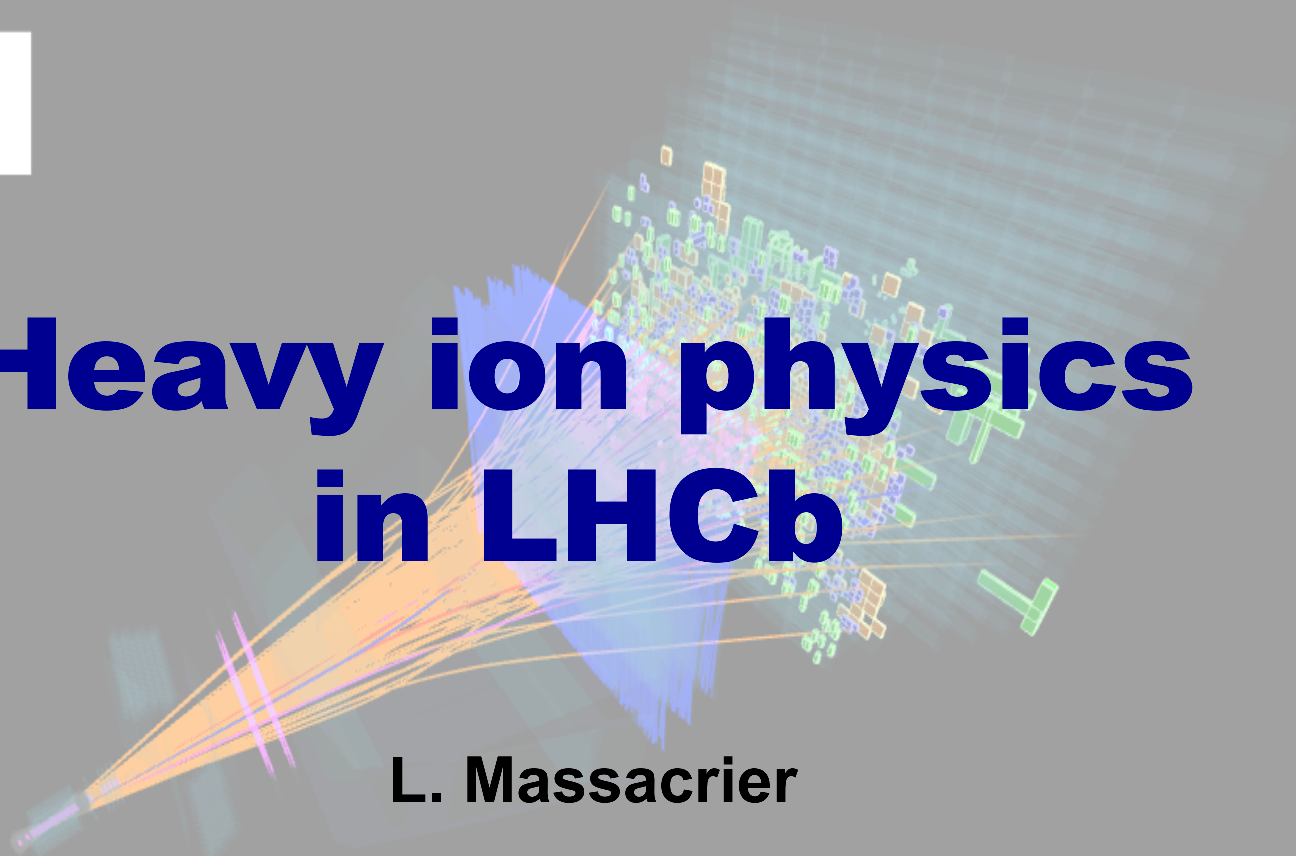


Heavy ion physics in LHCb

L. Massacrier

Laboratoire de l'Accélérateur Linéaire, Orsay
Institut de Physique Nucléaire d'Orsay

