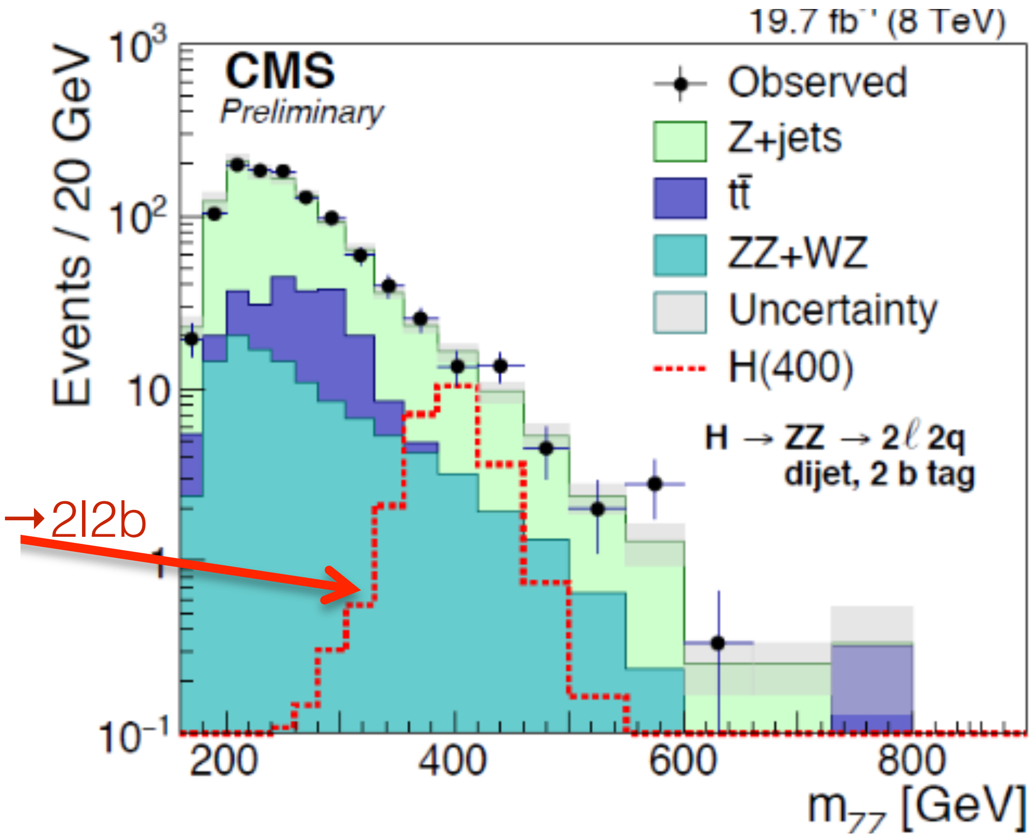
- ATLAS is combining with WW as well
- At 95% CL: $\Gamma_H/\Gamma_{SM} < 4$ (CMS) < 5.5 (ATLAS)

Higgs searches

- Rare/Exo
  - H→μμ $\sigma/\sigma_{SM}<7$ @ 95%CL (Both)
  - H→τμ: First direct limit (CMS) BR<0.75% (LFV channel)
  - H→J/ψγ probe H-c coupling(HL-LHC)
- Invisible (and quasi-invisible)
  - Updated with associated VH/VBF prod
  - New channels: mono-j, tt+MET, γ+MET
  - Direct limits: 30-80%, indirect: ~30%
- Additional Higgses (e.g. ZZ→llbb)
- HH searches
  - In preparation for Run2, not possible in Run I
- All searches gave negative results so far



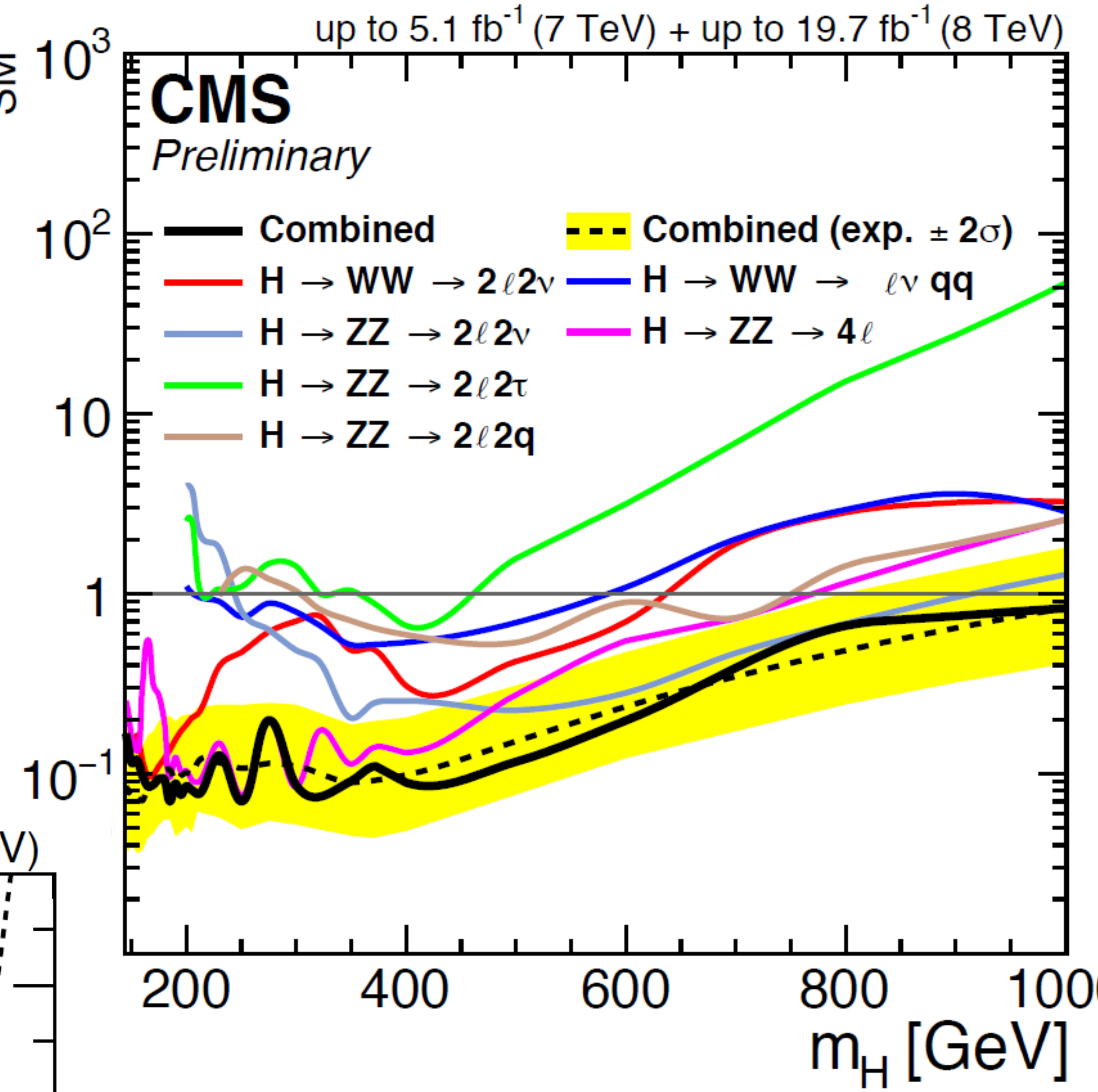
ATLAS: PLB 738 (2015) 68

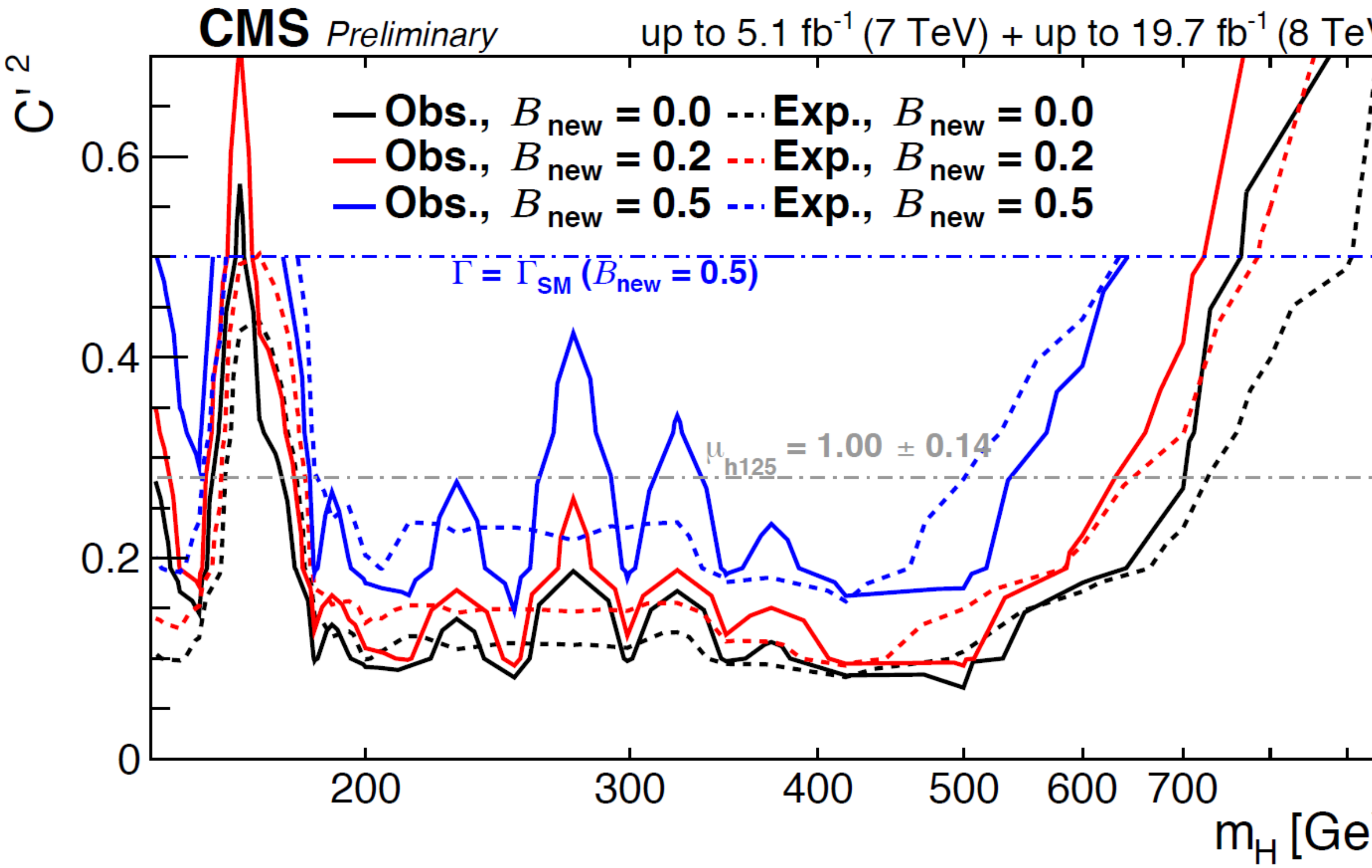


H→ZZ→2l2b

CMS High mass Higgs search

- CMS only
- No additional H seen with the full run1 dataset



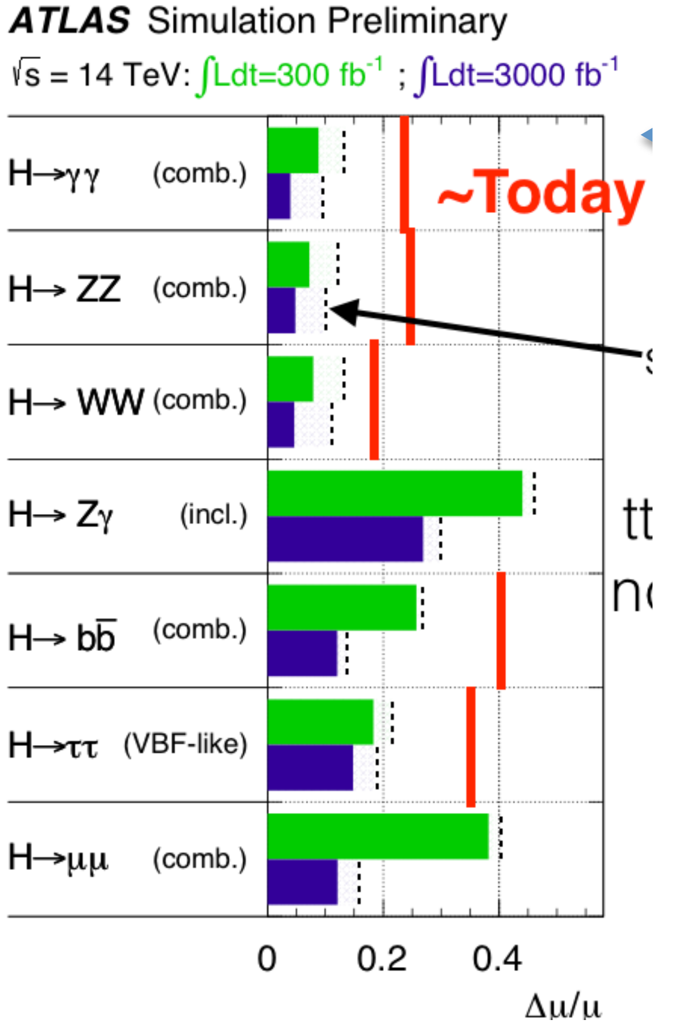


$$C = \frac{g_{h_1 VV,meas}}{g_{h_1 VV,SM}} \qquad C' = \frac{g_{h_2 VV,meas}}{g_{h_2 VV,SM}}$$

$$C^2 + C'^2 = 1$$

Higgs at the LHC: where we stand

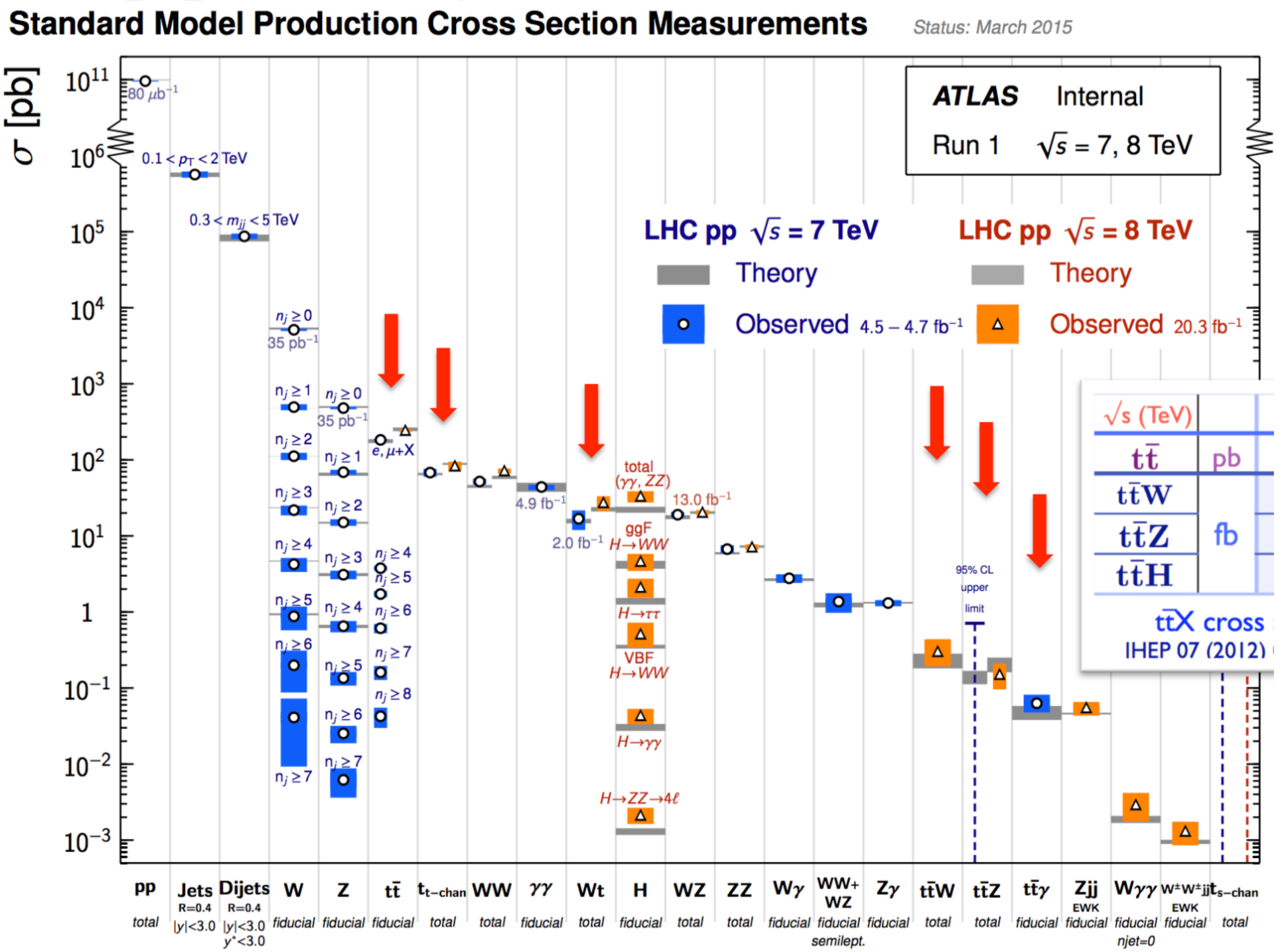
- The sheer amount of results delivered by the LHC in the Higgs sector is astounding
    - Impossible to cover all of them even in dedicated talks
- The precision of the results is much higher than was foreseen before run1
    - Already with this amount of data, we are a factor ~2 from theoretical uncertainties
    - Now our theory colleagues will need a huge effort to reduce them
- So far measurements are in very good agreement with SM predictions
- Composite H searches have turned out empty so far
    - Theoreticians are keen to find H composite of fermions for naturalness BUT
    - How to get Yukawas from fermions? Drop L_{eff}?



Outline

- Neutrinos
- Dark matter
- Scalar sector
- Standard Model
- BSM
- Top
- Heavy Flavours
- Miscellanea
- Prize winners: Higgs mass and LHCb B→$K^{*}\mu\mu$

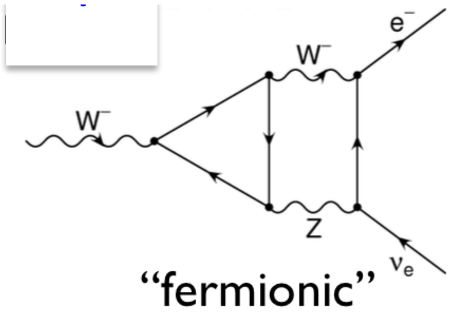
Overview



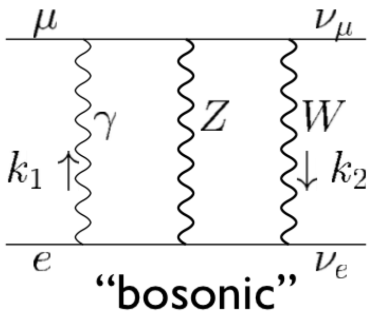
Standard Model Production Cross Section Measurements
Status: March 2015
σ [pb]
10^{11}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
1
10^{-1}
10^{-2}
10^{-3}
80 μb^{-1}
$0.1 < p_T < 2$ TeV
$0.3 < m_{jj} < 5$ TeV
$n_j \geq 0$
35 pb^{-1}
$n_j \geq 1$
$n_j \geq 2$
$n_j \geq 3$
$n_j \geq 4$
$n_j \geq 5$
$n_j \geq 6$
$n_j \geq 7$
$n_j \geq 8$
e, μ+X
4.9 fb^{-1}
2.0 fb^{-1}
13.0 fb^{-1}
total (γγ, ZZ)
ggF H→WW
H→ττ
VBF H→WW
H→γγ
H→ZZ→4ℓ
95% CL upper limit
ATLAS Internal
Run 1 $\sqrt{s}$ = 7, 8 TeV
LHC pp $\sqrt{s}$ = 7 TeV
Theory
Observed 4.5 – 4.7 fb^{-1}
LHC pp $\sqrt{s}$ = 8 TeV
Theory
Observed 20.3 fb^{-1}
√s (TeV)
tt̄ pb
tt̄W
tt̄Z fb
tt̄H
tt̄X cross
IHEP 07 (2012)
pp total
Jets R=0.4 |y|<3.0
Dijets R=0.4 |y|<3.0 y*<3.0
W fiducial
Z fiducial
tt̄ fiducial
t$_{t-chan}$ total
WW total
γγ fiducial
Wt total
H fiducial
WZ total
ZZ total
Wγ fiducial
WW+WZ fiducial semilept.
Zγ fiducial
tt̄W total
tt̄Z total
tt̄γ fiducial
Zjj EWK fiducial
Wγγ fiducial njet=0
W±W±jj EWK fiducial
t$_{s-chan}$ total

Global EWK fit

- The global fit now includes:
  - 2-loops EW corrections

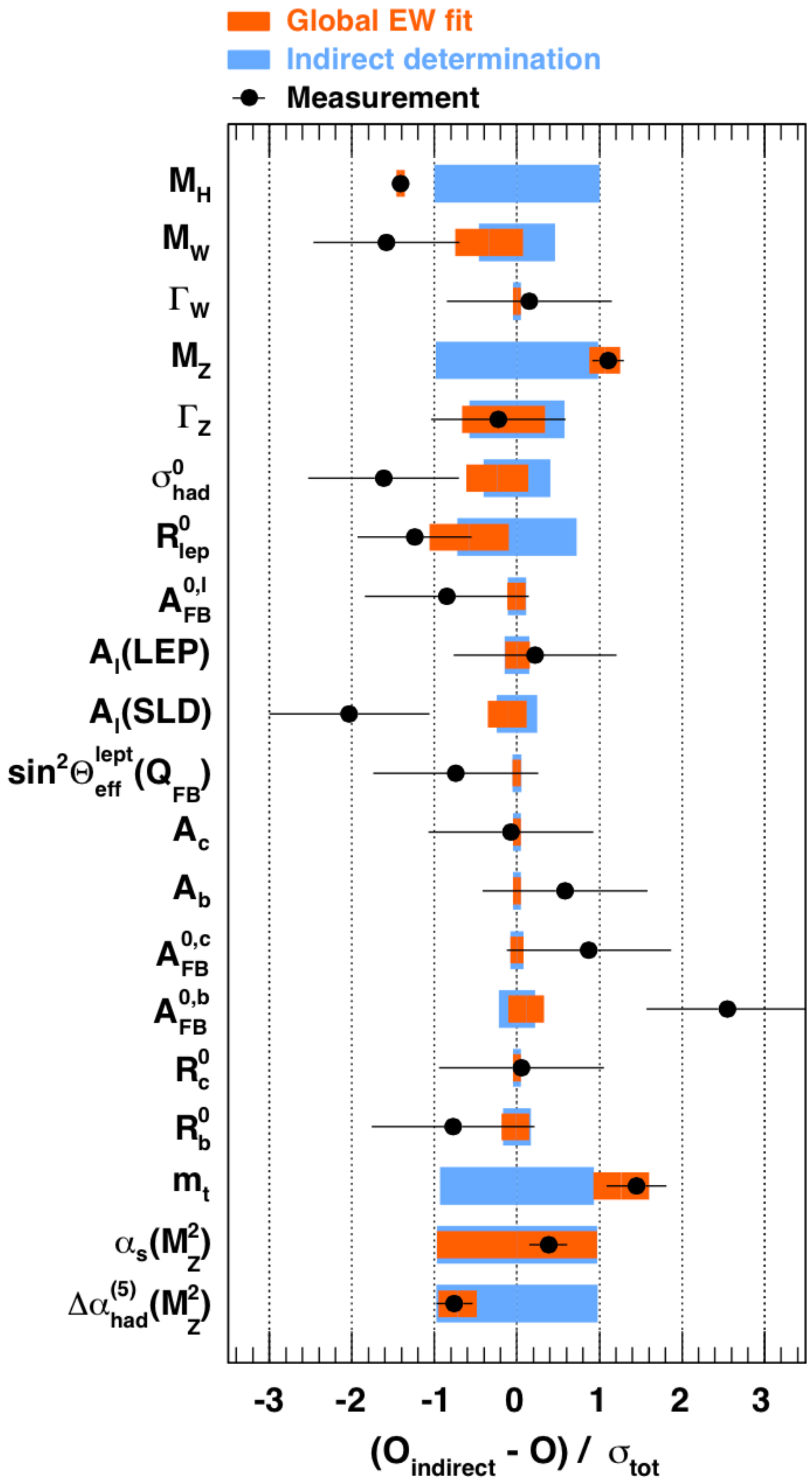


“fermionic”



“bosonic”

  - Mixed EW-QCD terms (at order $\alpha\alpha s$)
  - Theoretical uncertainty on top mass Δm_t=0.5GeV
- Consistent fit of all data
  - χ^2/NDF = 17.8/14
- Top priority: measure W mass
  - Δm_W=15MeV (direct) wrt 8 (fit)