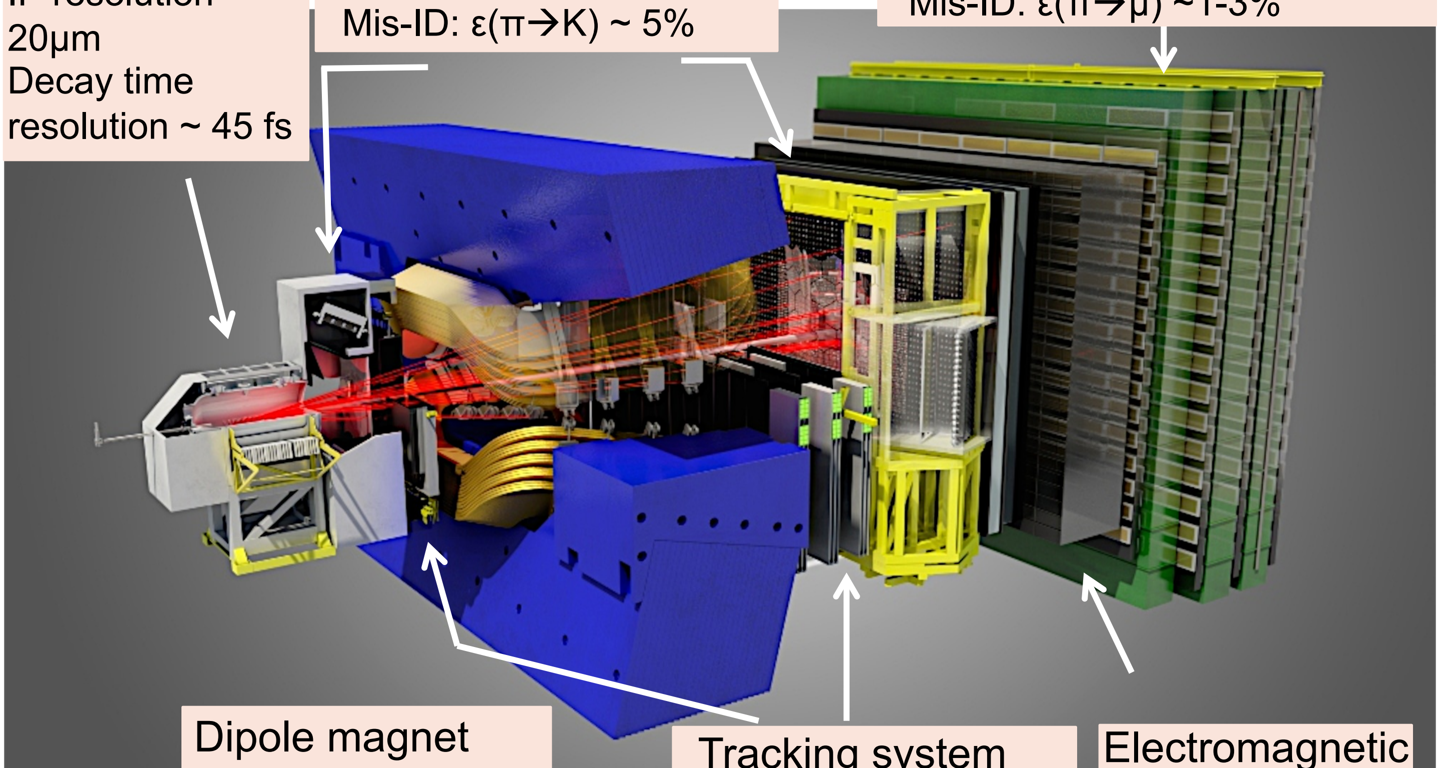
Heavy ion meeting
23rd March
Saclay, France

OUTLINE

- **The LHCb detector**
- **LHCb running modes**
- **LHCb phase space coverage**
- **Heavy ion physics programme of LHCb (a selection)**
- **Heavy ion studies in fixed target mode (SMOG)**
  - First look at p-He, p-Ne, p-Ar, Pb-Ar data taking (2015)
- **Heavy ion studies in collider mode**
  - Results from the pPb and Pbp data taking (2013)
  - First look at Pb-Pb data taking (2015)
- **Conclusions**

The LHCb detector

- Single arm spectrometer in the forward region
- Fully instrumented in its angular acceptance
- Pseudorapidity coverage $2 < \eta < 5$
- Designed initially for b-physics but general purpose detector (fixed target collisions, heavy ion physics program…)



Vertex detector
IP resolution ~ 20μm
Decay time resolution ~ 45 fs

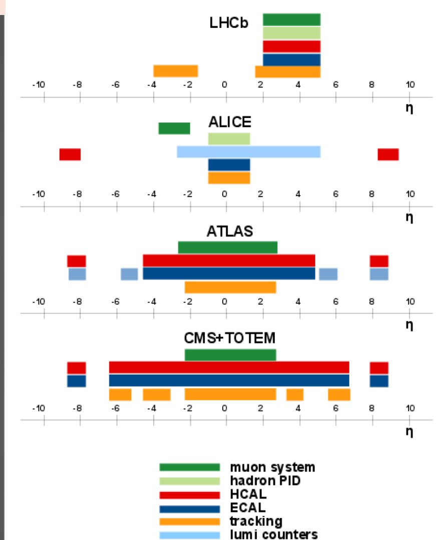
RHIC: K/π/p separation
ε(K→K) ~ 95%
Mis-ID: ε(π→K) ~ 5%

Muon system
μ identification: ε(μ→μ) ~ 97%
Mis-ID: ε(π→μ) ~1-3%

Dipole magnet
Bending power 4 Tm

Tracking system
Δp/p = 0.4% - 0.8%
(5 GeV/c – 100 GeV/c)

Electromagnetic + hadronic calorimeters



JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

LHCb running modes

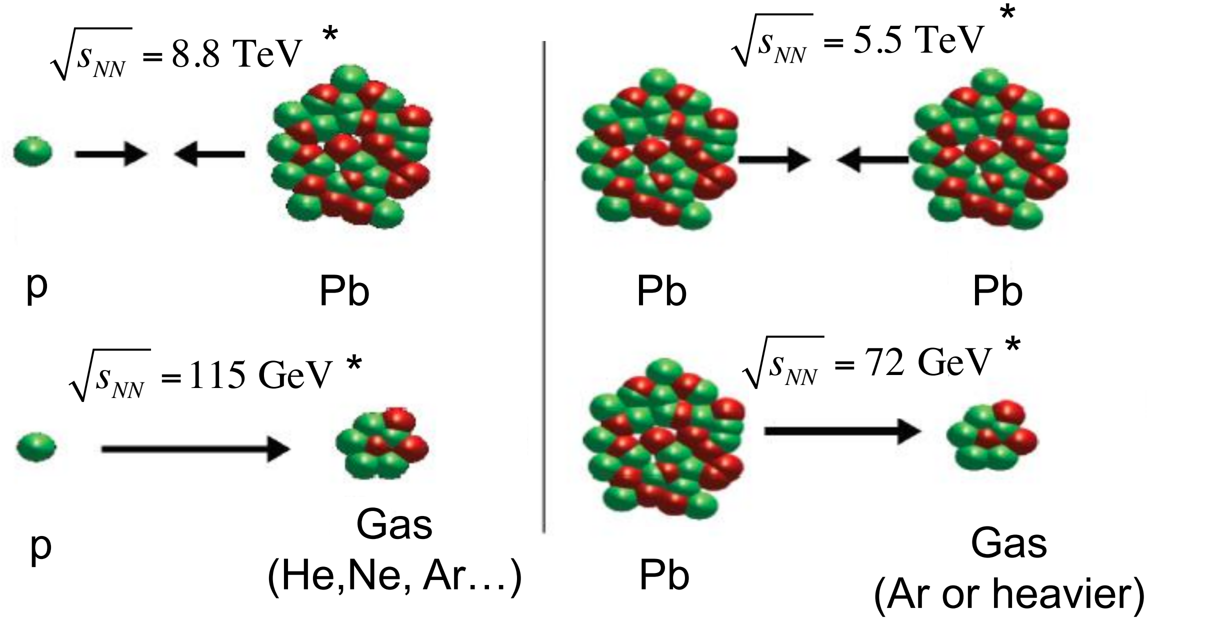
- LHCb can make valuable contributions to the study of pA and AB collisions in the forward region with a **precision not accessible by other experiments**