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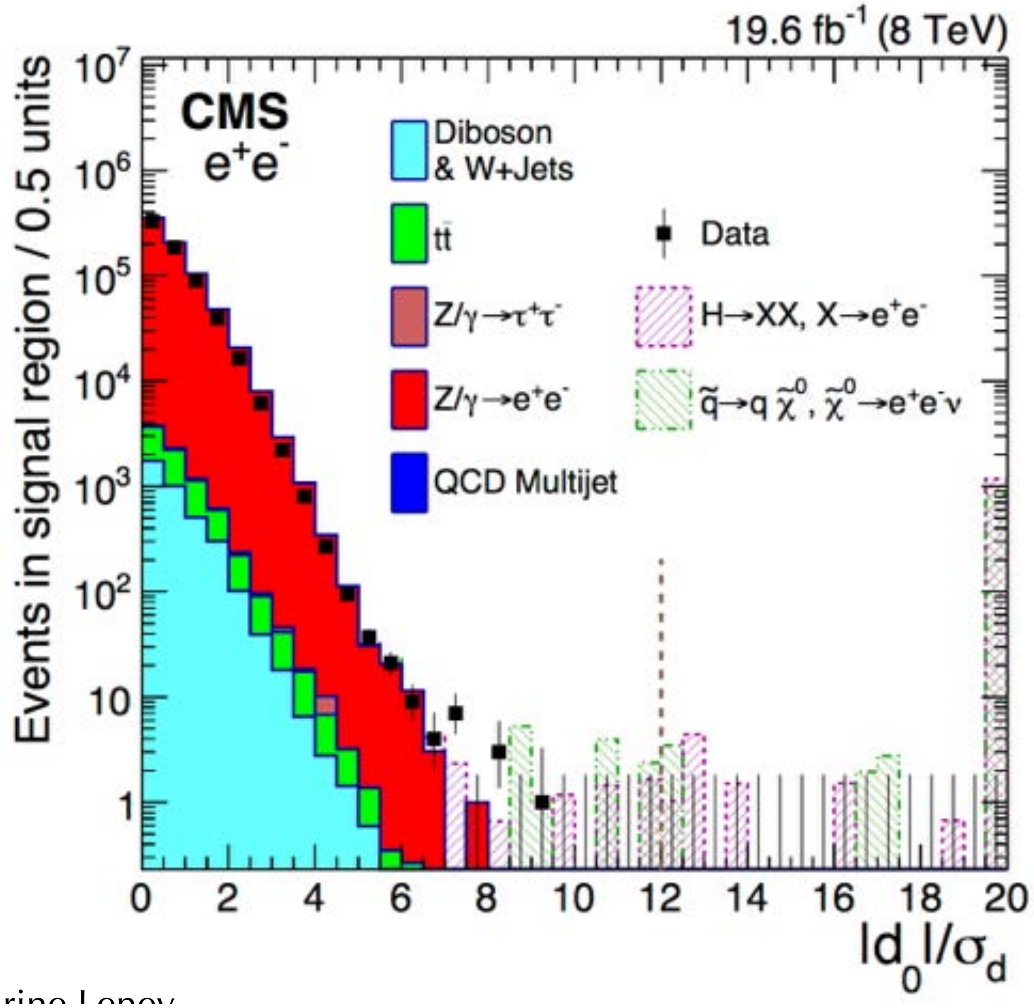
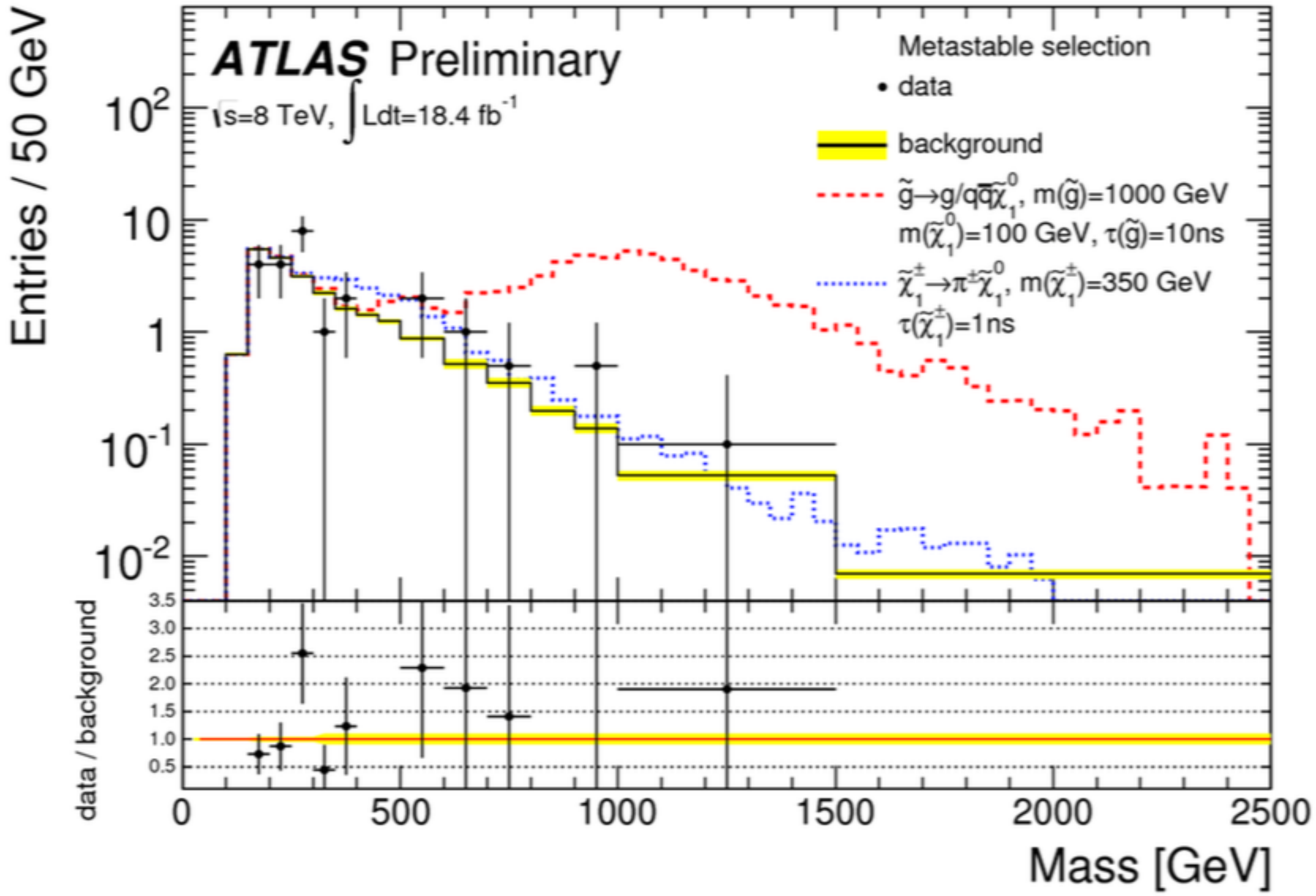
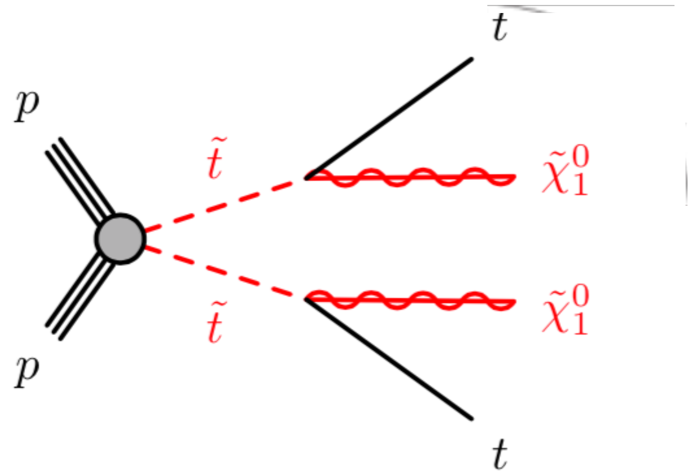
BSM Long-lived particles

- All “easy” or “fast” analyses already completed by Moriond2013
- Now looking in every corner we can with as much “ingenuity” as possible
- Search for Long-lived BSM particles is based on anomalous displaced vertex
- Or search for stable massive particle (de/dx)

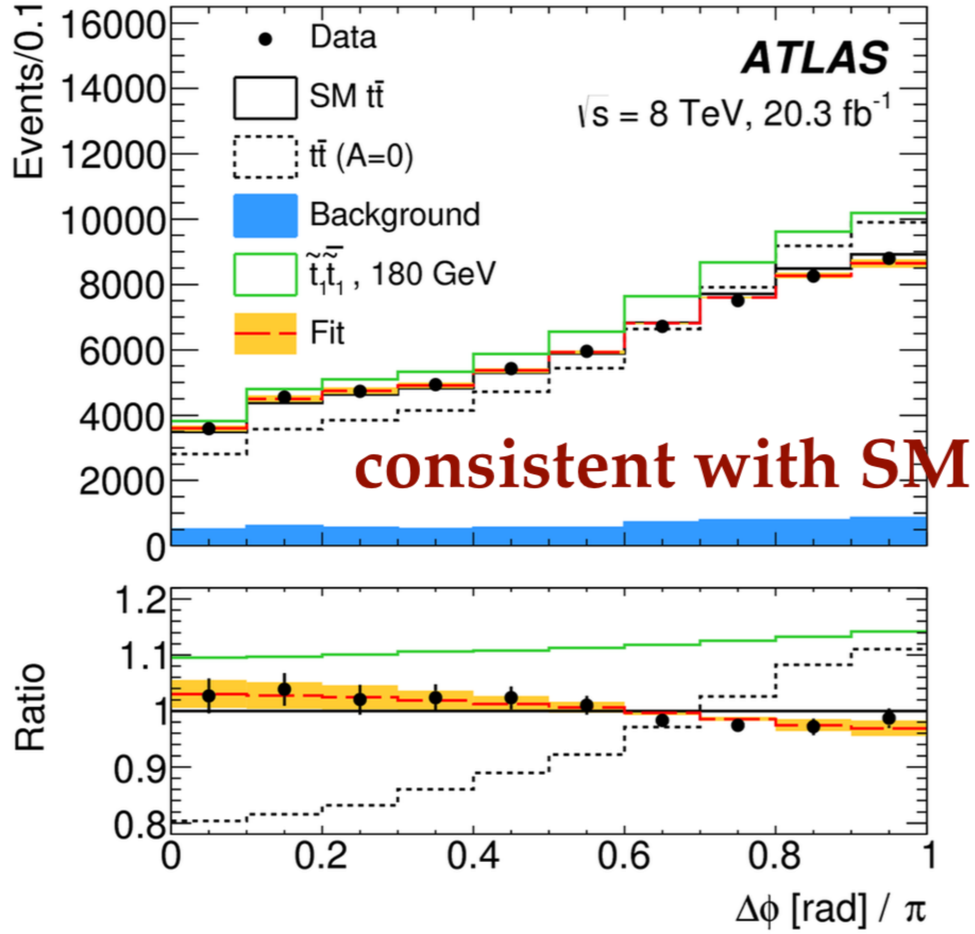




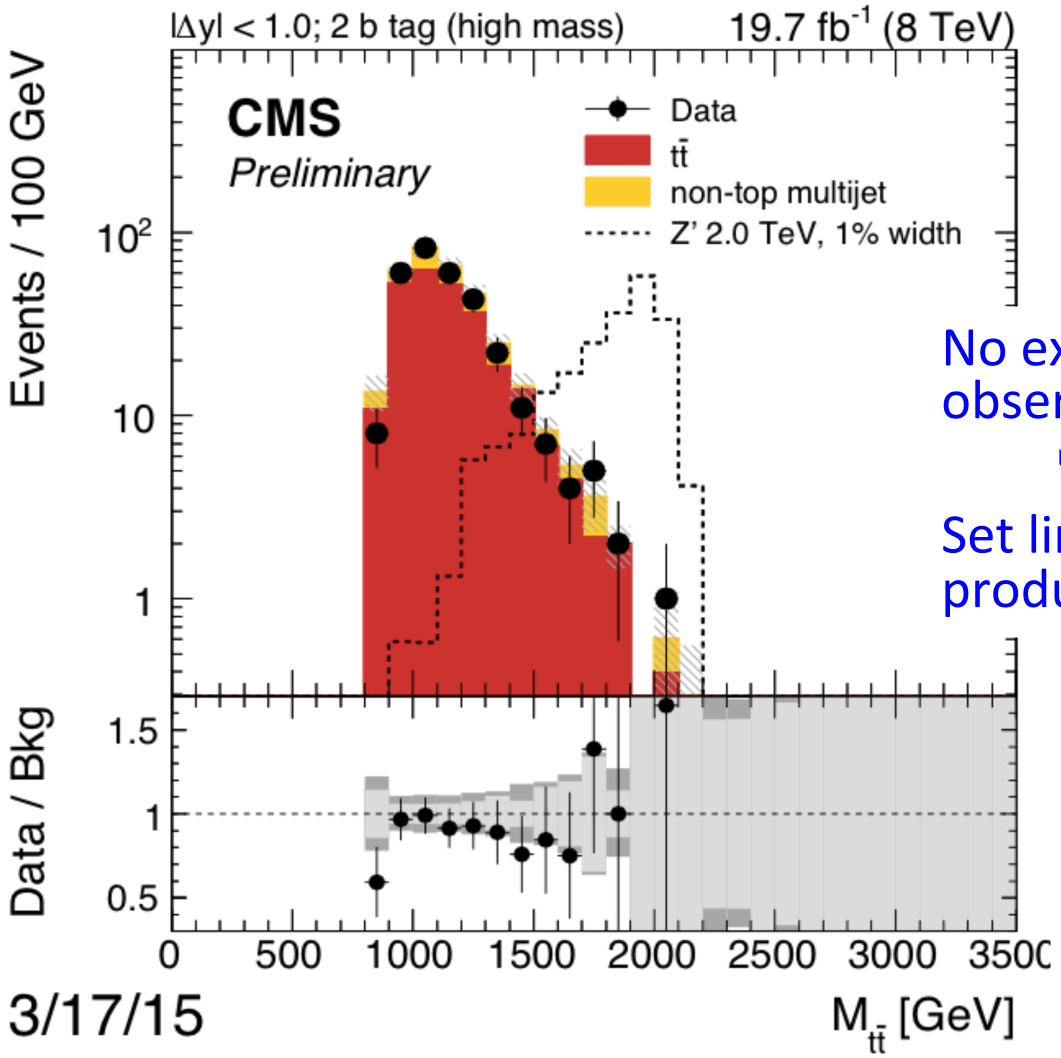
(S)top-pair searches



- Stop-pair with small top-stop Δm (“compressed SUSY
- Very similar to tt events!
- Possible helps:
  - Increase in cross-section
  - Modified spin correlations



consistent with SM



No excess observed
↓
Set limits on Z’ production

- Boosted top jets (Z’→tt)
- Jet substructure analysis mandatory
- Set limits on Z’ production

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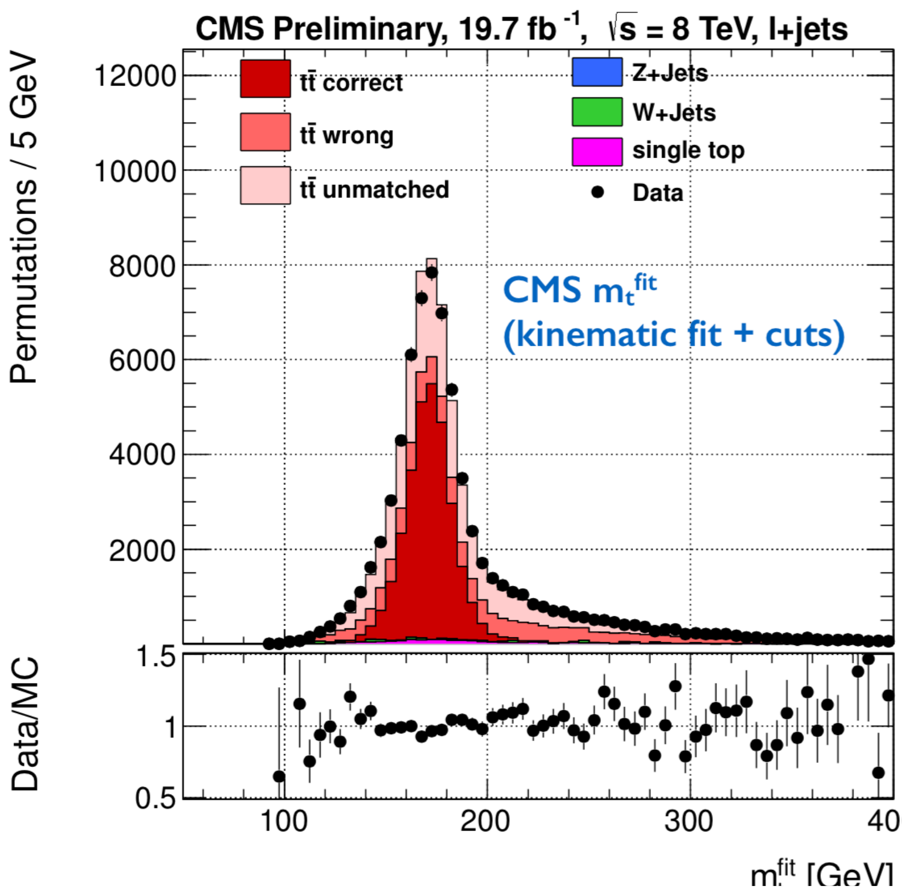
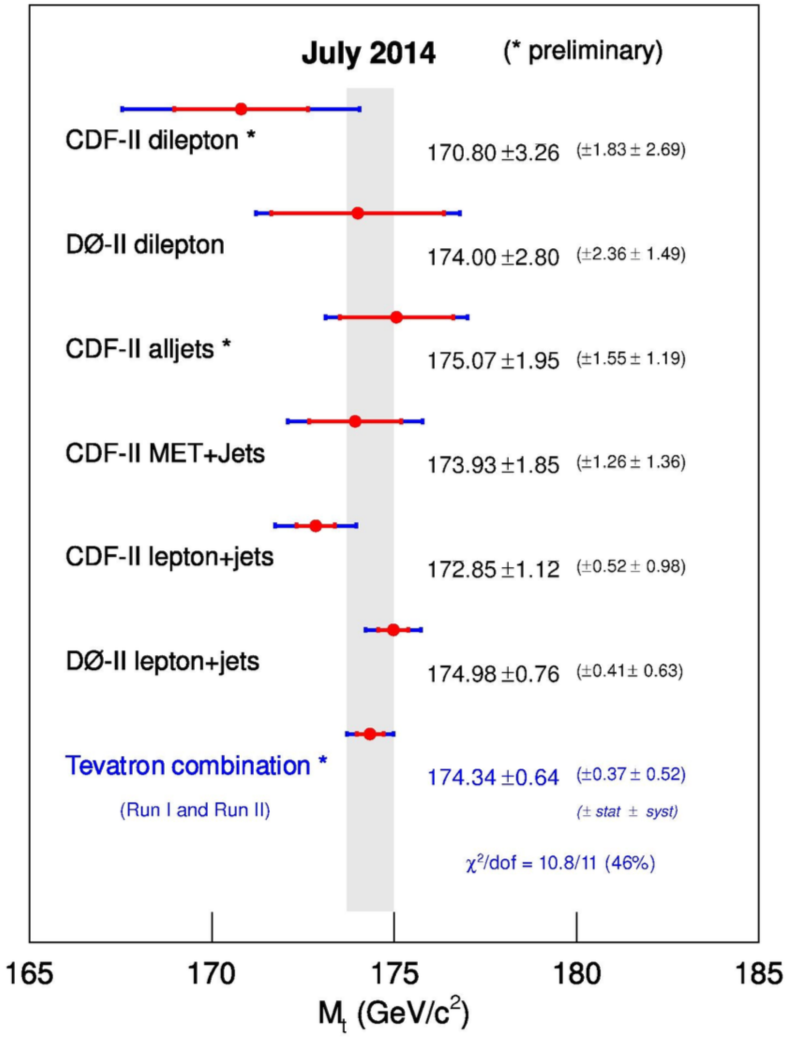
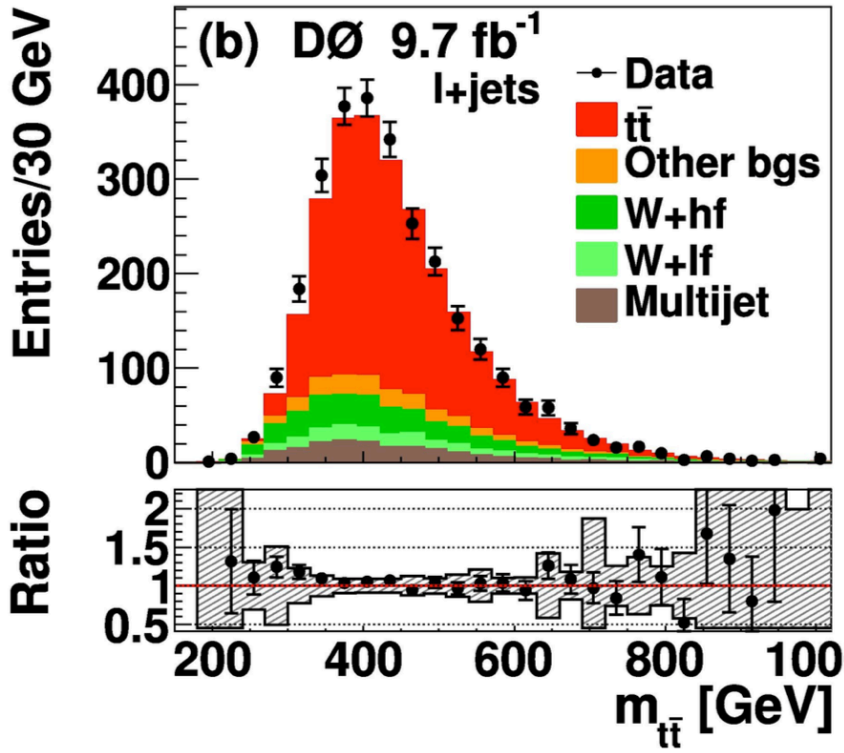
Top mass

- CMS claims the most precise single LHC measurement using lepton+jet
    - mt=172.0±0.2(stat)±0.8(syst)GeV
    - Very careful JES calibration
    - cross-check with b energy scale comparing events with Z+jet and Z+bjet

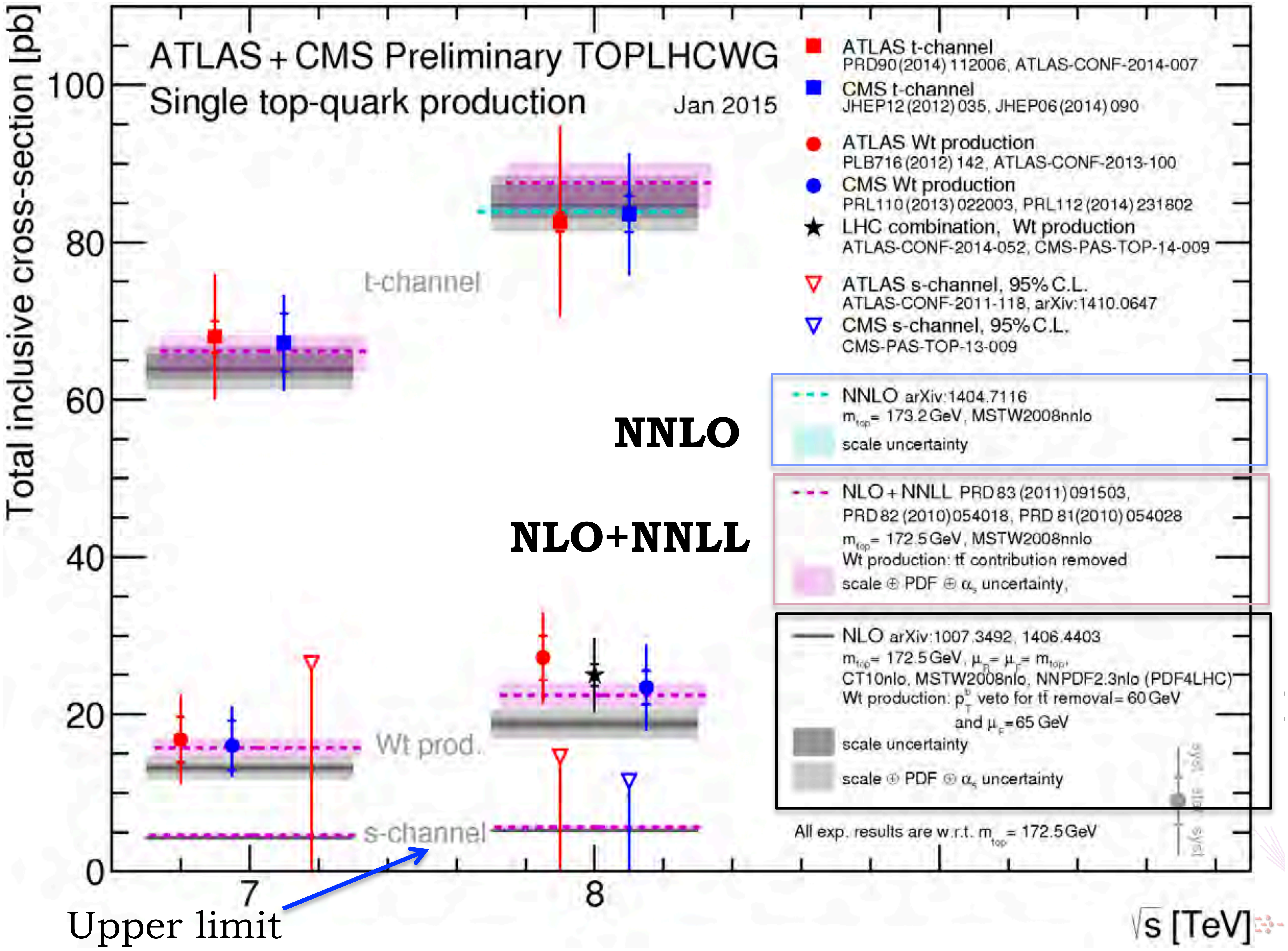




- But Tevatron combination is still slightly better
    - mt=174.34±0.37(stat) ±0.52(syst)GeV
- We should be more interested in Yt than m_t