  → Excellent vertex reconstruction (~20μm), mass resolution (~15 MeV/c^2) and PID

- LHCb can operate in **collider mode or fixed target mode**

Collider mode

Fixed target mode

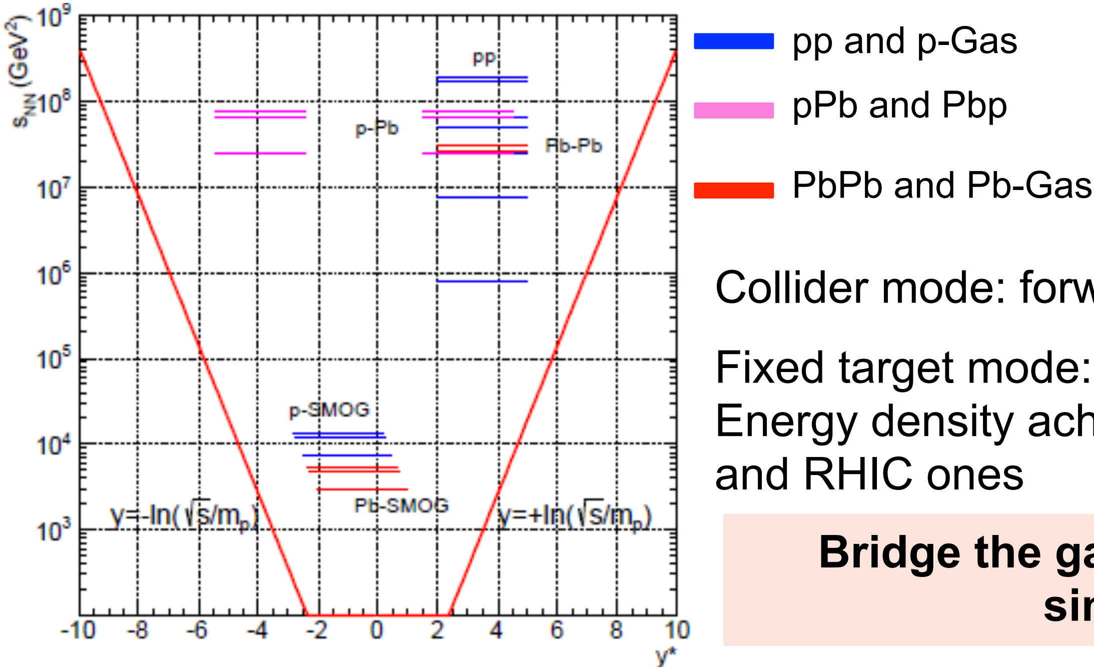


CNM studies (among others) **QGP studies (among others)**

*Highest nucleon-nucleon center of mass energy achievable

LHCb phase space coverage

- Kinematic acceptance and possible beam target configurations



y*: rapidity in the nucleon-nucleon center-of-mass, with forward direction (positive value) in the direction of the proton beam

Collider mode: forward and backward region covered

Fixed target mode: acceptance is central to backward
Energy density achieved which are between SPS and RHIC ones