Single top production

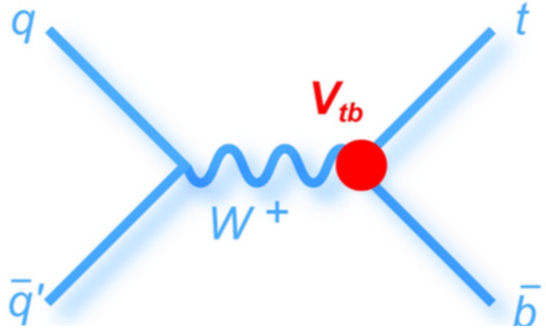


NNLO

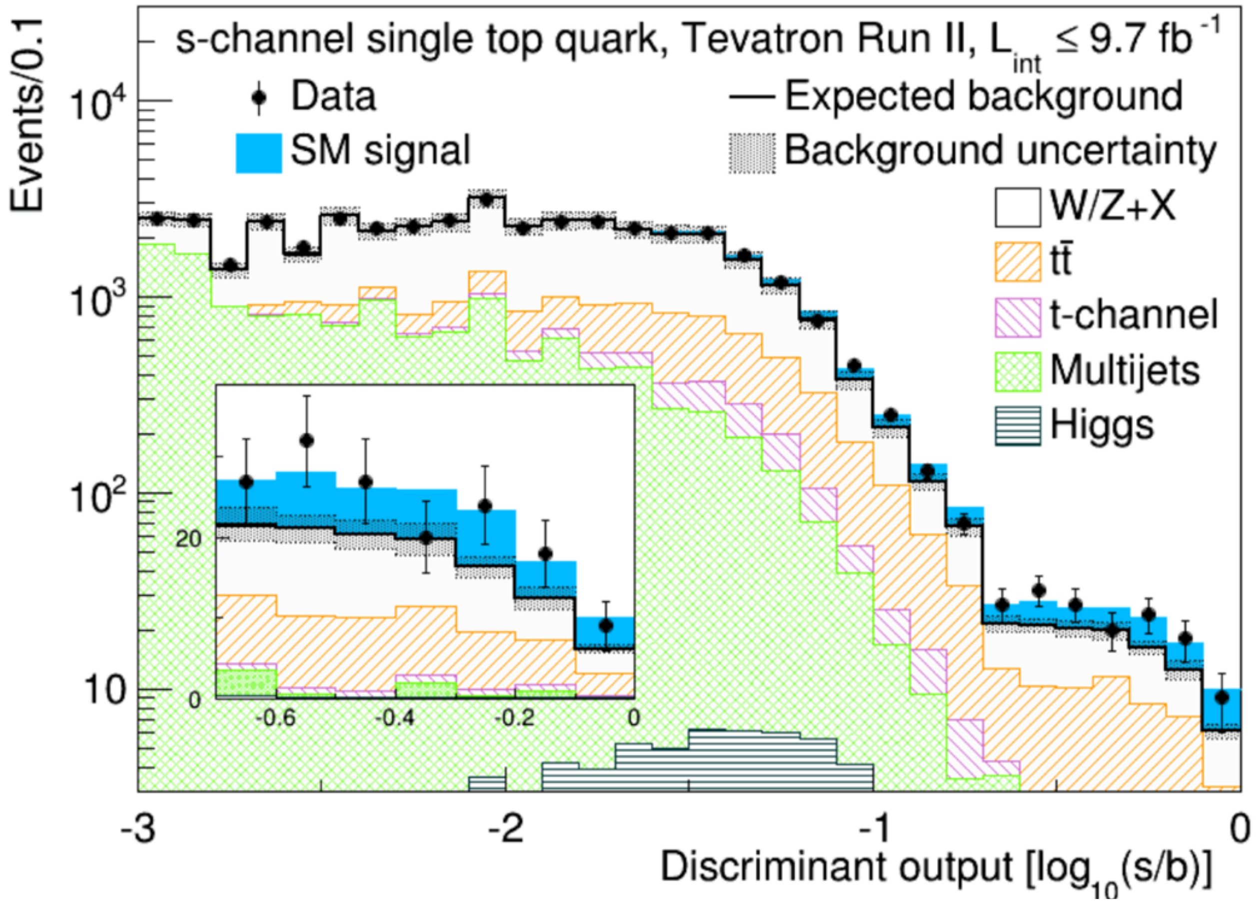
NLO+NNLL

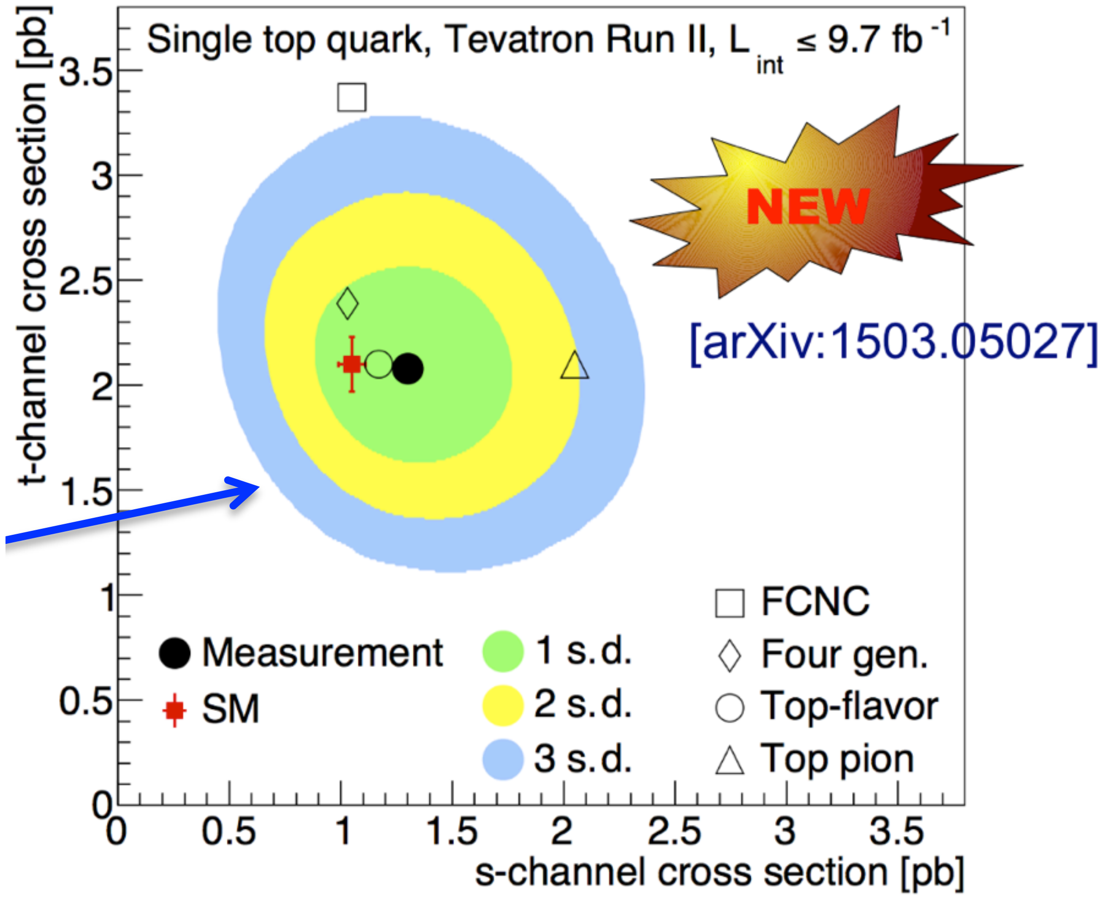
Upper limit

Single top s-channel production



- Tevatron produced the first observation (6.3σ) of the top production in the s-channel





[arXiv:1503.05027]

$|V_{tb}| > 0.92$ at 95% C.L.

$$|V_{tb}| = 1.02^{+0.06}_{-0.05}$$

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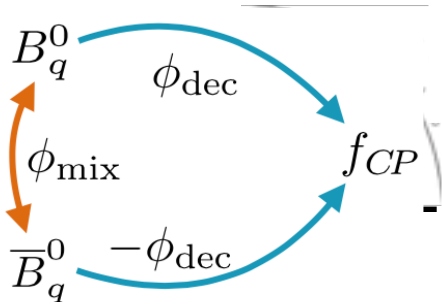
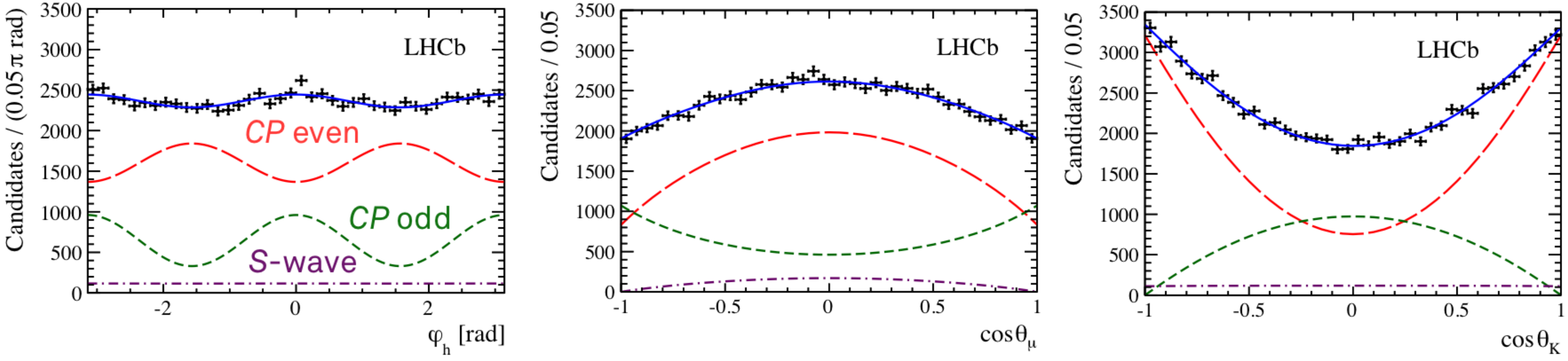
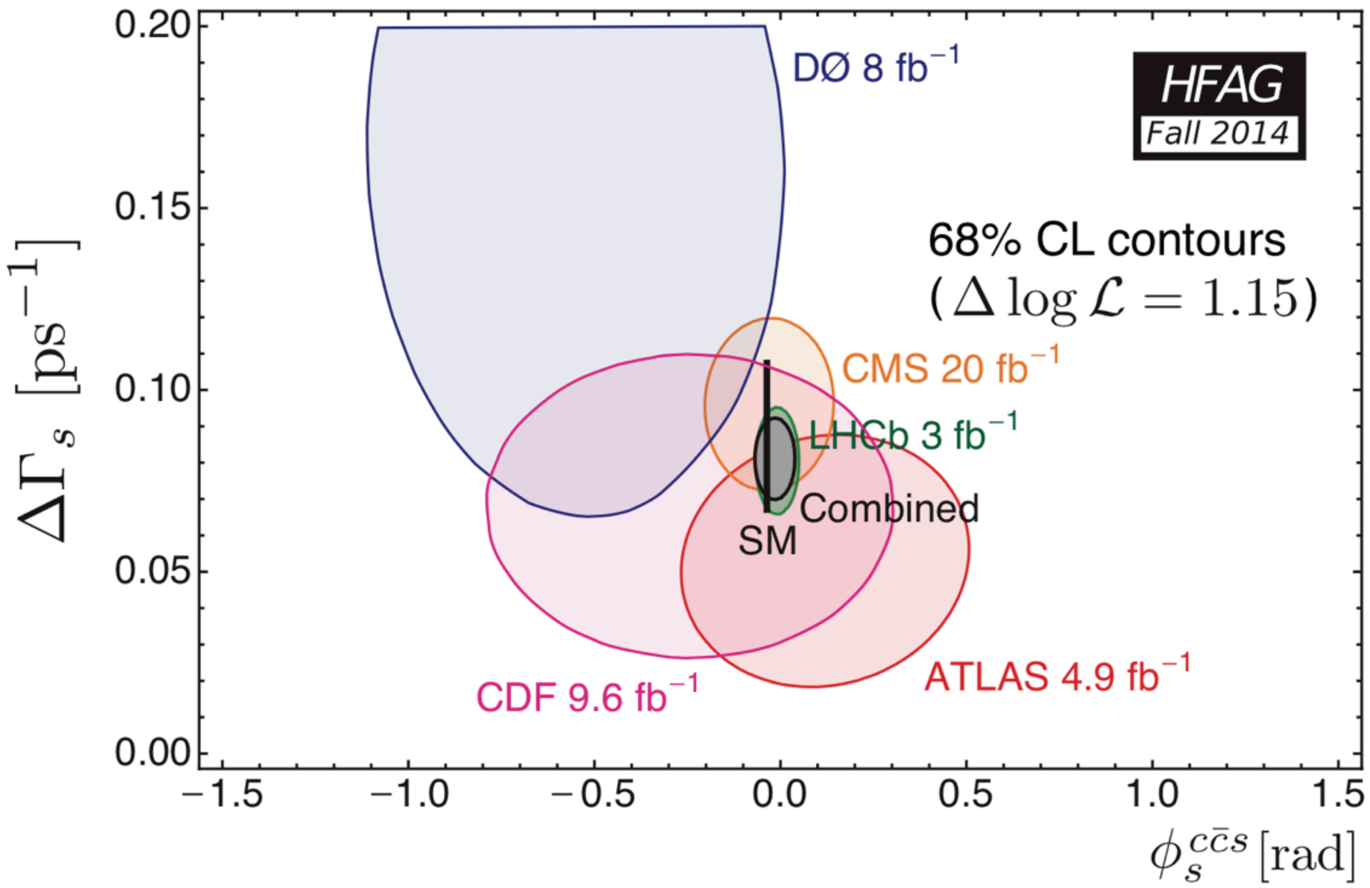




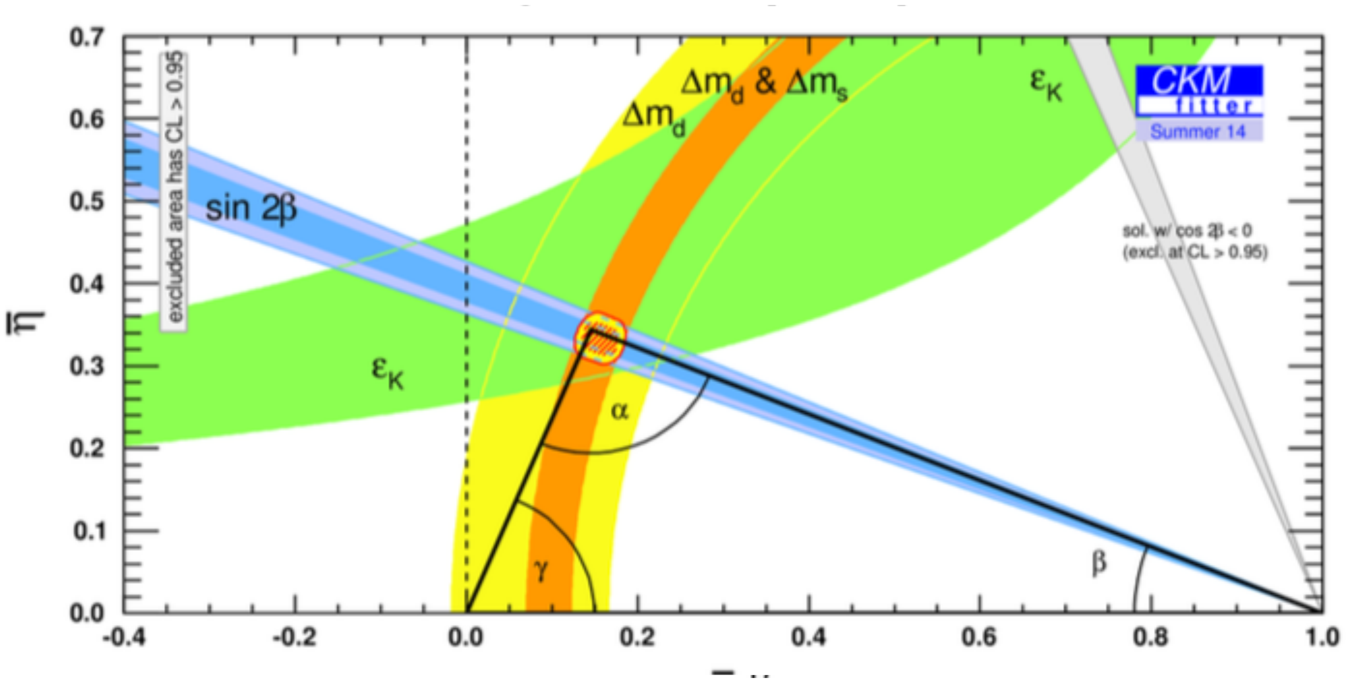
- World mesurement dominated by LHCb
- Main channels:
  - $B^0_s \rightarrow J/\psi\pi^+\pi^-$
  - $B^0_s \rightarrow J/\psi K^+K^-$

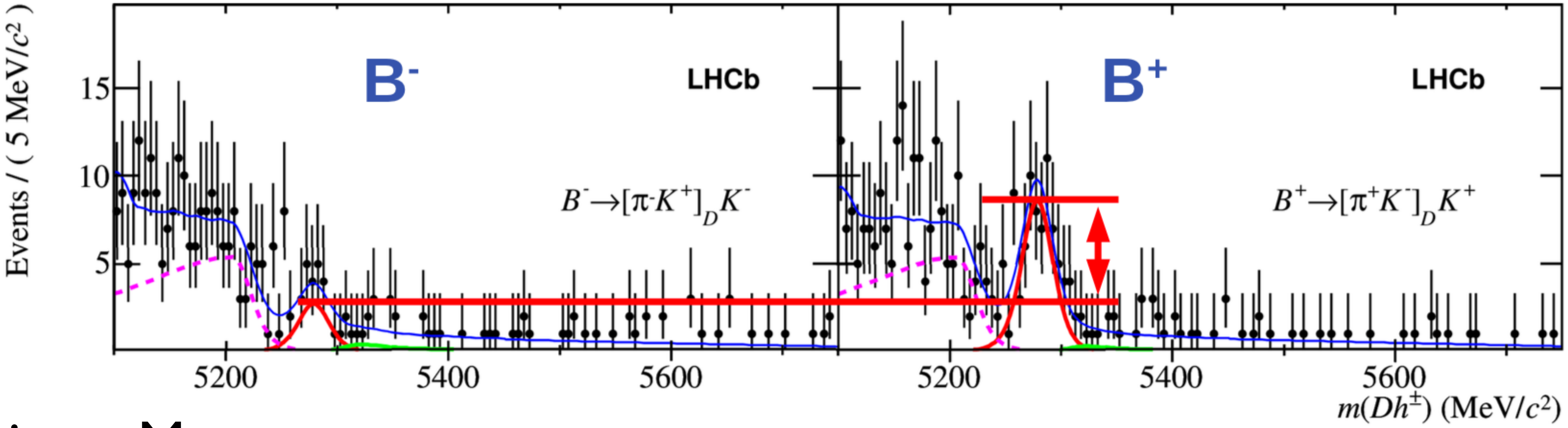


CKM: γ angle

$$\gamma \equiv \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$

- Indirect Measurement:
  - $\gamma = 66.9^{+1}_{-3.7}$ (CKMfitter)



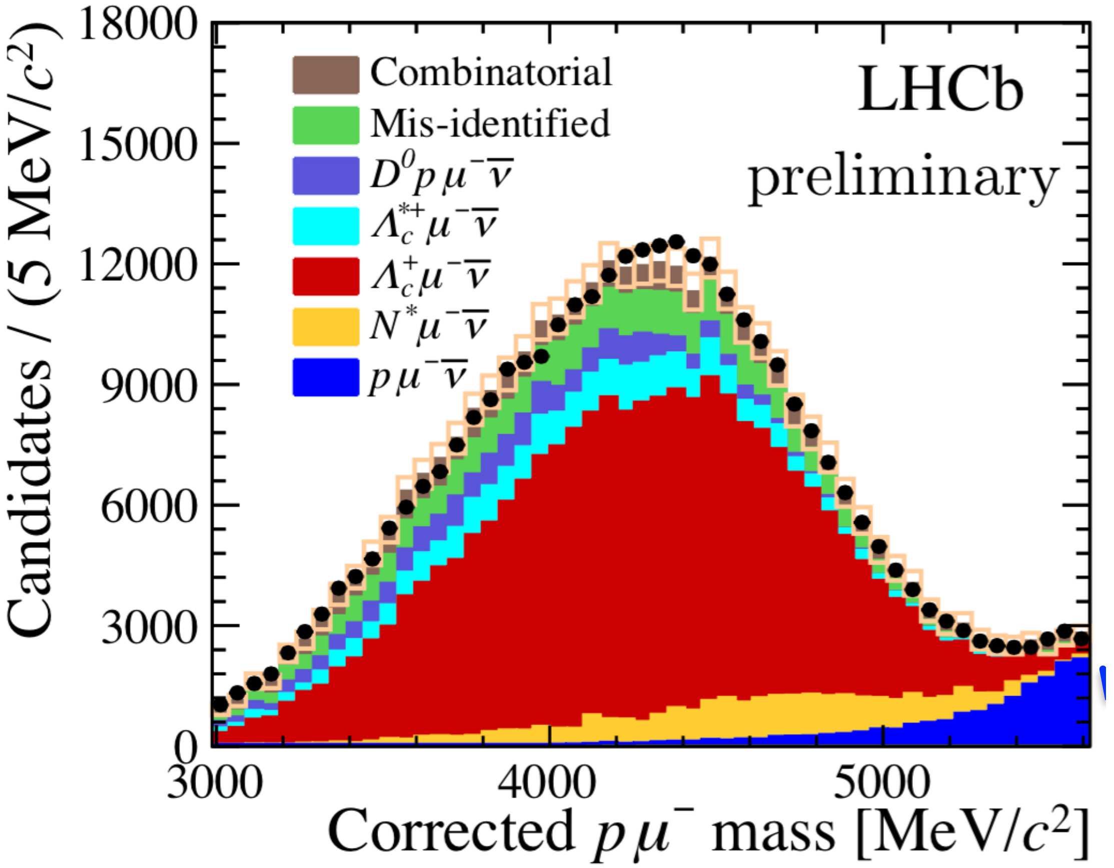


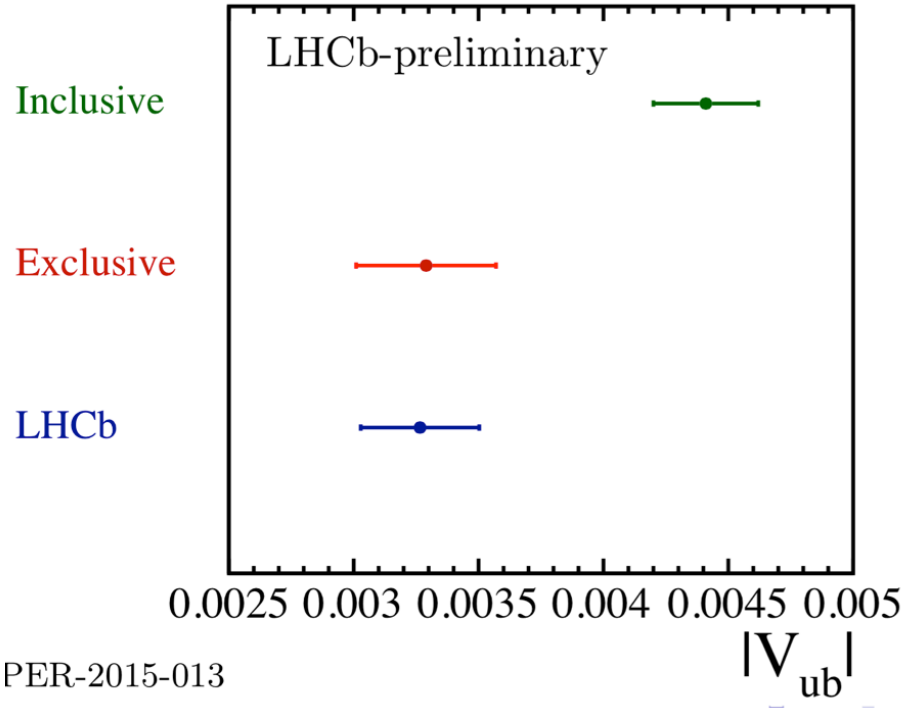
- Direct Measurements:
  - LHCb $\gamma = 73^{+9}_{-10}$
  - BaBar $\gamma = 69^{+17}_{-16}$, Belle 68^{+15}_{-14}

- Still a long way to go before matching indirect measurement

CKM: $|V_{ub}|$

- First ever observation of $\Lambda_b \to p\mu^-\nu$
  - $Br(\Lambda_b \to p\mu^-\nu) = (3.92 \pm 0.83) x 10^{-4}$
- Previous measurements showed tensions between $|V_{ub}|$ measurements in exclusive vs inclusive decays. LHCb results agree with exclusive measurements





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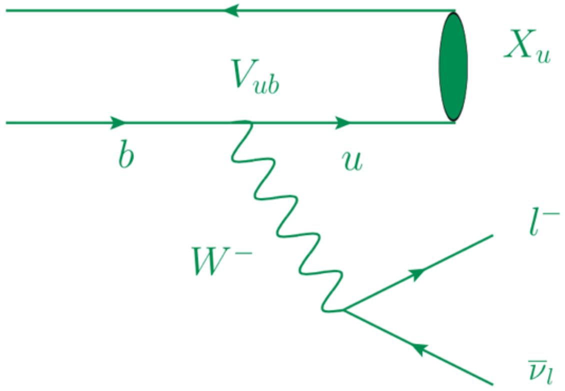

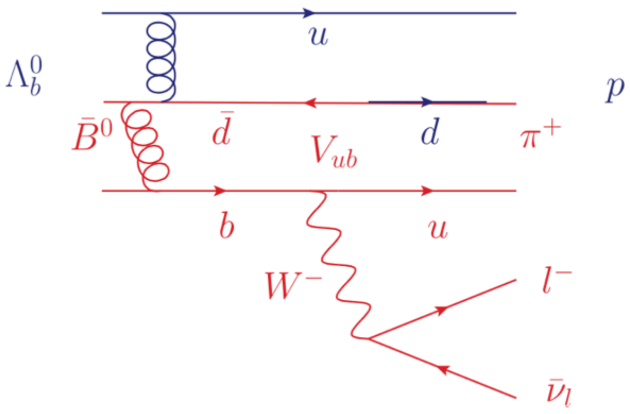

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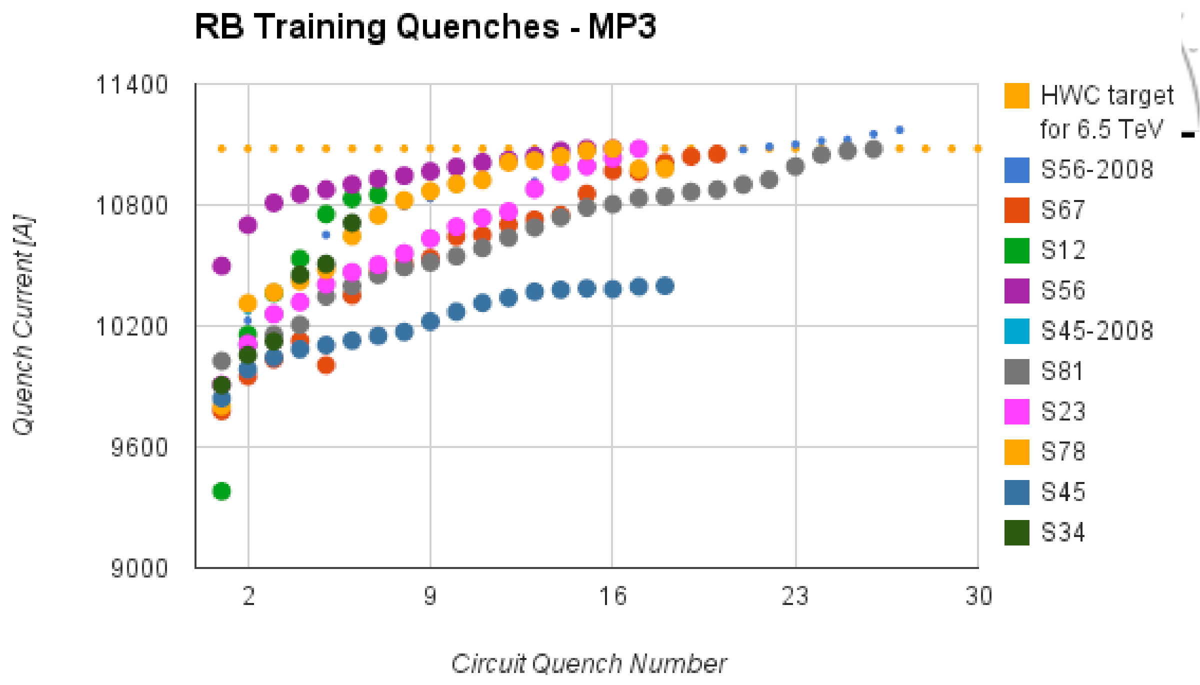
From K to Pseudo-Observables

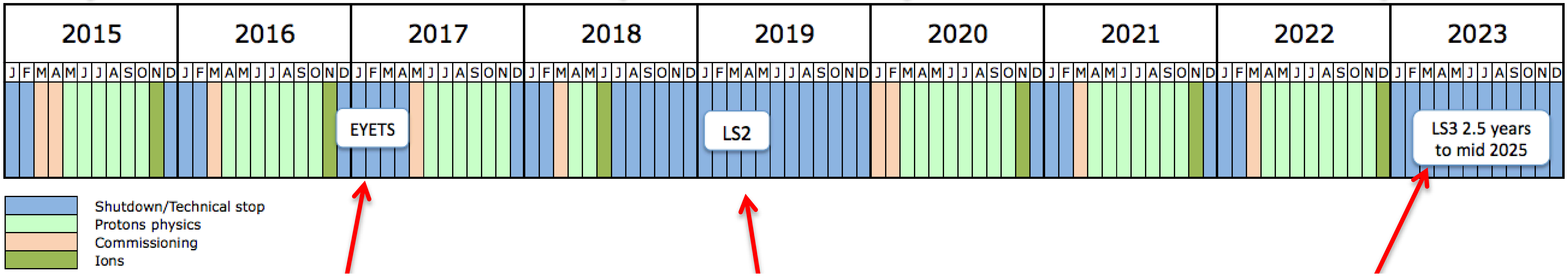
- The k-factors (coupling deviations) framework only affects yields. Not suited for the study of deviations of SM which affect shapes
- Since the run2 LHC program is full of searches for such deviations (SUSY, composite scalar, top partners) a new framework is needed
- Wilson coefficients are an obvious choice, but too much deeply rooted in theory, difficult to find a clear relation with observables
- Proposed solution: Pseudo-Observables, which will depend on the EFT and the experimental signatures of a given process.
  - This means experimentalists and theorists MUST work closely together to define the appropriate PO
- PO might be form factors, or parameters of DATA-MC discrepancies fits

LHC plans

- 2015 plans:
- 6.5TeV, 25ns, 40<β*<80cm
- Energy issues:
  - Lower quench margins, tolerance to beam loss, intensity set-up beams, Hardware closer to maximum (beam dumps, power converters…)
- Bunch spacing issues:
  - Electron-cloud, UFOs, more long range collisions, larger crossing angles, higher β*, beam current



- Ramp the current until single magnet quenches - “training quench”
- Repeat as necessary
- No magnet quenched more than once



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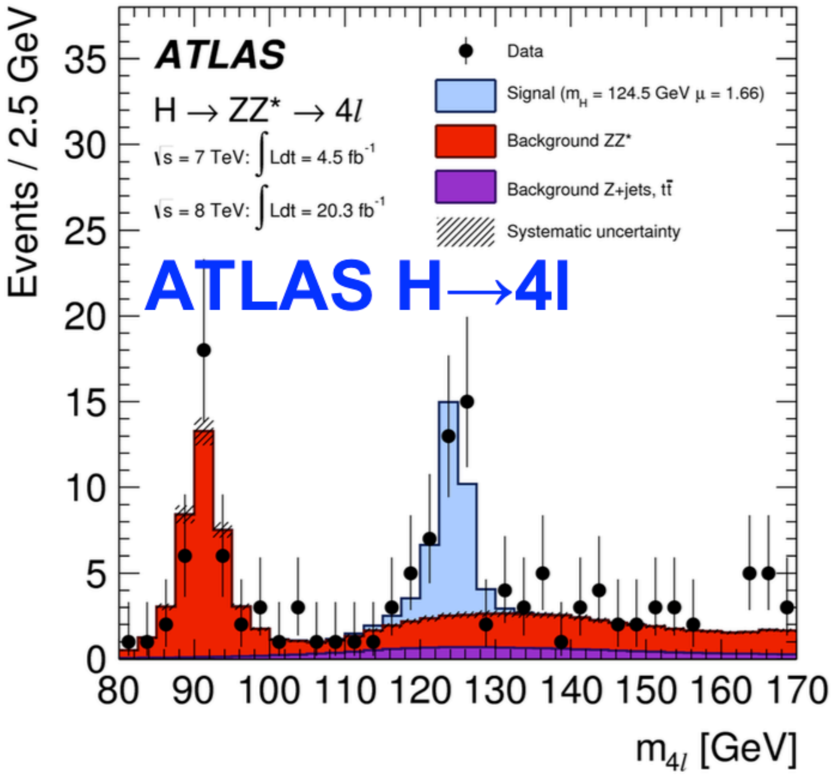
Silver medal: CMS+ATLAS Higgs mass

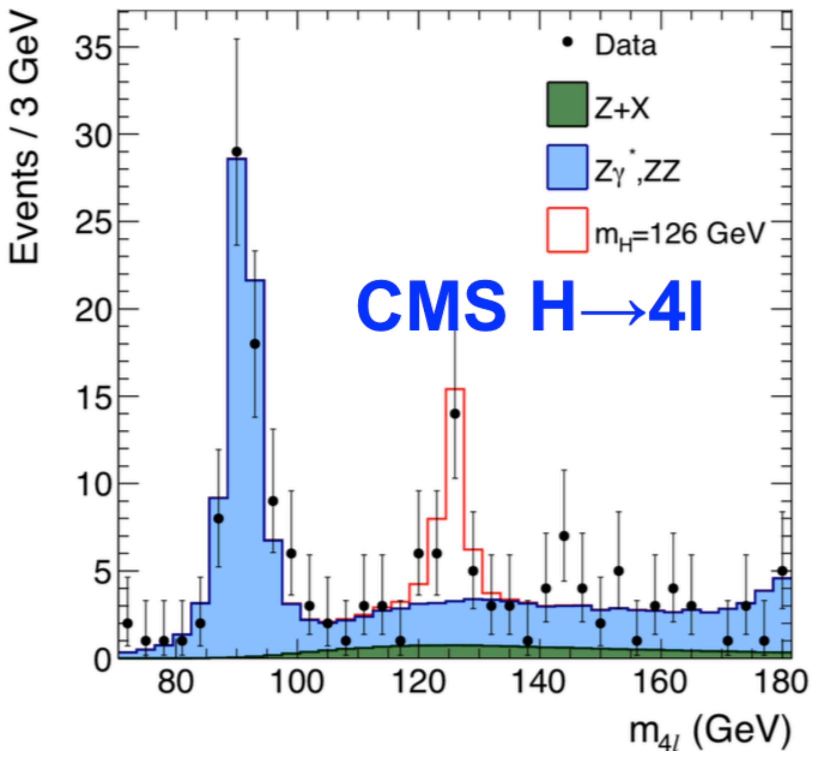
Precise mass determination possible in 2 channels:

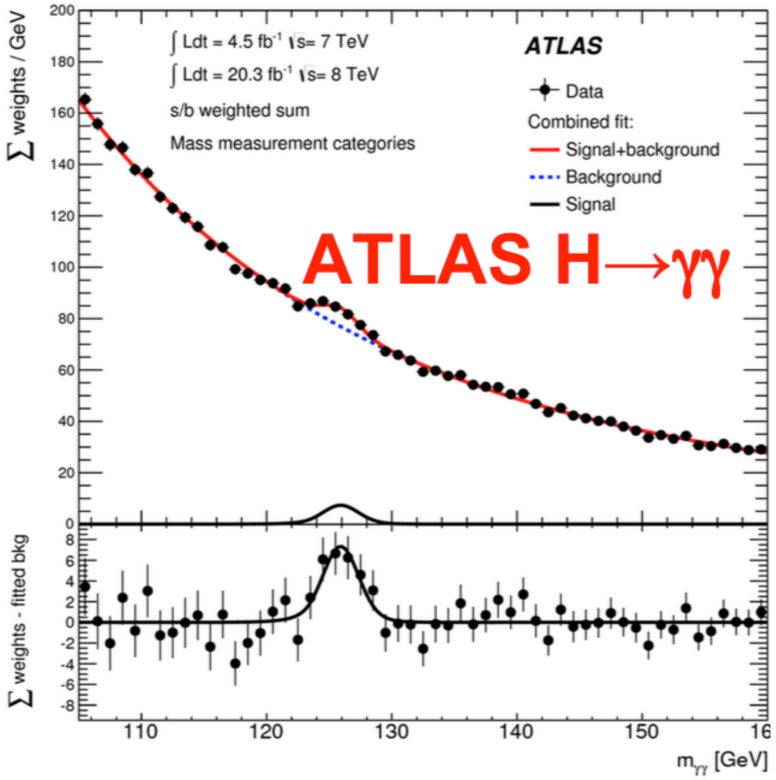
- 4l and γγ
- All other channels have ν or hadrons in final state

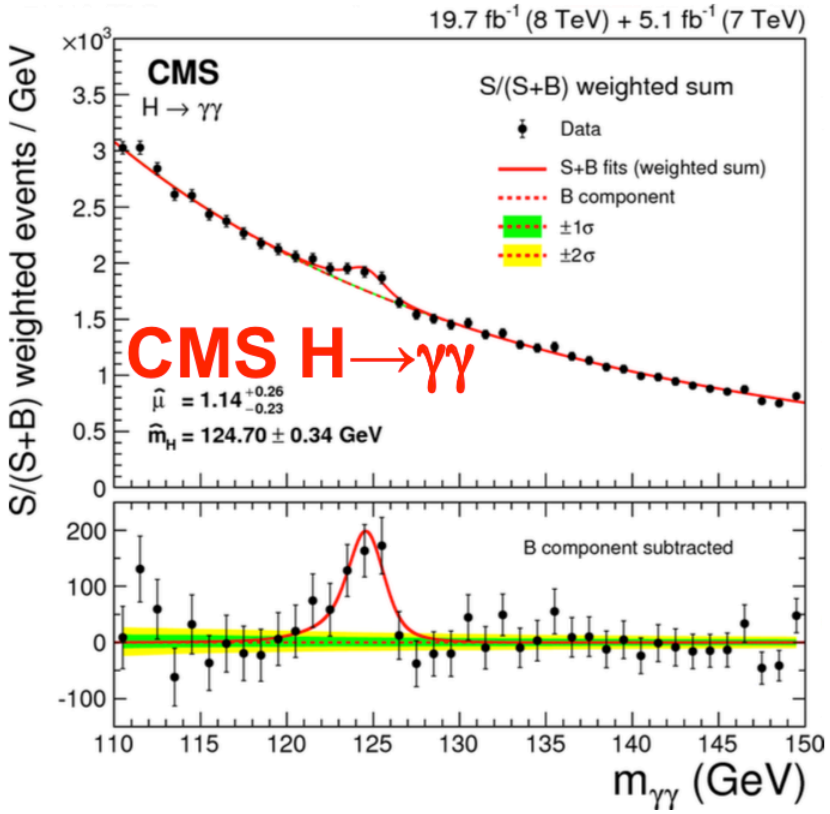
Comparable results among the 2 experiments

Lot of work to properly assess/correlate/quantify all the systematics in the 2 experiments in order to combine properly the likelihoods.

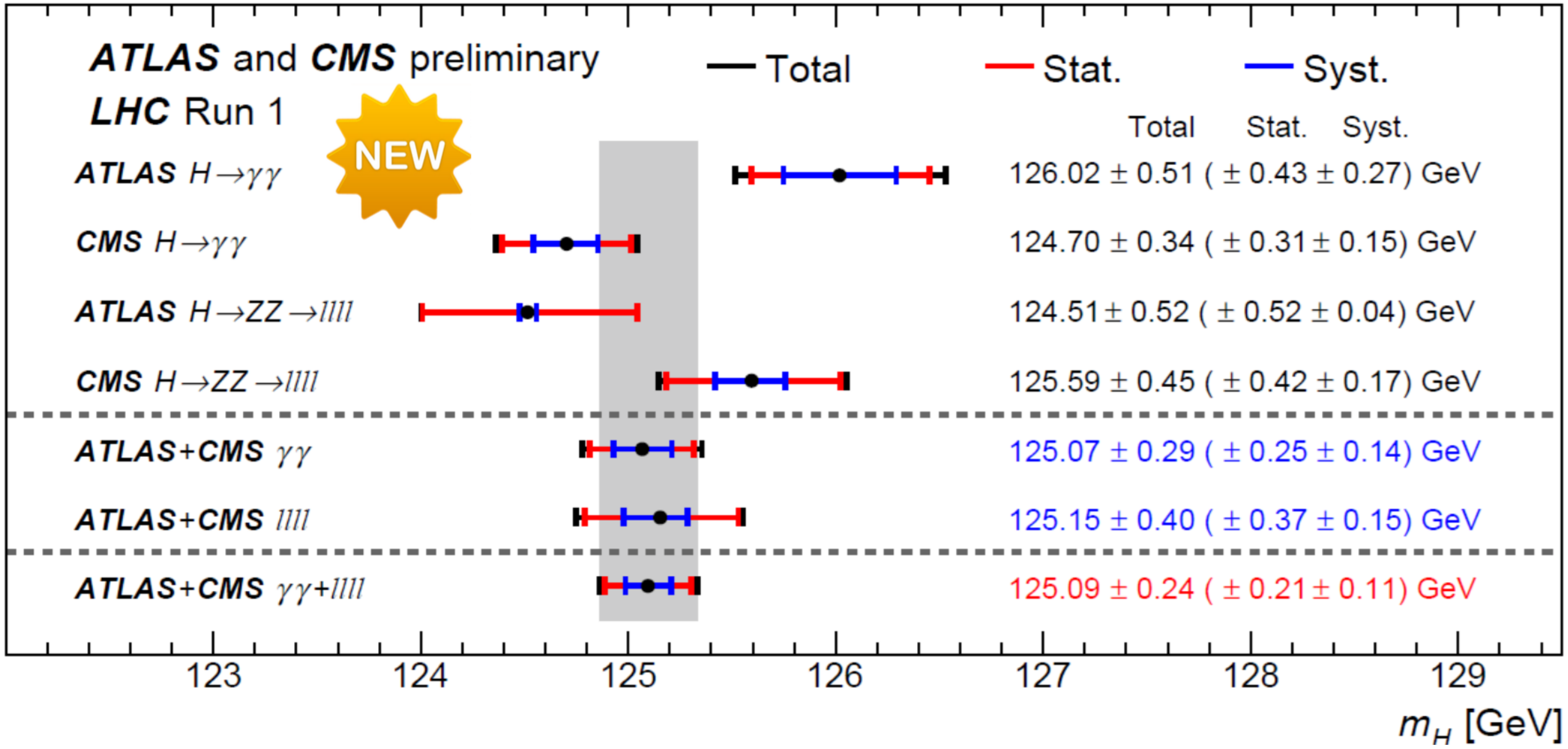






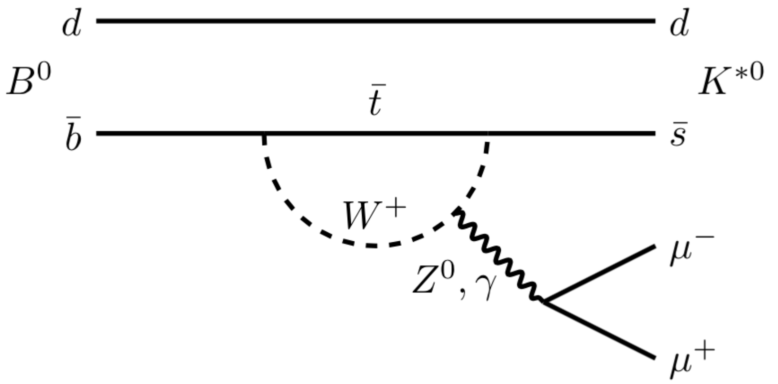


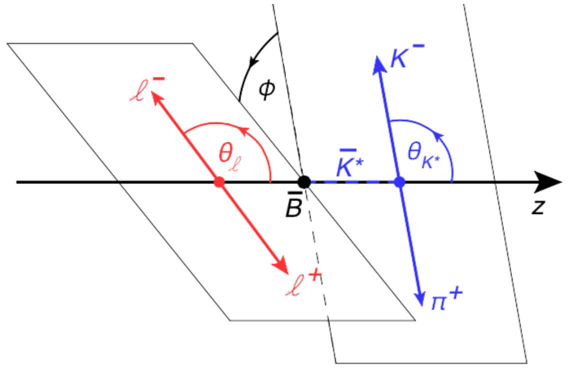
Silver medal: CMS+ATLAS Higgs mass



- mH=125.09±0.21(stat)±0.11(syst) GeV
- 0.19% precision! Among the most precise parameters of the EWK fit
- Systematics dominated by energy/momentum scale corrections (dominated by the available statistics)
- Tensions mostly within experiments, no indications of channel dependencies