Bridge the gap from SPS to LHC with a single experiment

Ebeam (p)	pp	p-Gas	pPb/Pbp	Pb-Gas	Pb-Pb
450 GeV	0.90 TeV				
1.38 TeV	2.76 TeV				
2.5 TeV	5 TeV	69 GeV			
3.5 TeV	7 TeV				
4.0 TeV	8 TeV	87 GeV	5 TeV	54 GeV	
6.5 TeV	13 TeV	110 GeV	8.2 TeV	69 GeV	5.1 TeV
7.0 TeV	14 TeV	115 GeV	8.8 TeV	72 GeV	5.5 TeV

Already collected

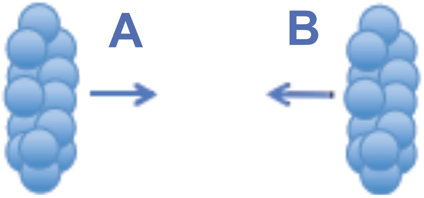
Preferred target Gas

	He	Ne	Ar	Kr	Xe
A	4	20	40	84	131

Heavy quarks and quarkonium studies in A-A collisions

Ultra-relativistic heavy ion collisions to:

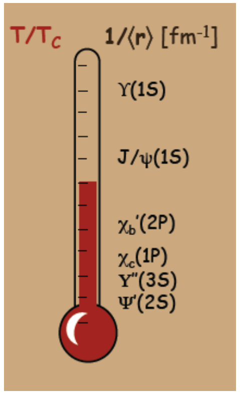
- ❑ Probe Quark gluon plasma formation
- ❑ Study the phase transition
- ❑ Test lattice QCD calculations



Study of Heavy flavour and quarkonia are important for the understanding of hot matter created in Heavy ion collisions

→ Quarkonia (J/ψ ,ψ', χ_c) are produced at the early stages of heavy ion collisions
→ They travel trought the medium and can be affected by it

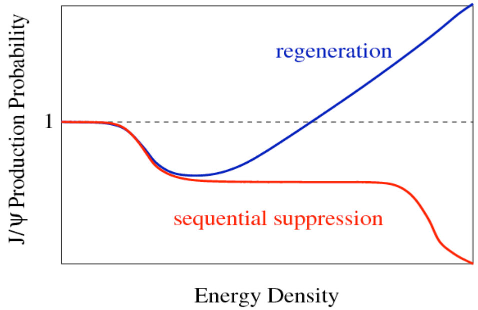
- ✓ Suppressed by color screening
- ✓ Provide measurement of QGP temperature through sequential melting of states



Courtesy of A. Mocsy

- ✓ High density of $c\bar{c}$ pairs in high energy central AA collisions at the LHC

→ Secondary production of charmonium by recombination



→ Open charm to study heavy quark energy loss in the QGP/ also a reference for quarkonia studies

Heavy quarks and quarkonium studies in A-A collisions

To confirm and study charmonium color screening and recombination, one must compare charmonium and open charm production in A-A collisions

Heavy quark hadronization:
- ~ 90% of $c\overline{c}$ → open charm
- ~ 10% of $c\overline{c}$ → charmonium

→ Open charm production reflects the original charm quark yield

→ QGP phase should not modify the overall heavy quark yields

→ QGP phase modify relative heavy quark (hidden/open) yields

LHCb is the only experiment capable to measure together open and hidden charm production, down to low p_T, in the forward region in heavy ion collisions, at low and high center of mass energies
Offers the possibility to measure all quarkonia states in heavy ion collisions (including χ_c !)
LHCb can measure separately prompt J/ψ, ψ(2S) from J/ψ, ψ(2S) from b

LHCb can study recombination at the TeV scale and color screening at the GeV scale

QGP formation in Pb-Ar at 71 GeV ?