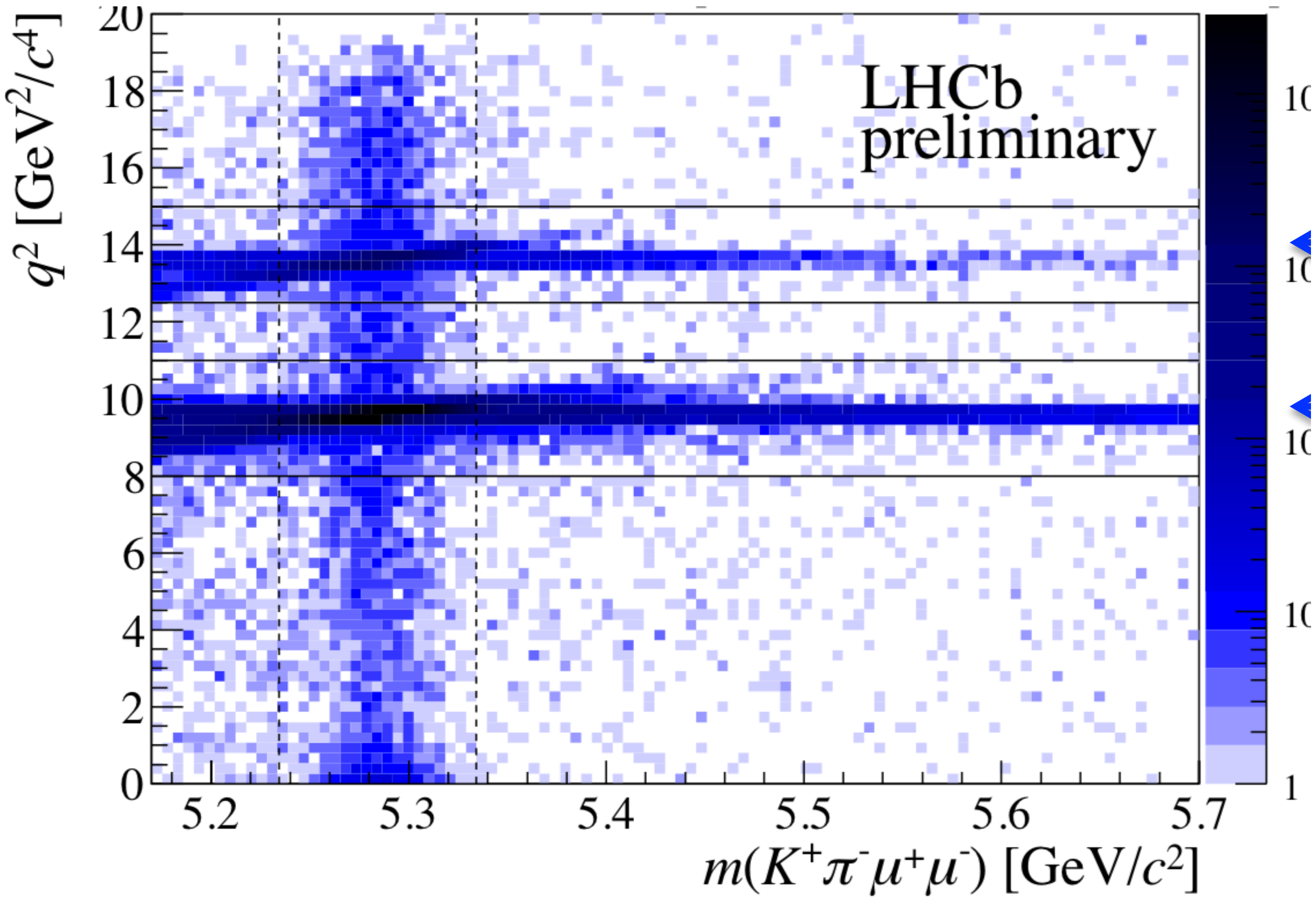
Gold medal: LHCb $B^0_s \to K^*\mu\mu$





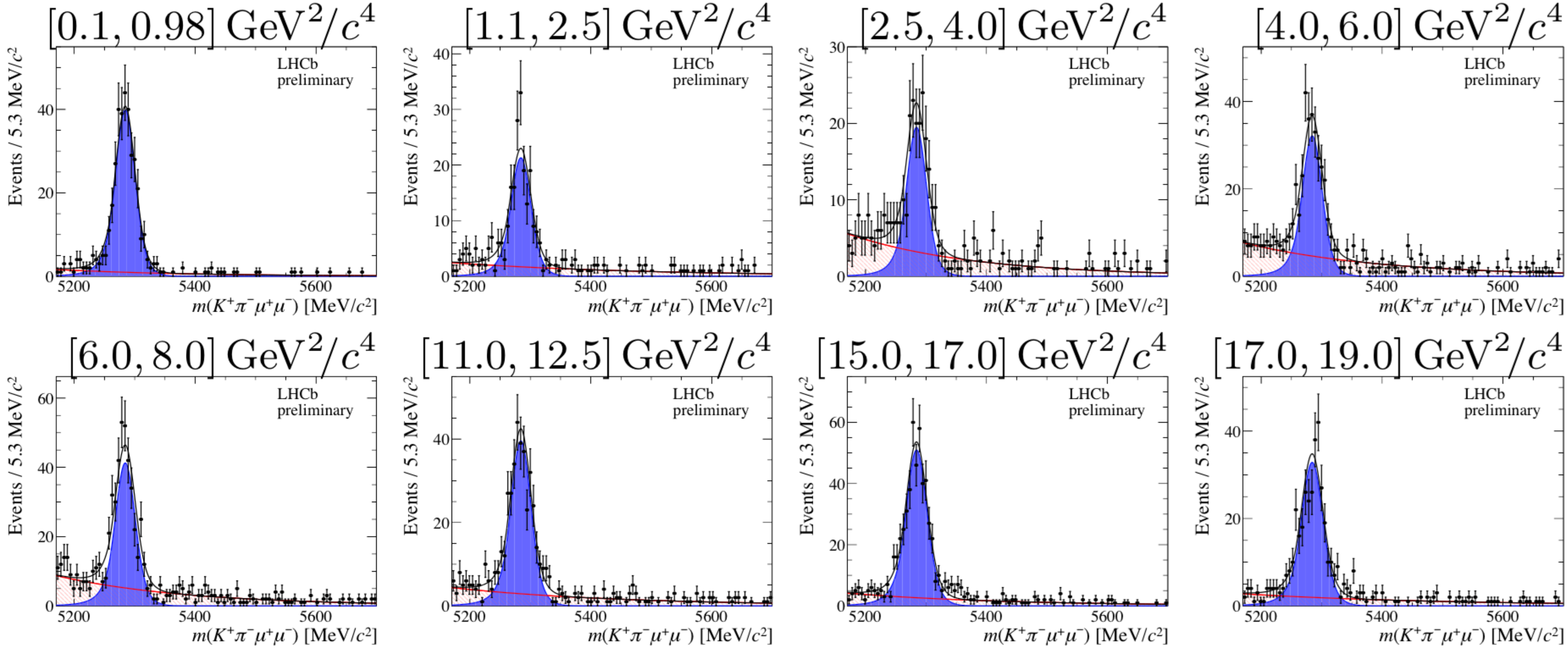
$\bar{K}^{*0} \to K^-\pi^+$

- Decay fully described by 3 helicity angles Ω and $q^2=m^2_{\mu\mu}$
- Total signal yield: 2398±57ev



Gold medal: LHCb $B^0_s \to K^*\mu\mu$

- Significant signal observed in all q^2 bins



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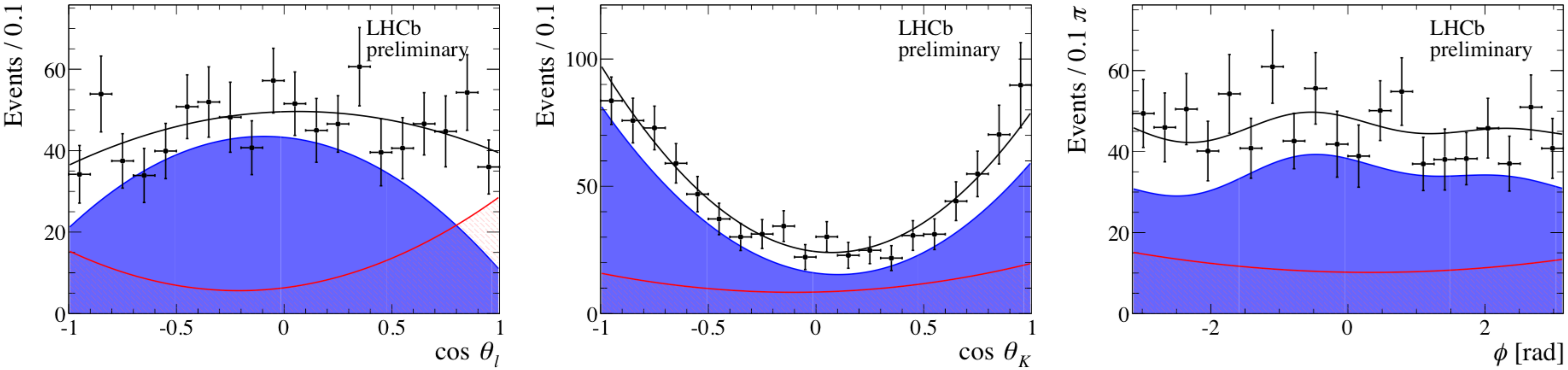
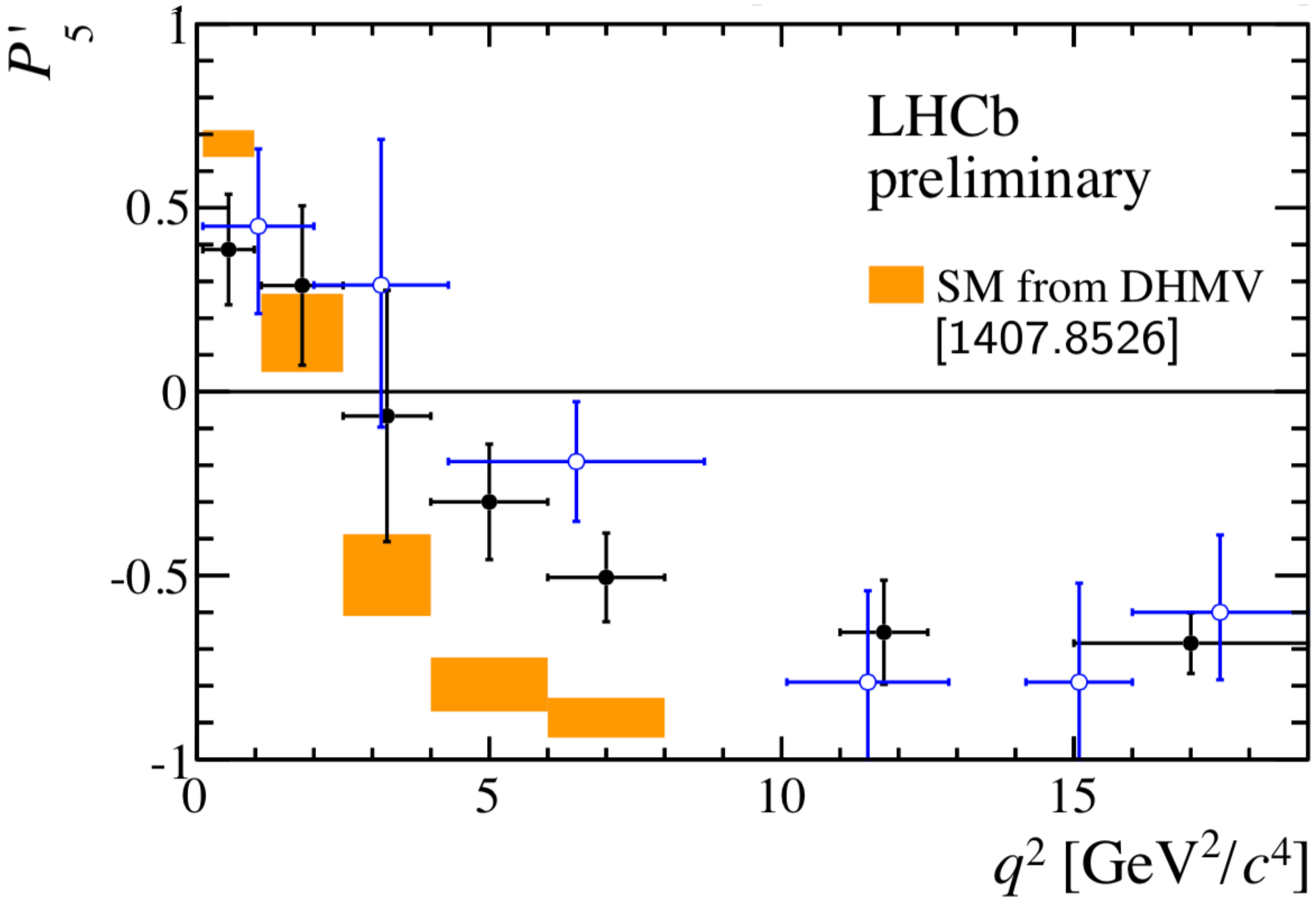
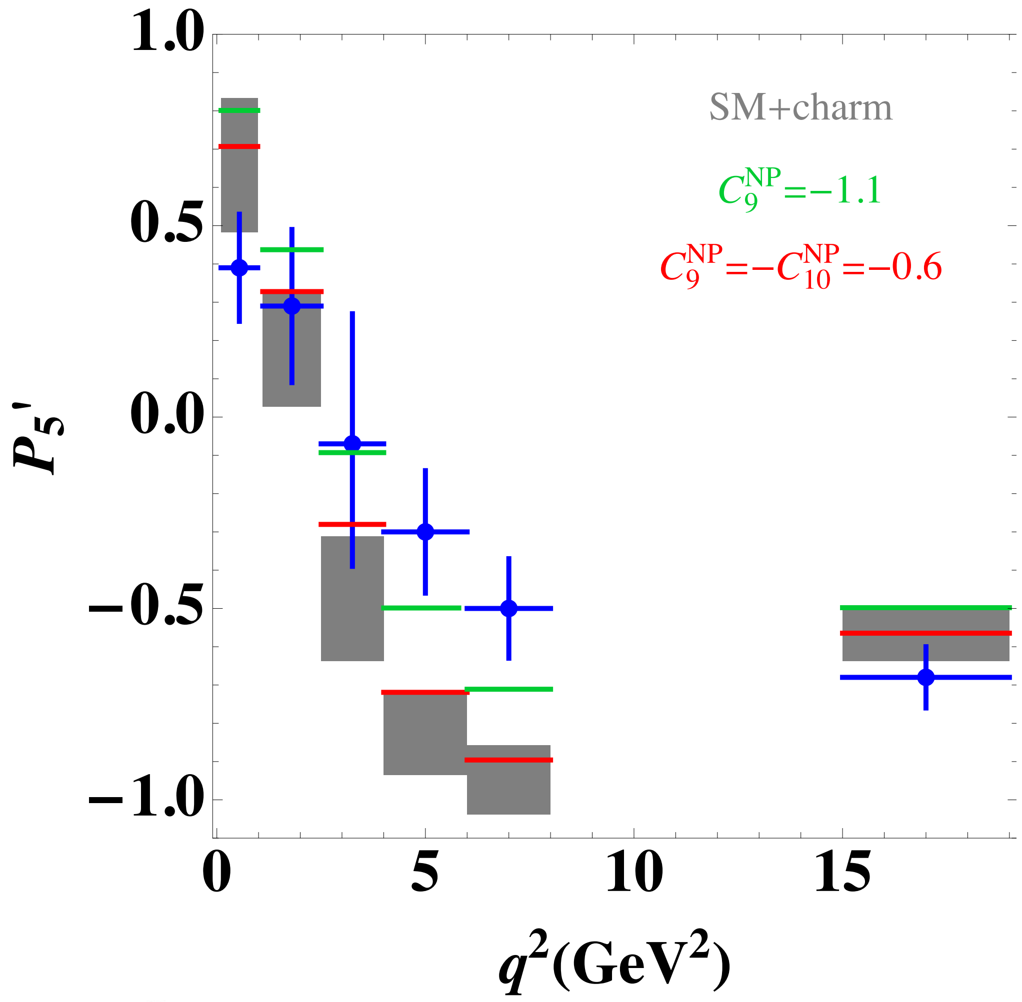


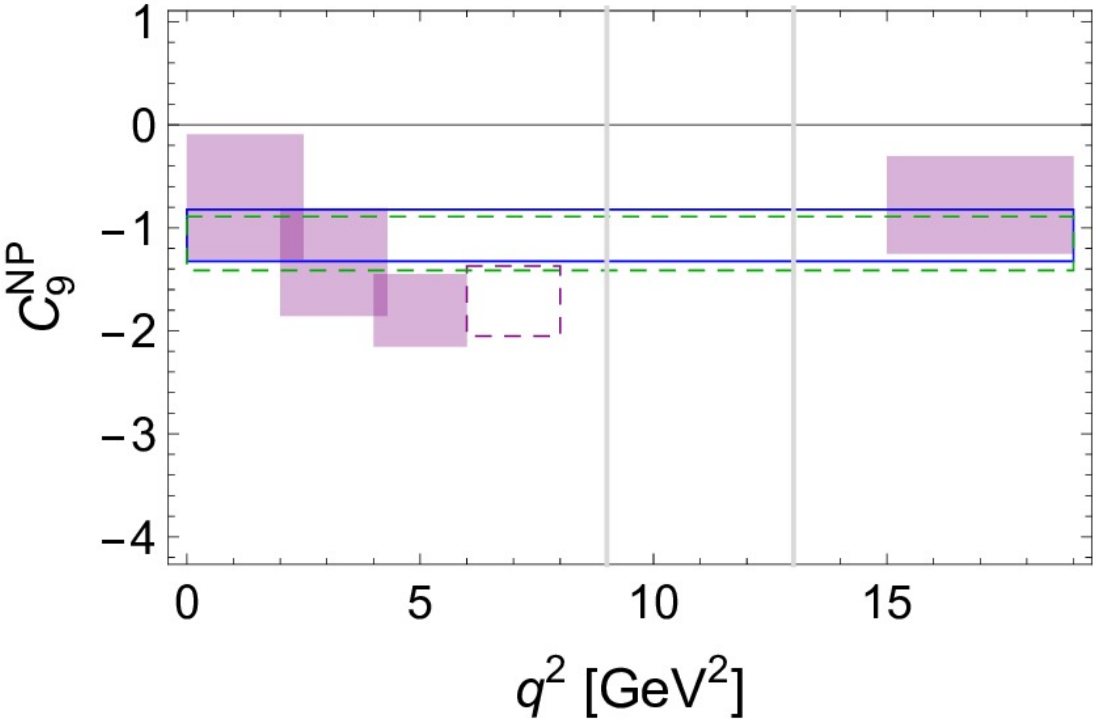


- P’5 is a combination of the fitted angular distributions for which hadronic form factors uncertainties should be small
- Discrepancy SM/Data in $4<q^2<8$ bins is about 3.7σ

Gold medal: LHCb $B^0_s \to K^*\mu\mu$

- J. Matias and D. Straub ran (independently) a global fit of the SM and compared it with LHCb data, adding Wilson coefficients for NP in the fit
    - χ^2_{SM}=116.9/88 (p=2.14%)
    - χ^2_{SM}=125.8/91 (p=0.92%) when including $b \to se^+e^-$
- BSM with NP in C^{NP}_9 preferred wrt SM by 3.7σ, 4.3σ when including $b \to se^+e^-$
- C^{NP}_9 is linked to LFUV theories
- QCD effects (charm loops) can mimic this. If it is NP than it should be q^2 independent





Conclusions

- An extremely rich physics program has been presented at Moriond this year
  - Great results on several topics: neutrinos, flavour physics, theory, standard model…
  - Unfortunately I couldn't put in everything, but I hope you enjoyed this presentation
- High expectations for LHC run2 and for HL-LHC
- Two especially impressive results:
  - from CMS/ATLAS the final h mass combination
  - from LHCb a 4.3σ SM incompatibility in $B \rightarrow K^{*}\mu\mu$

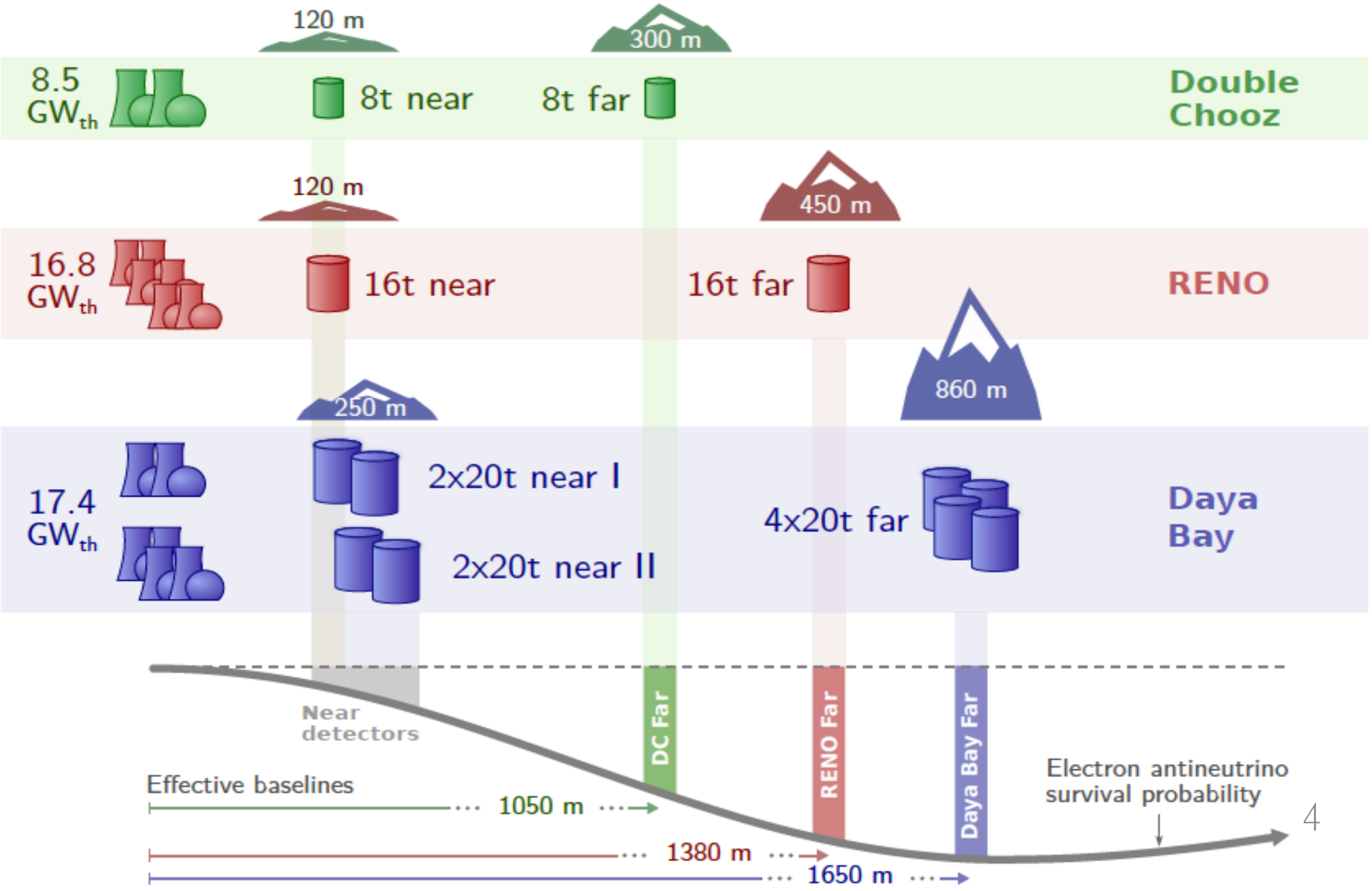
Comments

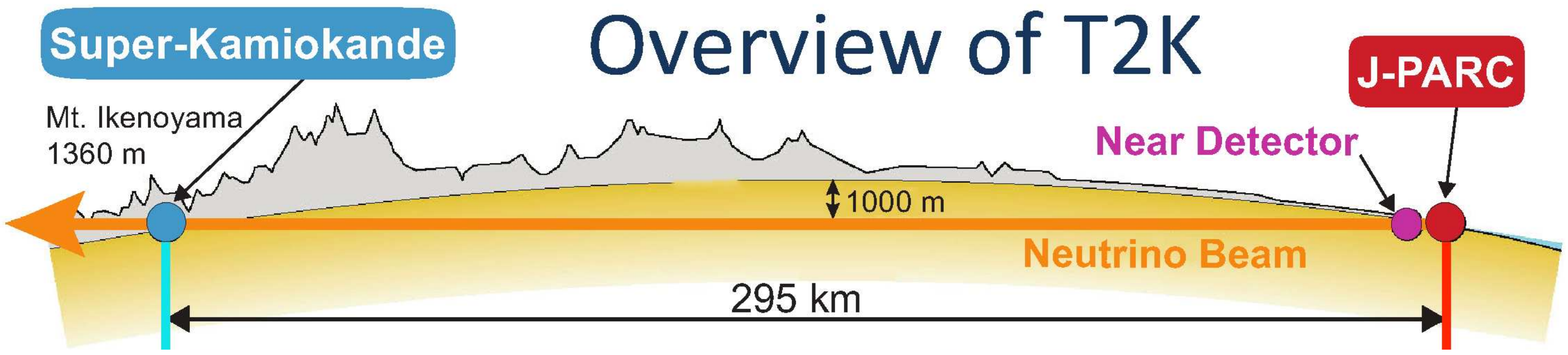
- SM looks as solid as ever (despite LHCb efforts)
- Some roads left:
  - 3 TeV SUSY, Z', flavour violation are still well in the game
- The experiments are delivering impressive results, but the theory seems to have difficulties to keep the pace
  - IMHO, we are headed again for an experiment driven period
  - Suggestions that adimensional gravity with $g_{gravity}$ reaching a plateau before10^{11}GeV might solve naturalness
  - Higgs fluctuation during inflation might give baryogenesys
  - Vacuum metastability does not depends on M_t/M_H alone
- EFT are the latest development, but might not be the best way out
  - Not clear how you can get at the same time FV and Yukawa couplings

BACKUP

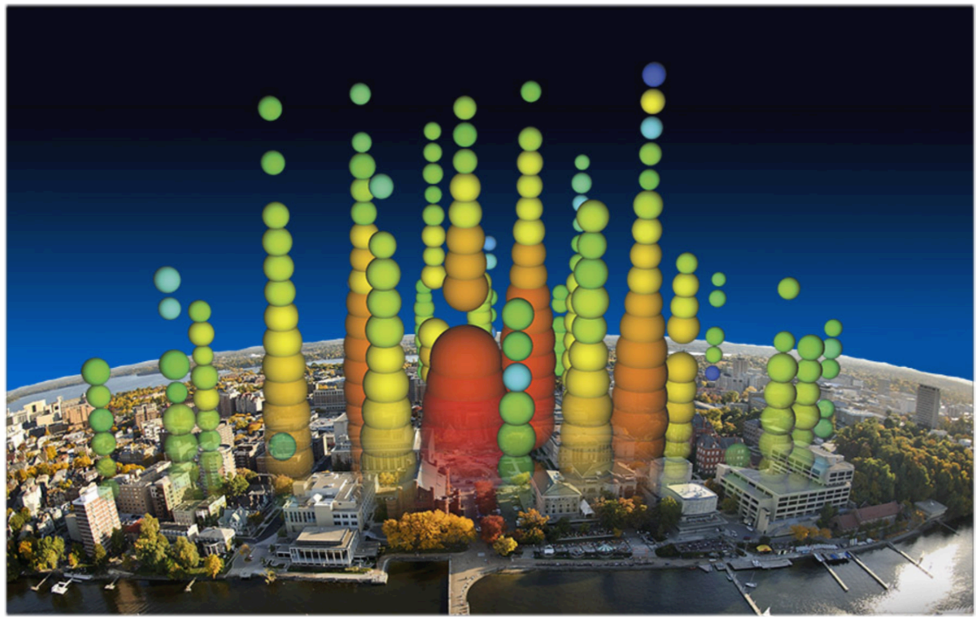
ν (and DM) detectors common features

- Deep underground
- Active/Passive shielding around active volume
- Fiducial volume to select fully contained events
- extremely high radio radiopurity
- Coincidence from more than 1 detection technique for signal
  - Ionization, Cherenkov light, phonons, scintillation light…



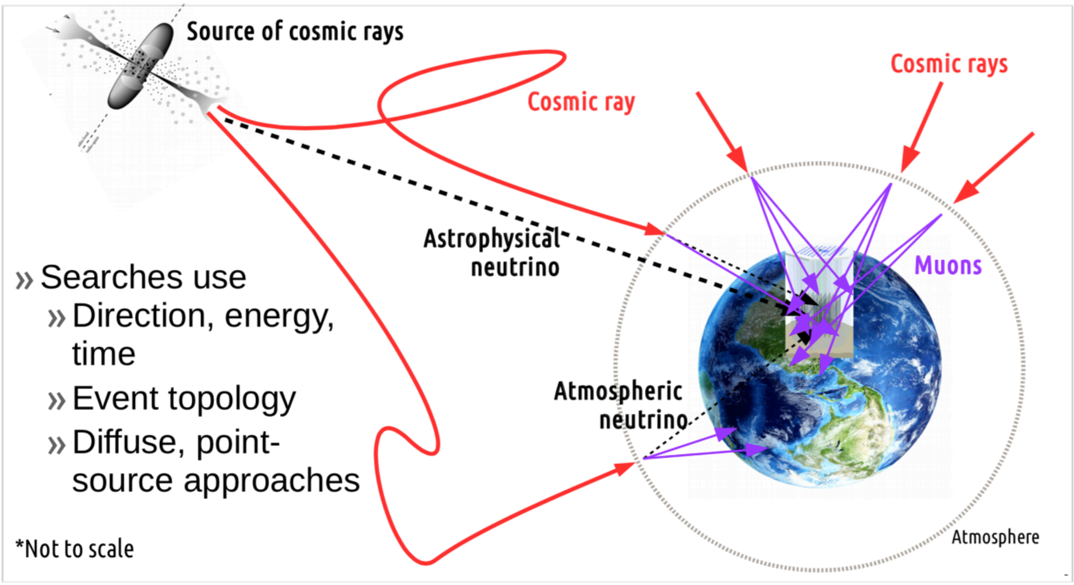


IceCube



- Cherenkov light in ice
- Located at geo south pole
  - atm ν only from above
- 1km^3 active volume
- 1.5-2.5km deep
- ν detection threshold: ~200GeV

- Goal: study the very high energetic cosmological ν and look for possible cosmological sources
- Possible hints for DM, help to study extreme cosmological phenomena

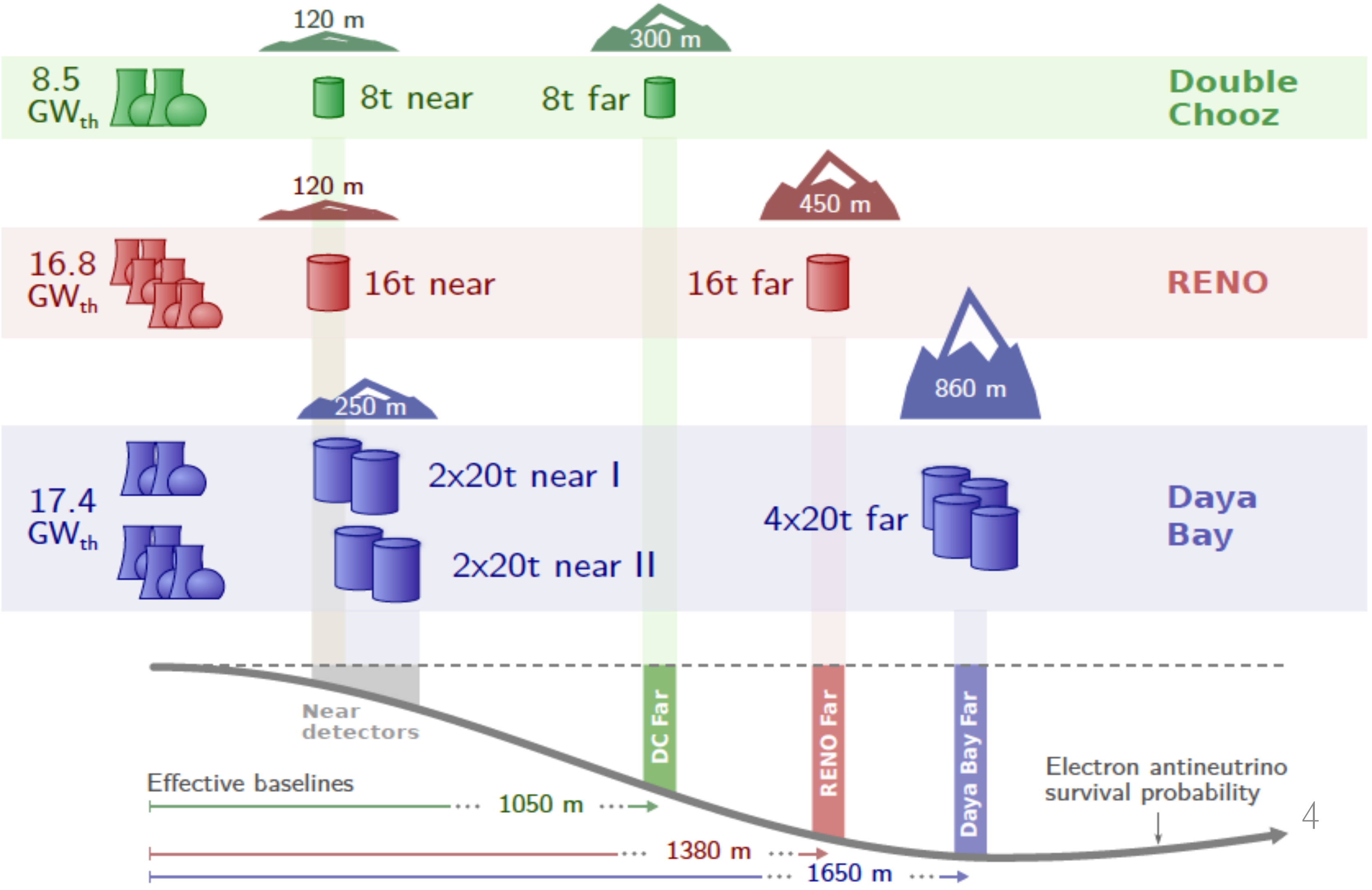


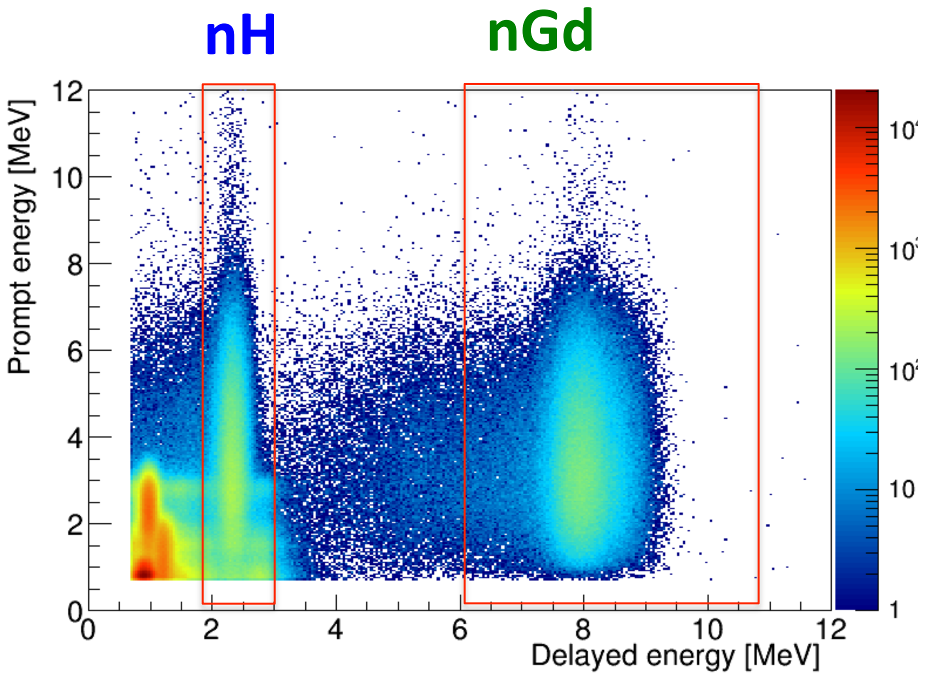
» Searches use
  » Direction, energy, time
  » Event topology
  » Diffuse, point-source approaches

Results from ν reactors

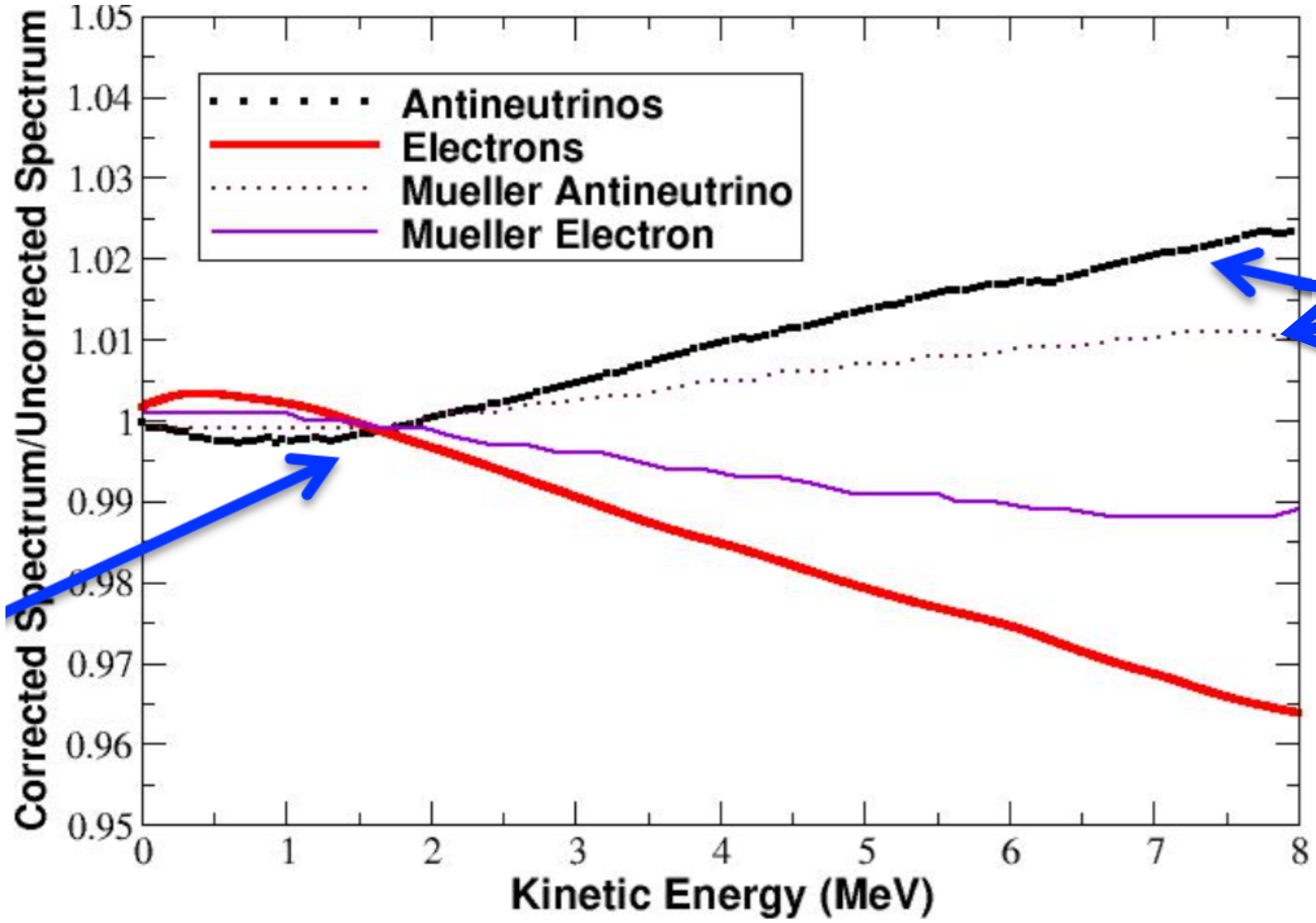
Inverse Beta Decay (IBD): $\bar{\nu}_e + p \rightarrow e^+ + n$

$$\left| \begin{array}{l} +H \rightarrow D + \gamma \\ +Gd \rightarrow Gd^* \rightarrow Gd + \gamma' s \end{array} \right.$$





Uncertainties on expected flux

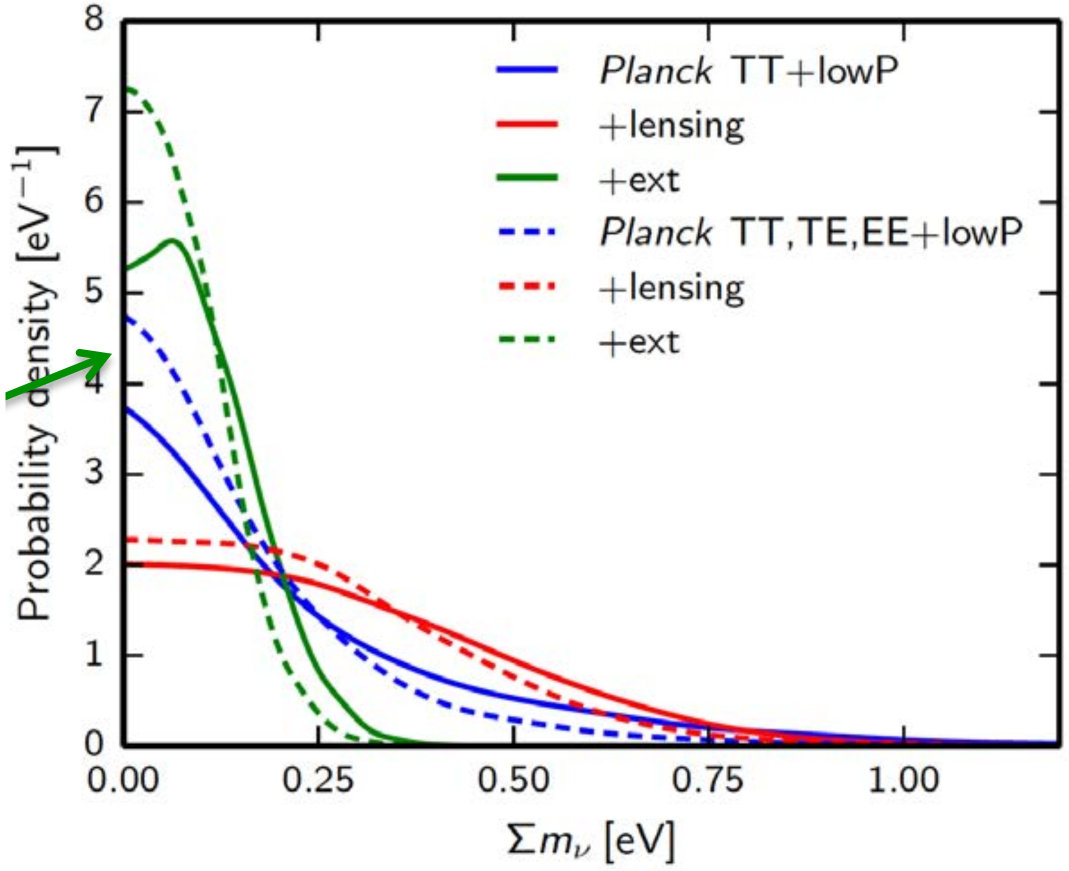


Different calculations yield to largely different results

- These are really difficult calculations
  - Impossible to decide which one is better on theoretical grounds alone
  - Quoted syst. are underestimated by ~2. This can cover the anomaly
- Need for new experiments (such as PROSPECT, SOLID, NUCIFER, STEREO)
  - Until new data, claims for ν_s on this basis should be rejected

Planck

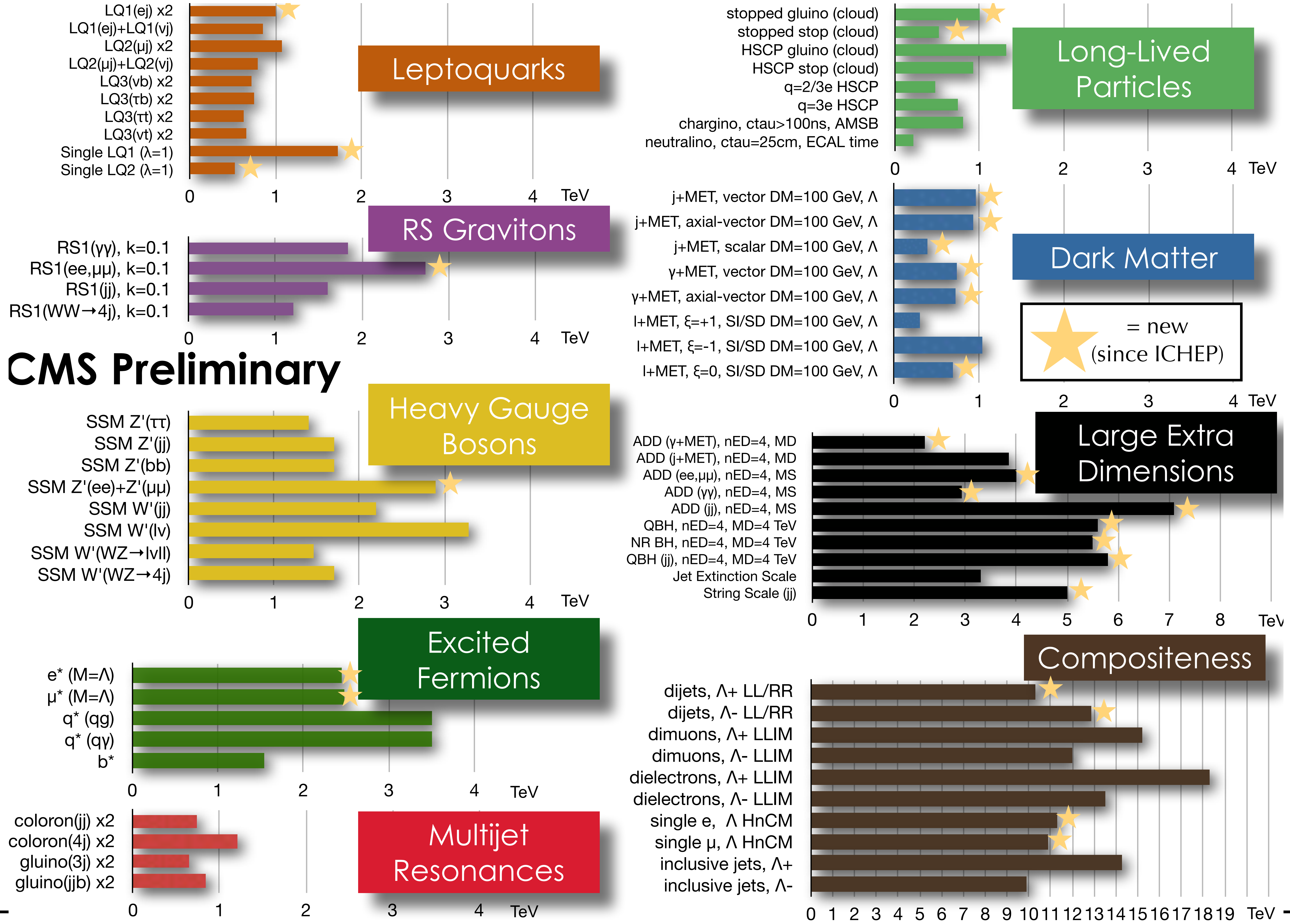
- Improvements for 2015:
  - Data calibration
  - Better control of systematics
  - Full mission data (increase statistics)
  - Polarization from Planck own instruments
    - No need to rely on maps anymore



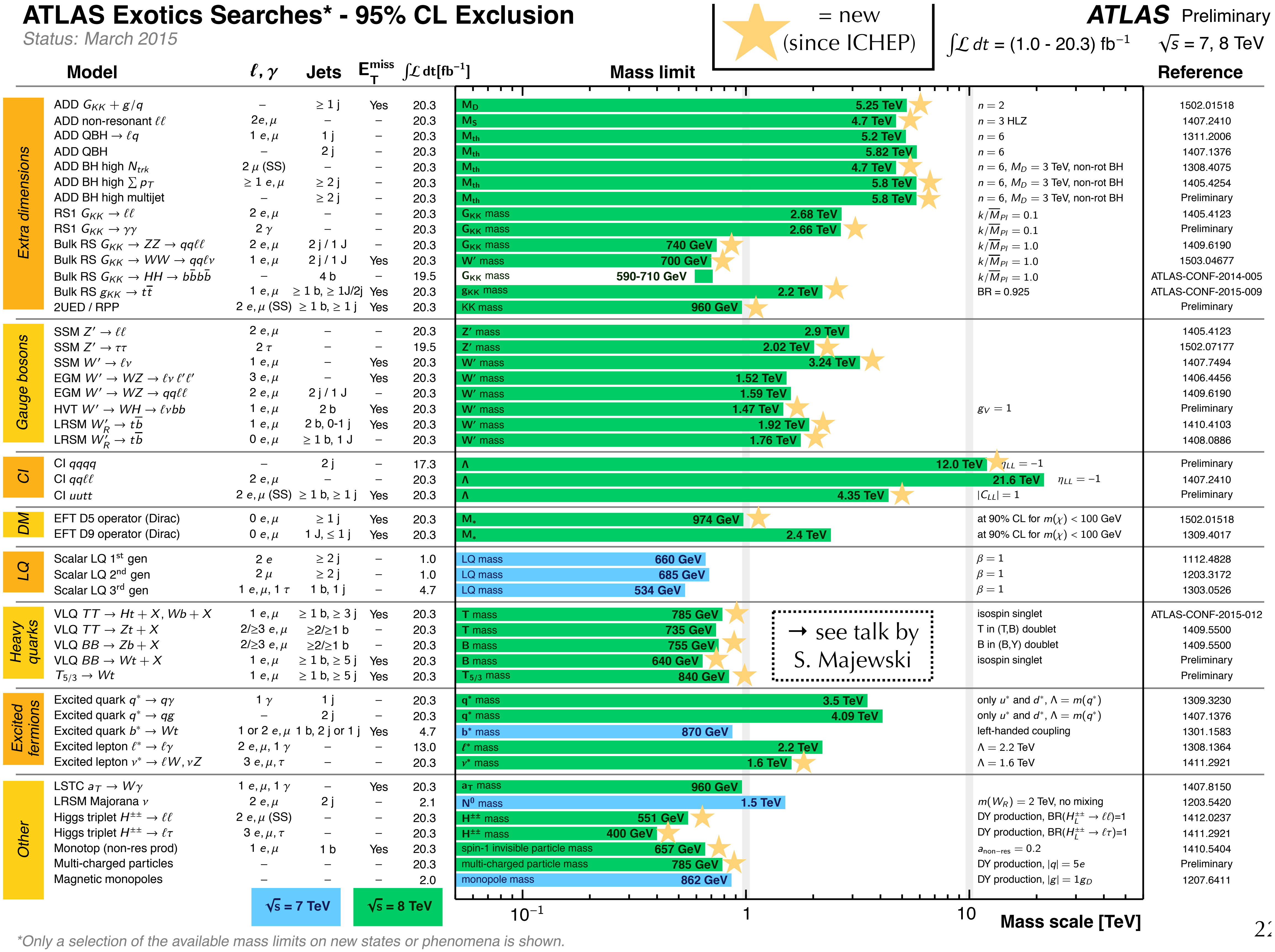
- Results
  - Update Temperature spectrum + polarization spectrum
  - $\Sigma m_\nu > 0.23$eV, close to what we need to test hierarchy
  - Number of Relativistic DOF (3.046 if only photons and ν)

$$N_{\rm eff} = 2.99 \pm 0.20 \quad \textit{Planck}\ \mathrm{TT, TE, EE+lowP}\,;$$
$$N_{\rm eff} = 3.04 \pm 0.18 \quad \textit{Planck}\ \mathrm{TT, TE, EE+lowP+BAO}\,.$$

BSM status


CMS Preliminary
Leptoquarks
LQ1(ej) x2
LQ1(ej)+LQ1(νj)
LQ2(μj) x2
LQ2(μj)+LQ2(νj)
LQ3(νb) x2
LQ3(τb) x2
LQ3(ττ) x2
LQ3(νt) x2
Single LQ1 (λ=1)
Single LQ2 (λ=1)
0 1 2 3 4 TeV
RS Gravitons
RS1(γγ), k=0.1
RS1(ee,μμ), k=0.1
RS1(jj), k=0.1
RS1(WW→4j), k=0.1
0 1 2 3 4 TeV
Heavy Gauge Bosons
SSM Z'(ττ)
SSM Z'(jj)
SSM Z'(bb)
SSM Z'(ee)+Z'(μμ)
SSM W'(jj)
SSM W'(lν)
SSM W'(WZ→lνll)
SSM W'(WZ→4j)
0 1 2 3 4 TeV
Excited Fermions
e* (M=Λ)
μ* (M=Λ)
q* (qg)
q* (qγ)
b*
0 1 2 3 4 TeV
Multijet Resonances
coloron(jj) x2
coloron(4j) x2
gluino(3j) x2
gluino(jjb) x2
0 1 2 3 4 TeV
Long-Lived Particles
stopped gluino (cloud)
stopped stop (cloud)
HSCP gluino (cloud)
HSCP stop (cloud)
q=2/3e HSCP
q=3e HSCP
chargino, ctau>100ns, AMSB
neutralino, ctau=25cm, ECAL time
0 1 2 3 4 TeV
Dark Matter
j+MET, vector DM=100 GeV, Λ
j+MET, axial-vector DM=100 GeV, Λ
j+MET, scalar DM=100 GeV, Λ
γ+MET, vector DM=100 GeV, Λ
γ+MET, axial-vector DM=100 GeV, Λ
l+MET, ξ=+1, SI/SD DM=100 GeV, Λ
l+MET, ξ=-1, SI/SD DM=100 GeV, Λ
l+MET, ξ=0, SI/SD DM=100 GeV, Λ
0 1 2 3 4 TeV
★ = new (since ICHEP)
Large Extra Dimensions
ADD (γ+MET), nED=4, MD
ADD (j+MET), nED=4, MD
ADD (ee,μμ), nED=4, MS
ADD (γγ), nED=4, MS
ADD (jj), nED=4, MS
QBH, nED=4, MD=4 TeV
NR BH, nED=4, MD=4 TeV
QBH (jj), nED=4, MD=4 TeV
Jet Extinction Scale
String Scale (jj)
0 1 2 3 4 5 6 7 8 TeV
Compositeness
dijets, Λ+ LL/RR
dijets, Λ- LL/RR
dimuons, Λ+ LLIM
dimuons, Λ- LLIM
dielectrons, Λ+ LLIM
dielectrons, Λ- LLIM
single e, Λ HnCM
single μ, Λ HnCM
inclusive jets, Λ+
inclusive jets, Λ-
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 TeV

BSM status



ATLAS Exotics Searches* - 95% CL Exclusion

Status: March 2015

★ = new (since ICHEP)

ATLAS Preliminary

$\int\mathcal{L}\,dt$ = (1.0 - 20.3) fb^{-1} $\sqrt{s}$ = 7, 8 TeV

	Model	ℓ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Extra dimensions	ADD $G_{KK}+g/q$	–	≥ 1 j	Yes	20.3	M_D 5.25 TeV ★	$n=2$	1502.01518
	ADD non-resonant $\ell\ell$	$2e,\mu$	–	–	20.3	M_S 4.7 TeV ★	$n=3$ HLZ	1407.2410
	ADD QBH $\to\ell q$	1 e,μ	1 j	–	20.3	M_{th} 5.2 TeV	$n=6$	1311.2006
	ADD QBH	–	2 j	–	20.3	M_{th} 5.82 TeV	$n=6$	1407.1376
	ADD BH high N_{trk}	2 μ (SS)	–	–	20.3	M_{th} 4.7 TeV ★	$n=6$, $M_D=3$ TeV, non-rot BH	1308.4075
	ADD BH high $\sum p_T$	≥ 1 e,μ	≥ 2 j	–	20.3	M_{th} 5.8 TeV ★	$n=6$, $M_D=3$ TeV, non-rot BH	1405.4254
	ADD BH high multijet	–	≥ 2 j	–	20.3	M_{th} 5.8 TeV ★	$n=6$, $M_D=3$ TeV, non-rot BH	Preliminary
	RS1 $G_{KK}\to\ell\ell$	2 e,μ	–	–	20.3	G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl}=0.1$	1405.4123
	RS1 $G_{KK}\to\gamma\gamma$	2 γ	–	–	20.3	G_{KK} mass 2.66 TeV ★	$k/\overline{M}_{Pl}=0.1$	Preliminary
	Bulk RS $G_{KK}\to ZZ\to qq\ell\ell$	2 e,μ	2 j / 1 J	–	20.3	G_{KK} mass 740 GeV ★	$k/\overline{M}_{Pl}=1.0$	1409.6190
	Bulk RS $G_{KK}\to WW\to qq\ell\nu$	1 e,μ	2 j / 1 J	Yes	20.3	W′ mass 700 GeV ★	$k/\overline{M}_{Pl}=1.0$	1503.04677
	Bulk RS $G_{KK}\to HH\to b\bar{b}b\bar{b}$	–	4 b	–	19.5	G_{KK} mass 590-710 GeV	$k/\overline{M}_{Pl}=1.0$	ATLAS-CONF-2014-005
	Bulk RS $g_{KK}\to t\bar{t}$	1 e,μ	≥ 1 b, ≥ 1J/2j	Yes	20.3	g_{KK} mass 2.2 TeV ★	BR = 0.925	ATLAS-CONF-2015-009
	2UED / RPP	2 e,μ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	KK mass 960 GeV ★		Preliminary
Gauge bosons	SSM $Z'\to\ell\ell$	2 e,μ	–	–	20.3	Z′ mass 2.9 TeV		1405.4123
	SSM $Z'\to\tau\tau$	2 τ	–	–	19.5	Z′ mass 2.02 TeV ★		1502.07177
	SSM $W'\to\ell\nu$	1 e,μ	–	Yes	20.3	W′ mass 3.24 TeV ★		1407.7494
	EGM $W'\to WZ\to\ell\nu\,\ell'\ell'$	3 e,μ	–	Yes	20.3	W′ mass 1.52 TeV		1406.4456
	EGM $W'\to WZ\to qq\ell\ell$	2 e,μ	2 j / 1 J	–	20.3	W′ mass 1.59 TeV		1409.6190
	HVT $W'\to WH\to\ell\nu bb$	1 e,μ	2 b	Yes	20.3	W′ mass 1.47 TeV ★	$g_V=1$	Preliminary
	LRSM $W'_R\to t\bar{b}$	1 e,μ	2 b, 0-1 j	Yes	20.3	W′ mass 1.92 TeV ★		1410.4103
	LRSM $W'_R\to t\bar{b}$	0 e,μ	≥ 1 b, 1 J	–	20.3	W′ mass 1.76 TeV ★		1408.0886
CI	CI $qqqq$	–	2 j	–	17.3	Λ 12.0 TeV ★	$\eta_{LL}=-1$	Preliminary
	CI $qq\ell\ell$	2 e,μ	–	–	20.3	Λ 21.6 TeV	$\eta_{LL}=-1$	1407.2410
	CI $uutt$	2 e,μ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	Λ 4.35 TeV ★	$\lvert C_{LL}\rvert=1$	Preliminary
DM	EFT D5 operator (Dirac)	0 e,μ	≥ 1 j	Yes	20.3	M_* 974 GeV ★	at 90% CL for $m(\chi)<100$ GeV	1502.01518
	EFT D9 operator (Dirac)	0 e,μ	1 J, ≤ 1 j	Yes	20.3	M_* 2.4 TeV	at 90% CL for $m(\chi)<100$ GeV	1309.4017
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	1.0	LQ mass 660 GeV	$\beta=1$	1112.4828
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	1.0	LQ mass 685 GeV	$\beta=1$	1203.3172
	Scalar LQ 3rd gen	1 e,μ, 1 τ	1 b, 1 j	–	4.7	LQ mass 534 GeV	$\beta=1$	1303.0526
Heavy quarks	VLQ $TT\to Ht+X, Wb+X$	1 e,μ	≥ 1 b, ≥ 3 j	Yes	20.3	T mass 785 GeV ★	isospin singlet	ATLAS-CONF-2015-012
	VLQ $TT\to Zt+X$	2/≥3 e,μ	≥2/≥1 b	–	20.3	T mass 735 GeV	T in (T,B) doublet	1409.5500
	VLQ $BB\to Zb+X$	2/≥3 e,μ	≥2/≥1 b	–	20.3	B mass 755 GeV ★	B in (B,Y) doublet	1409.5500
	VLQ $BB\to Wt+X$	1 e,μ	≥ 1 b, ≥ 5 j	Yes	20.3	B mass 640 GeV ★	isospin singlet	Preliminary
	$T_{5/3}\to Wt$	1 e,μ	≥ 1 b, ≥ 5 j	Yes	20.3	$T_{5/3}$ mass 840 GeV ★		Preliminary
Excited fermions	Excited quark $q^*\to q\gamma$	1 γ	1 j	–	20.3	q* mass 3.5 TeV	only u^* and d^*, $\Lambda=m(q^*)$	1309.3230
	Excited quark $q^*\to qg$	–	2 j	–	20.3	q* mass 4.09 TeV	only u^* and d^*, $\Lambda=m(q^*)$	1407.1376
	Excited quark $b^*\to Wt$	1 or 2 e,μ	1 b, 2 j or 1 j	Yes	4.7	b* mass 870 GeV	left-handed coupling	1301.1583
	Excited lepton $\ell^*\to\ell\gamma$	2 e,μ, 1 γ	–	–	13.0	ℓ^* mass 2.2 TeV	$\Lambda=2.2$ TeV	1308.1364
	Excited lepton $\nu^*\to\ell W,\nu Z$	3 e,μ,τ	–	–	20.3	ν^* mass 1.6 TeV ★	$\Lambda=1.6$ TeV	1411.2921
Other	LSTC $a_T\to W\gamma$	1 e,μ, 1 γ	–	Yes	20.3	a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e,μ	2 j	–	2.1	N^0 mass 1.5 TeV	$m(W_R)=2$ TeV, no mixing	1203.5420
	Higgs triplet $H^{\pm\pm}\to\ell\ell$	2 e,μ (SS)	–	–	20.3	$H^{\pm\pm}$ mass 551 GeV ★	DY production, BR($H_L^{\pm\pm}\to\ell\ell$)=1	1412.0237
	Higgs triplet $H^{\pm\pm}\to\ell\tau$	3 e,μ,τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV ★	DY production, BR($H_L^{\pm\pm}\to\ell\tau$)=1	1411.2921
	Monotop (non-res prod)	1 e,μ	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV ★	$a_{\text{non-res}}=0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV ★	DY production, $\lvert q\rvert=5e$	Preliminary
	Magnetic monopoles	–	–	–	2.0	monopole mass 862 GeV	DY production, $\lvert g\rvert=1g_D$	1207.6411

→ see talk by S. Majewski

*Only a selection of the available mass limits on new states or phenomena is shown.

Multi-Boson scattering

Measurement of the WW production cross section:

$\sigma_{W^+W^-}$=60.1±0.9(stat)±3.2(exp)±3.1(th)±1.6(lumi)pb

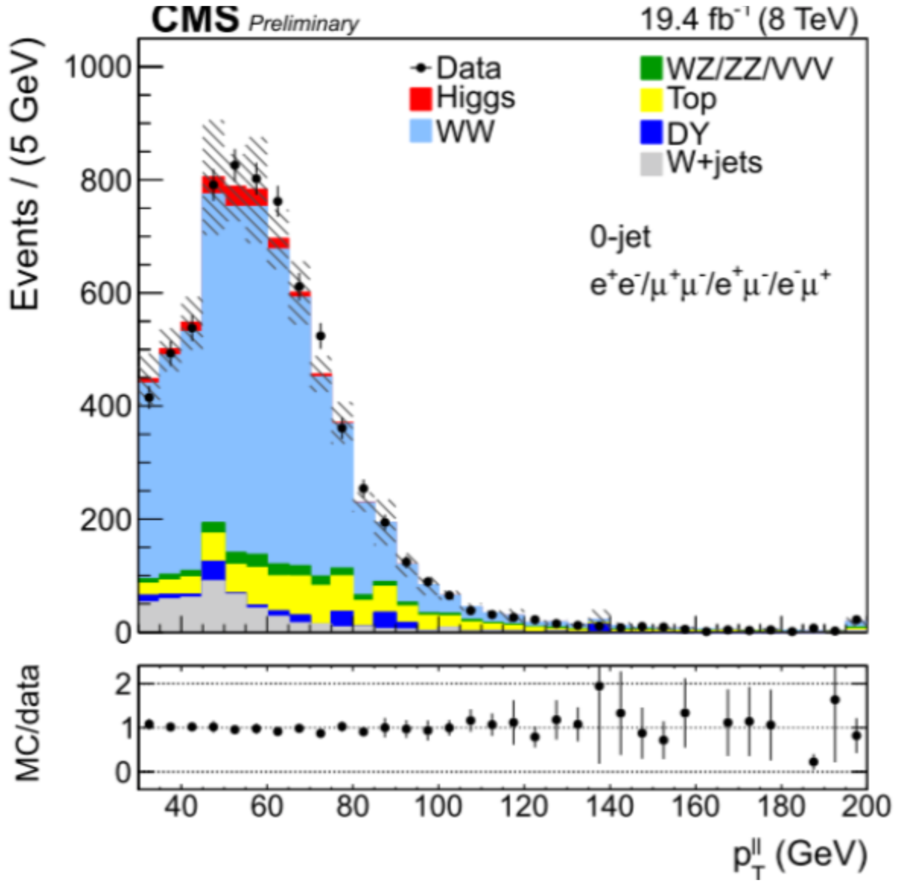
- Consistent with NNLO (59.8$^{+1.3}_{-1.1}$pb)

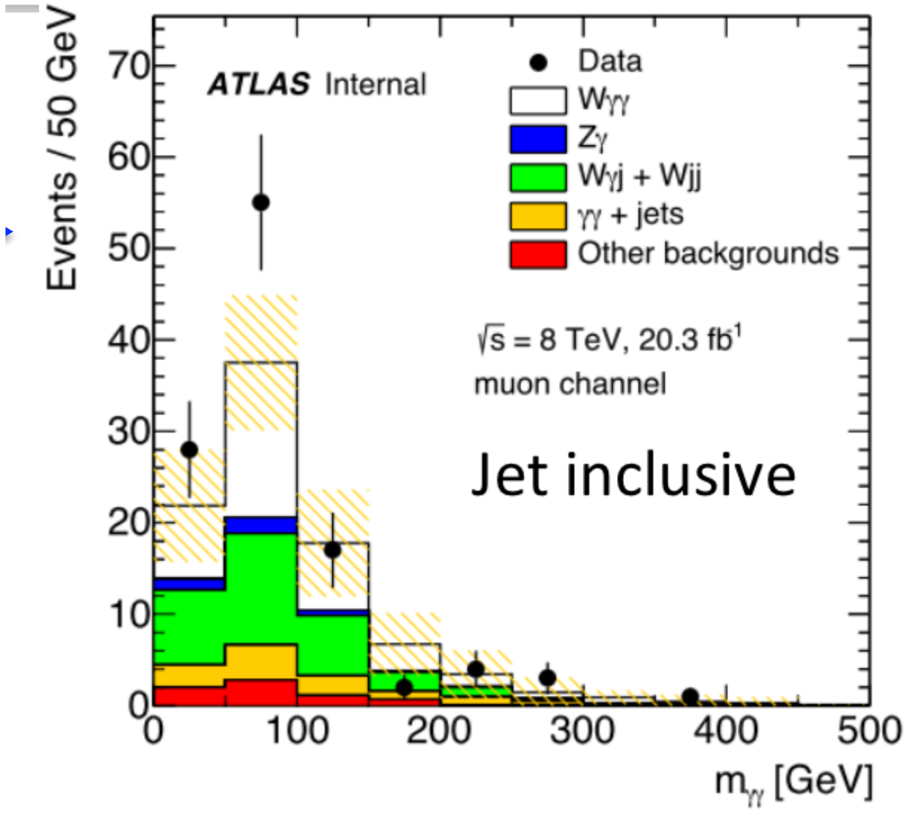
First evidence (3.7σ) of 3-bosons final state (ATLAS)

- Wγγ→lνγγ

Issue: NLO EWK corrections are (in most cases) not available

Their effect is larger at high pt, exactly where data are most sensitive for anomalous couplings effects

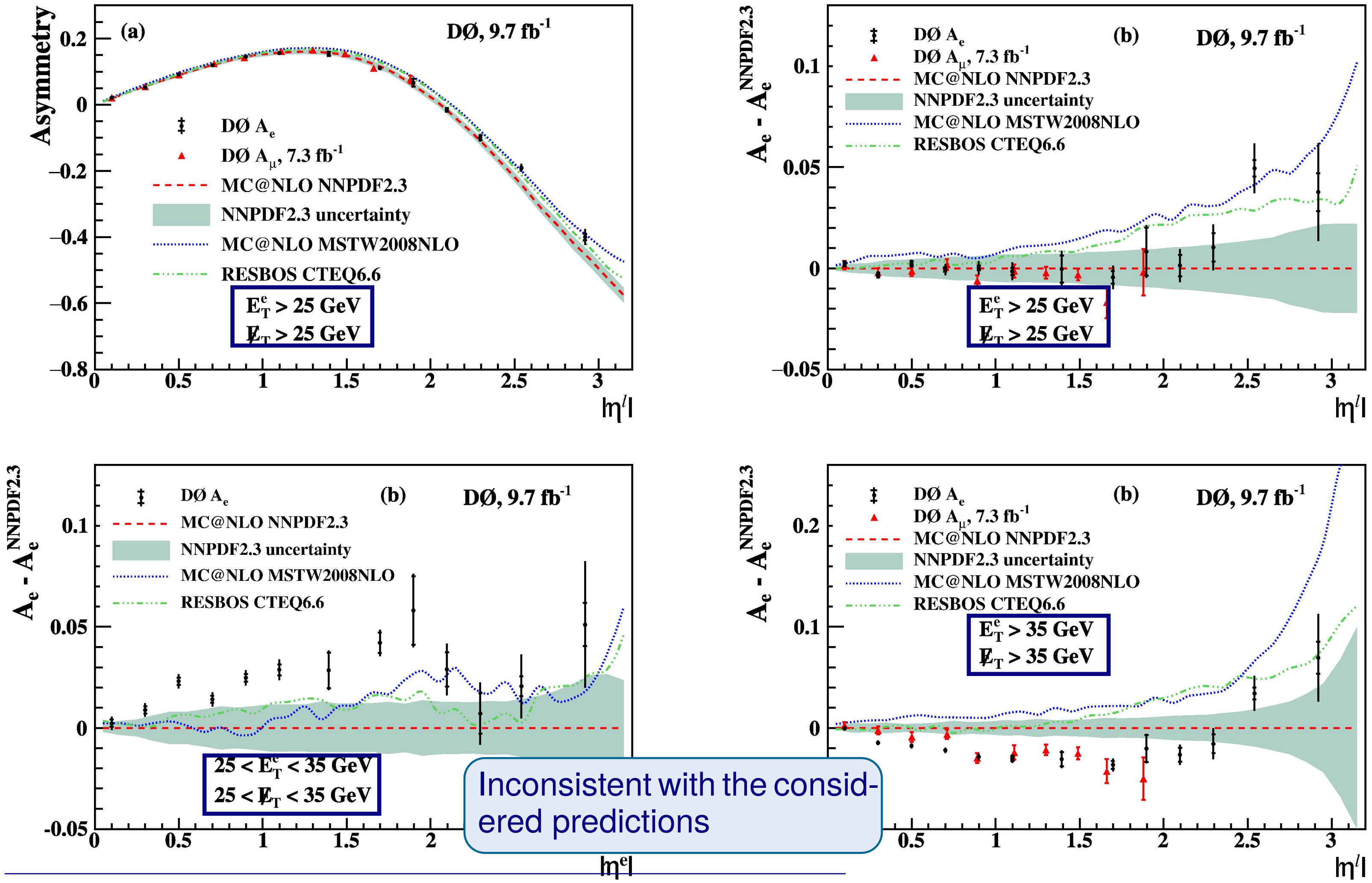




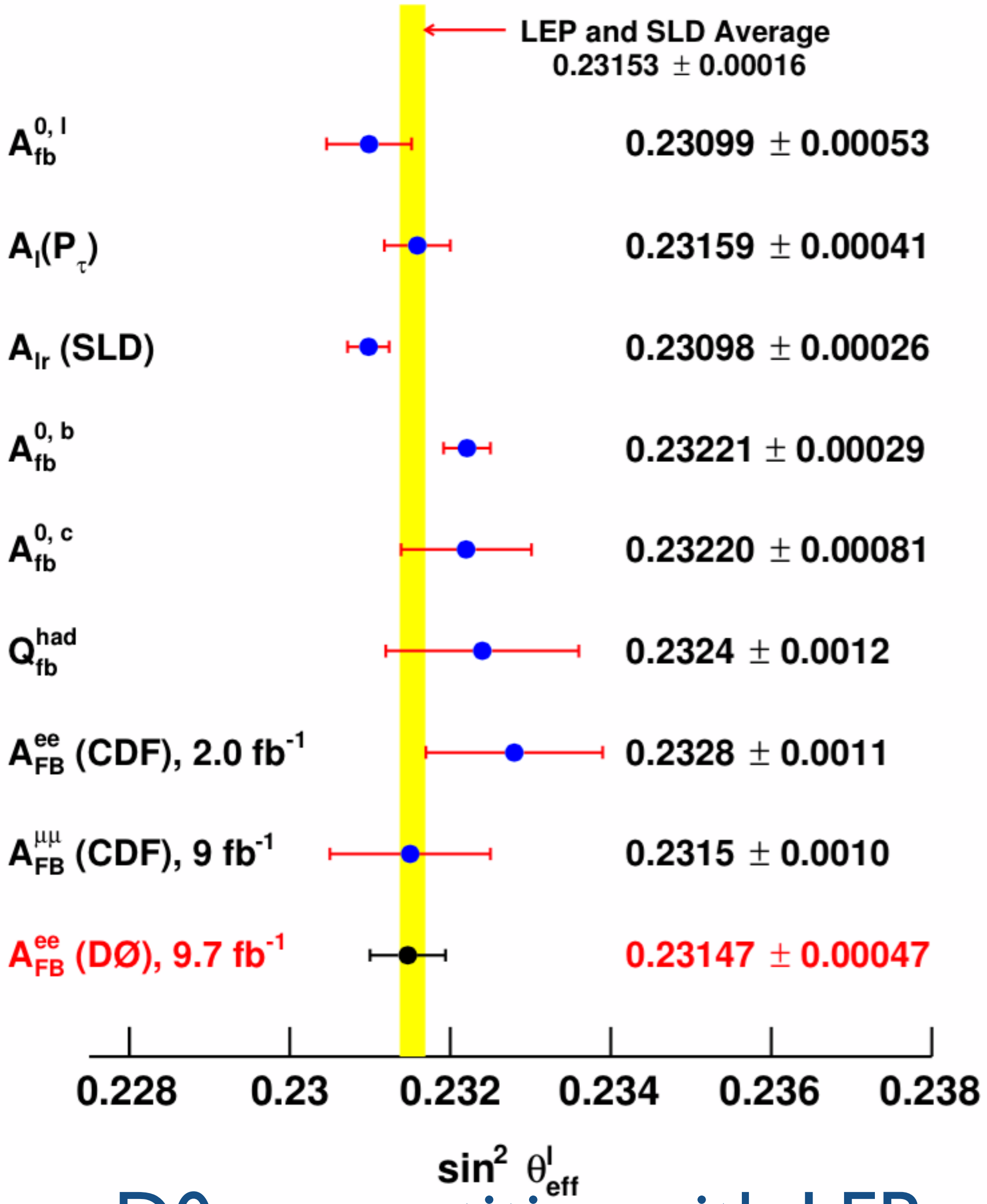
EWK results from Tevatron

When coming to EWK measurement, Tevatron has the advantage of being able to study asymmetries in the collisions

W→eν charge asymmetry inclusive predictions are well describes, but low/high pt regions show some inconsistencies



Inconsistent with the considered predictions



D0 competitive with LEP in the Zee forward/backward asymmetry

Sensitive to u,d couplings

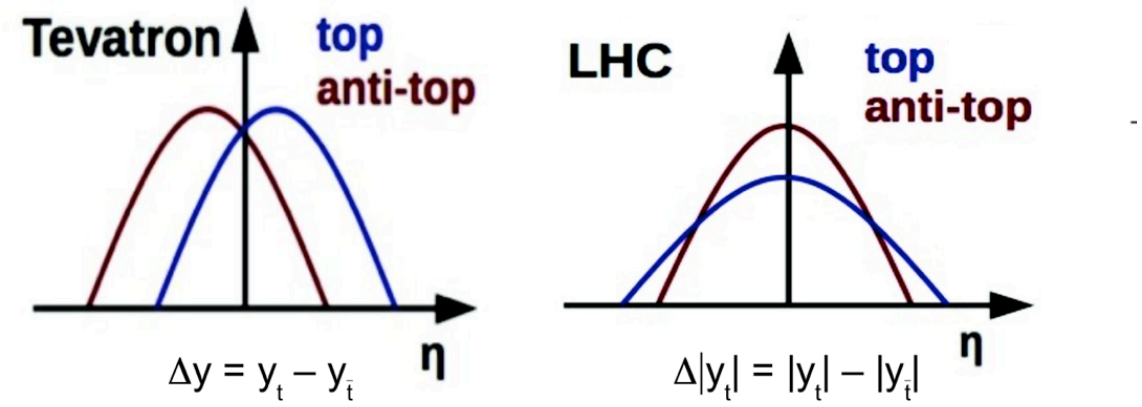
Gold medal: LHCb $B^0_s \rightarrow K^*\mu\mu$

Coeff.	best fit	1σ	2σ	$\sqrt{\chi^2_{\text{b.f.}} - \chi^2_{\text{SM}}}$	p [%]
C_7^{NP}	-0.04	$[-0.07, -0.02]$	$[-0.10, 0.01]$	1.52	1.1
C_7'	0.00	$[-0.05, 0.06]$	$[-0.11, 0.11]$	0.05	0.8
C_9^{NP}	-1.12	$[-1.34, -0.88]$	$[-1.55, -0.63]$	4.33	10.6
C_9'	-0.04	$[-0.26, 0.18]$	$[-0.49, 0.40]$	0.18	0.8
C_{10}^{NP}	0.65	$[0.40, 0.91]$	$[0.17, 1.19]$	2.75	2.5
C_{10}'	-0.01	$[-0.19, 0.16]$	$[-0.36, 0.33]$	0.09	0.8
$C_9^{\text{NP}} = C_{10}^{\text{NP}}$	-0.20	$[-0.41, 0.05]$	$[-0.60, 0.33]$	0.82	0.8
$C_9^{\text{NP}} = -C_{10}^{\text{NP}}$	-0.57	$[-0.73, -0.41]$	$[-0.90, -0.27]$	3.88	6.8
$C_9' = C_{10}'$	-0.08	$[-0.33, 0.17]$	$[-0.58, 0.41]$	0.32	0.8
$C_9' = -C_{10}'$	-0.00	$[-0.11, 0.10]$	$[-0.22, 0.20]$	0.03	0.8

χ^2_{SM} =125.8 for 91 measurements ($p = 0.92$ %)

- Most of the discrepancy in C^{NP}_9, linked to LFV!

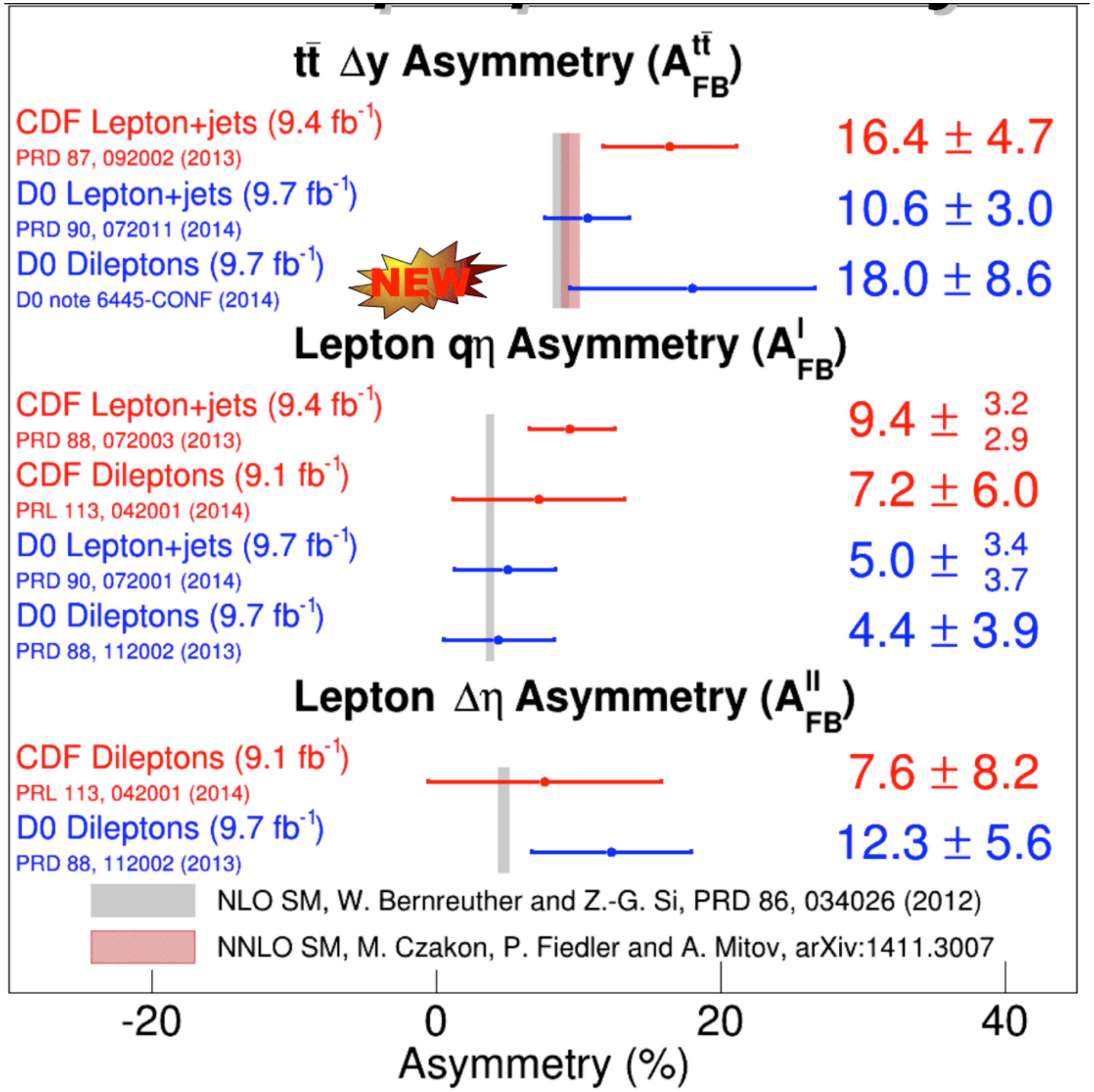
Top asymmetries



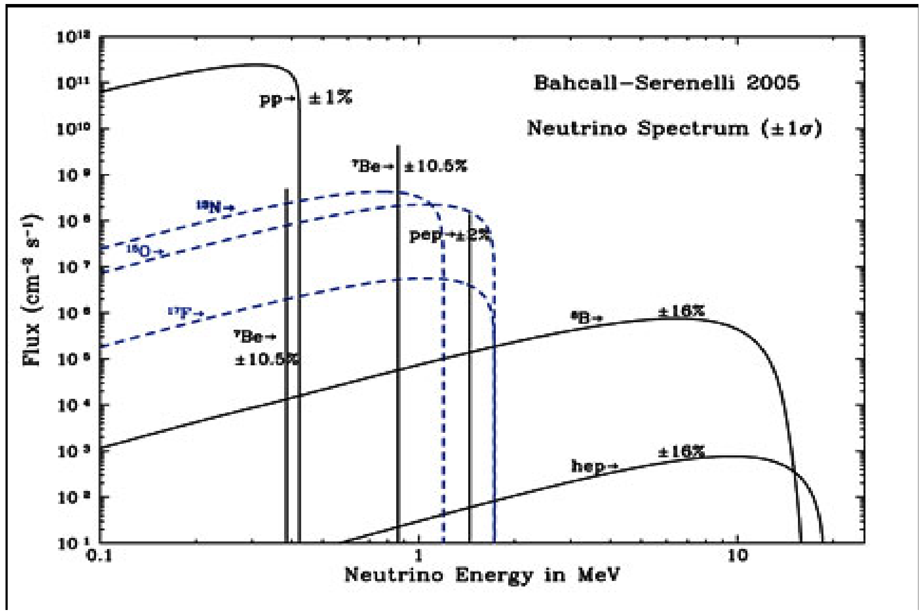
$$A_{FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

$$A_C = \frac{N(\Delta|y_t| > 0) - N(\Delta|y_t| < 0)}{N(\Delta|y_t| > 0) + N(\Delta|y_t| < 0)}$$

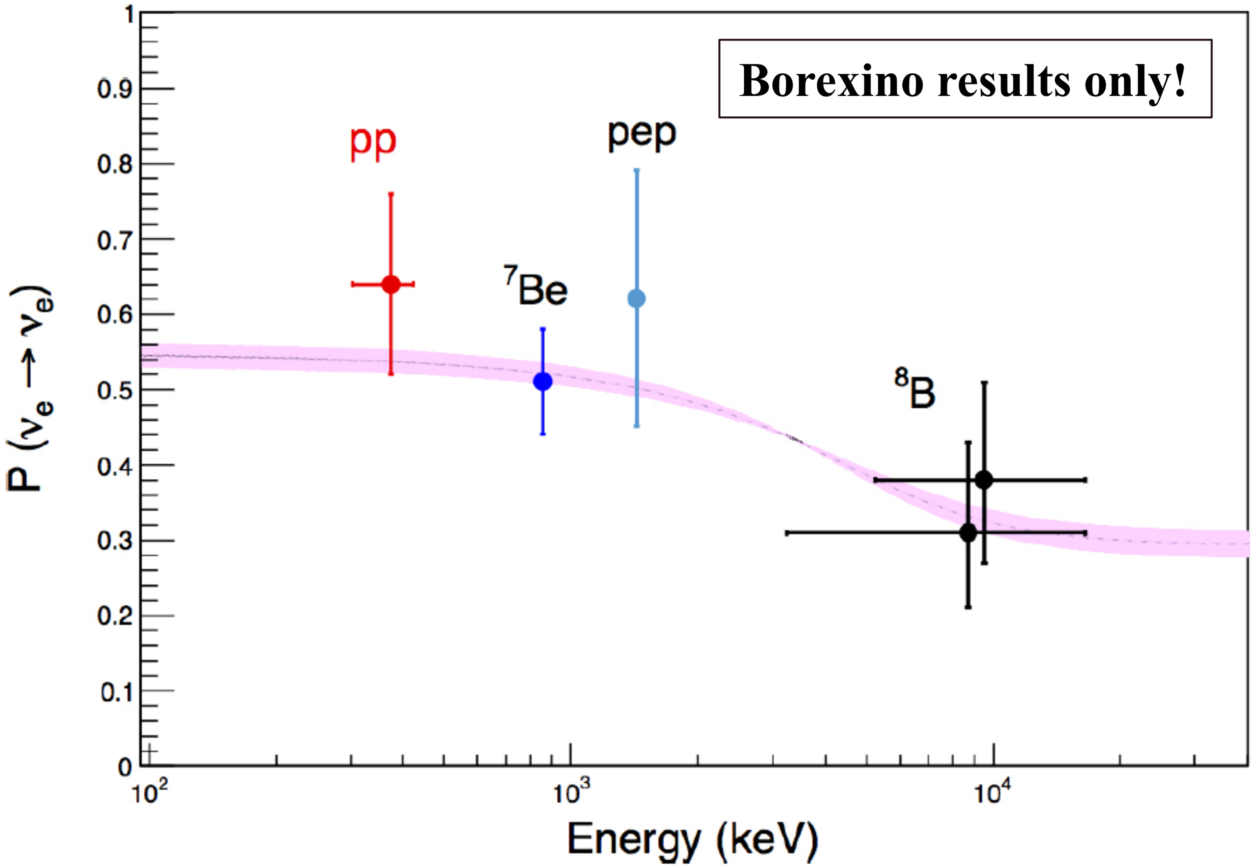
- Lot of interest for top asymmetries, since preliminary Tevatron results showed deviations from the SM
- Impossible to study top asymmetries at the LHC
- Tevatron leads in this study
- Full Tevatron dataset agrees with (N)NLO predictions

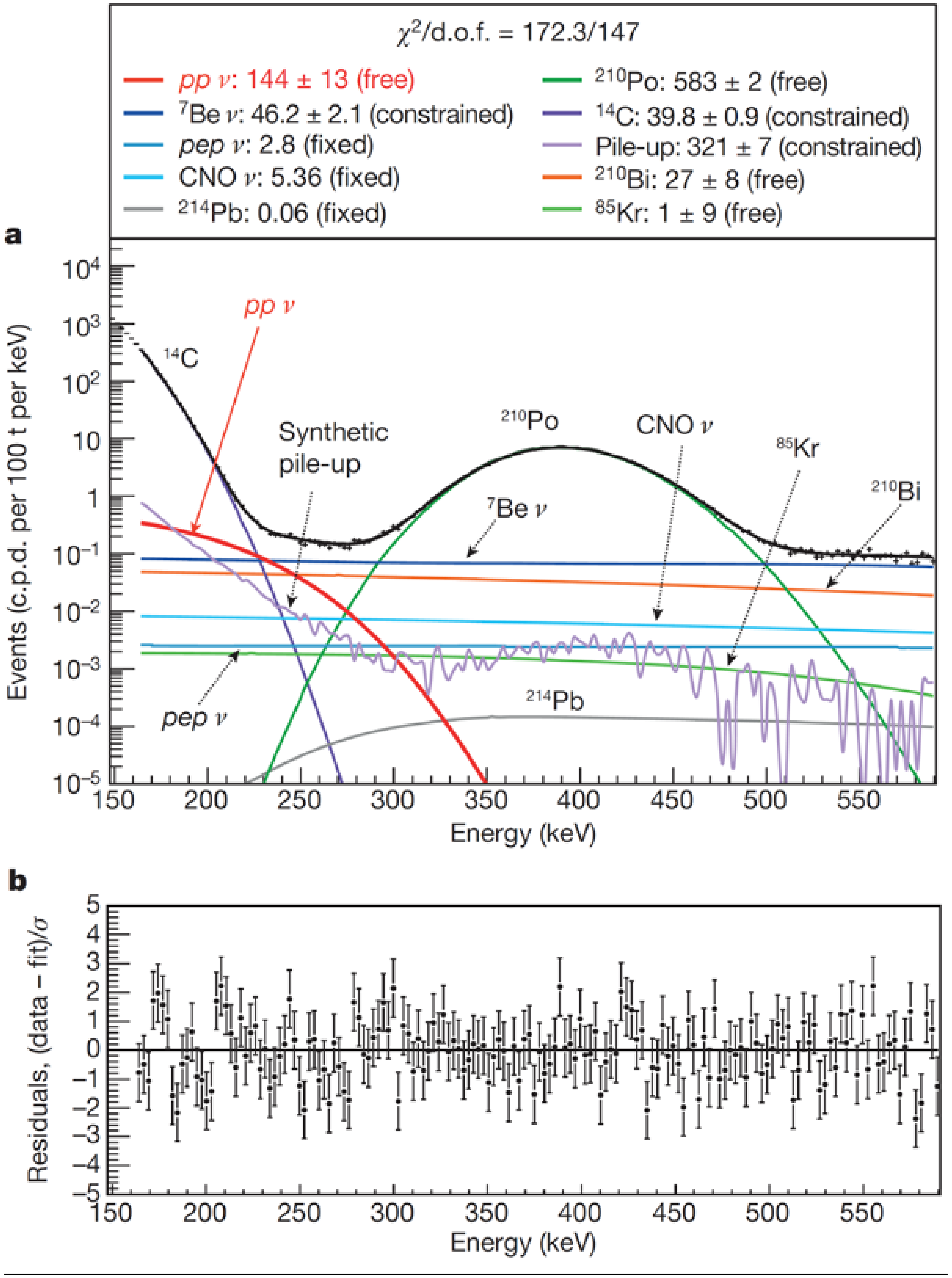


Results from Borexino



- pp-ν rate = 144±13±10 cdp/100t
- $\Phi_{pp}=6.6\pm0.7\text{x}10^{10}\text{cm}^{-2}\text{s}^{-1}$ (10σ)

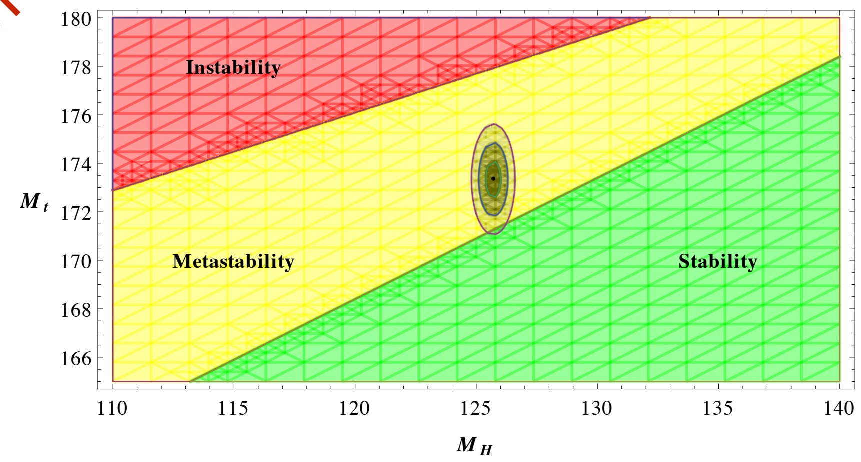


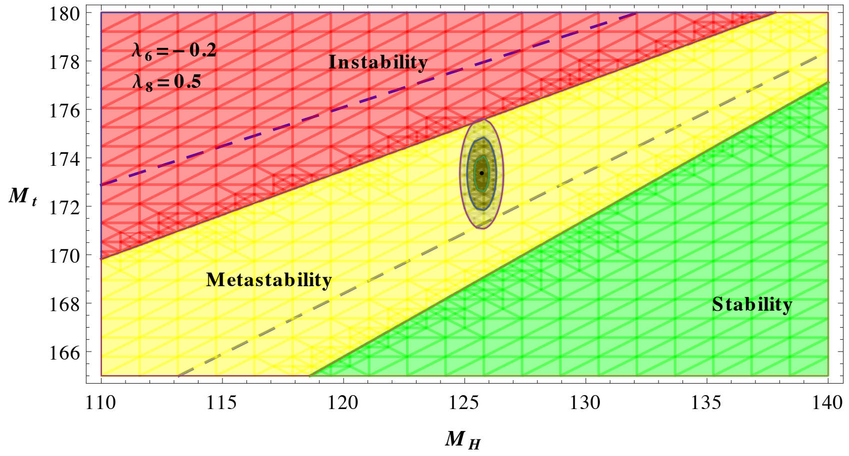


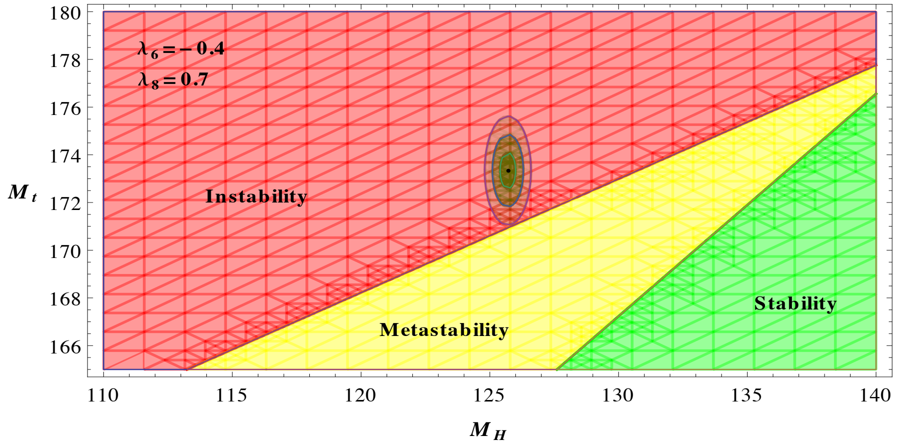
Vacuum Stability

V. Branchina

"Precision Measurements of M_t"







Precision measurements of M_t (and M_H) **cannot discriminate** between stability, metastability or criticality … The knowledge of M_t and M_H alone is **not sufficient** to decide of the EW vacuum stability condition. We need informations on NEW PHYSICS in order to asses this question …

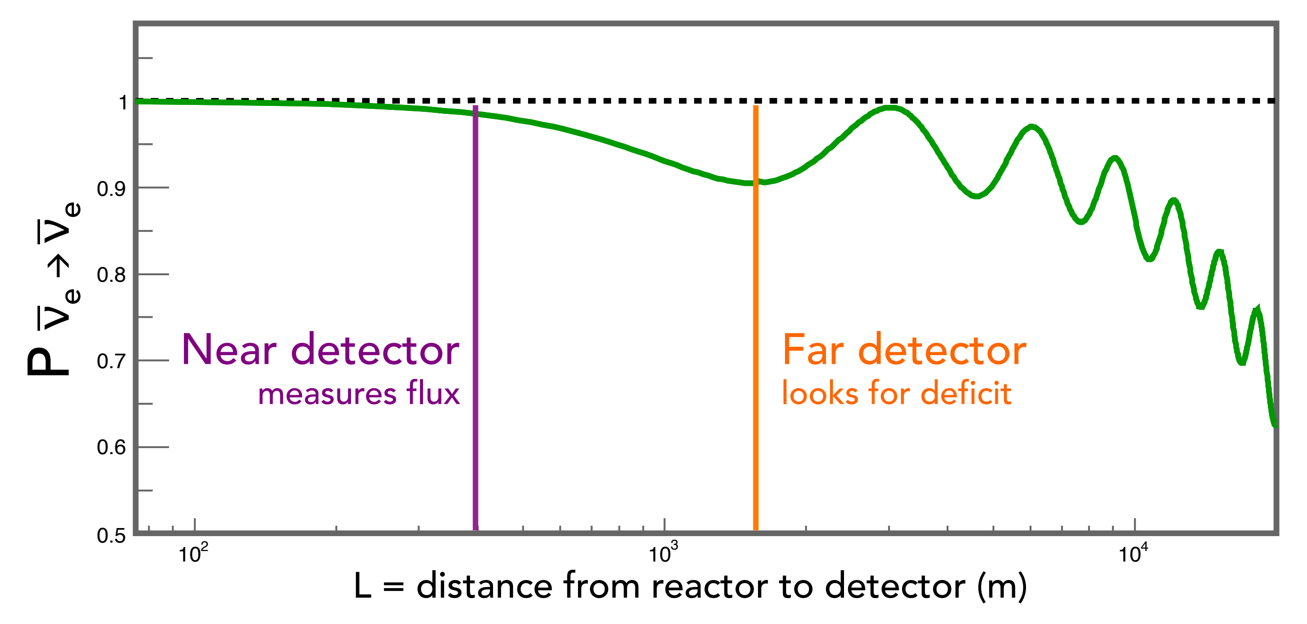
v θ measurement

ve disappearence

Courtesy of Rachel Carr

$$P_{\bar{\nu}_e\to\bar{\nu}_e} = 1 - \sin^2 2\theta_{13}\,\sin^2\left(1.27\,\Delta\widetilde{m}^2_{31}\,L/E\right)$$

+ term with θ_{12} dependence, negligible for L $\lesssim$ 1 km



$[\Delta\widetilde{m}^2_{31}]$ = eV^2, $[L]$ = m, $[E]$ = MeV $\quad \Delta\widetilde{m}^2_{31} = \Delta m^2_{ee} = \cos^2\theta_{12}|\Delta m^2_{31}| + \sin^2\theta_{12}|\Delta m^2_{32}|$

1. $\boldsymbol{\nu_\mu \to \nu_e}$ appearance in accelerator beam (T2K, NOνA)

$$\begin{aligned} P_{\nu_\mu\to\nu_e} \approx\ & \sin^2\theta_{23}\,\sin^2 2\theta_{13}\,\frac{\sin^2[(1-x)\Delta_{31}]}{(1-x)^2} \\ & + \alpha^2\cos^2\theta_{23}\sin^2 2\theta_{12}\,\frac{\sin^2(x\Delta_{31})}{x^2} \\ & + \alpha\sin 2\theta_{12}\ \sin 2\theta_{13}\sin 2\theta_{23}\,\frac{\sin^2(x\Delta_{31})}{x^2}\,\frac{\sin^2[(1-x)\Delta_{31}]}{(1-x)^2} \\ & \times\left(\cos\Delta_{31}\cos\delta_{CP} - \sin\Delta_{31}\sin\delta_{CP}\right) \end{aligned}$$