System \ centrality	60 – 100%	50 – 60%	40 – 50%	30 – 40%	20 – 30%	10 – 20 %	0 – 10%
PbNe – 71 GeV	108.6	254.4	392.5	588.0	814.5	1086.0	1494.9
PbAr – 71 GeV	**123,6**	**308,8**	**496,5**	**806,6**	**1228,3**	**1711,9**	**2372,7**
PbKr – 71 GeV	196,9	533,6	919,1	1451,2	2205,5	2986,6	4084,3
PbPb – 17 GeV	**124,2**	**331,6**	**605,9**	**919,6**	**1338,7**	**2035,8**	**2980,5**

EPOS-LHC-v3400

Heavy quarks and quarkonium studies in pA collisions

→ Proton-nucleus collisions are interesting by themselves but also provide reference for heavy ion studies

❑ **Heavy flavours and Quarkonia as tools to study cold nuclear matter effect (CNM)**

→ Necessary reference to disentangle QGP effects from CNM effects in AA collisions

Initial state effects

- **Nuclear shadowing**
  → **gluon shadowing at LHC [1]**
- **Parton saturation / CGC [2]**
- **Radiative energy loss [3]**
- **Cronin effects [4]**

Final state effects

- **Nuclear absorption [6]**:
  → **Expected to be small at LHC [7]**
- **Radiative energy loss [8]**
- **Comovers [9]**

Neither initial nor final

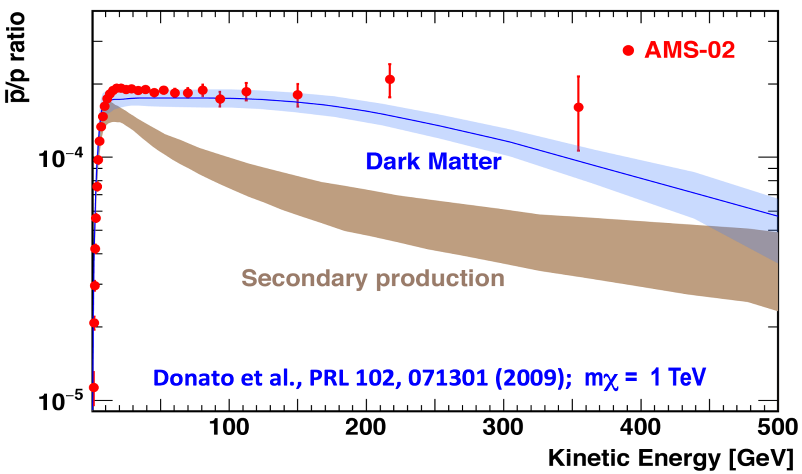
- **Coherent energy loss[5]**

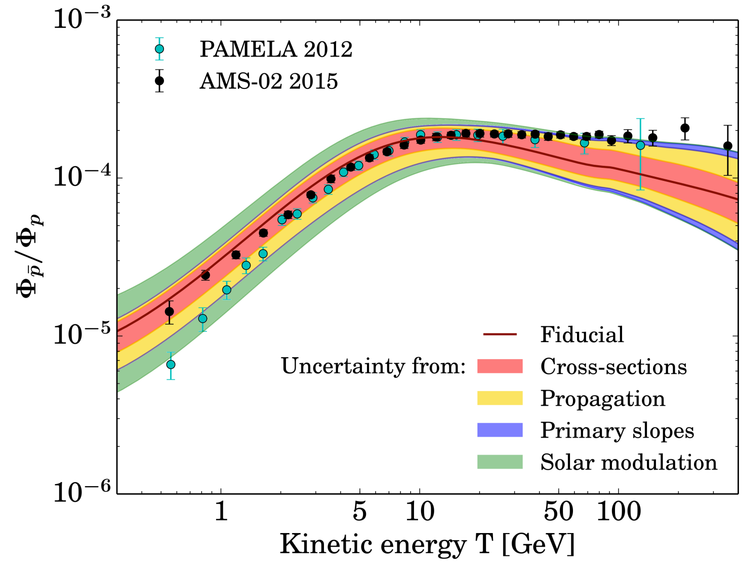
[1] K.J. Eskola et al., JHEP 0904 (2009) 065.
[2] D. Kharzeev et al., Nucl. Phys. A770 (2006) 40.
[3] S. Gavin et al., Phys. Rev. Lett. 68 (1992) 1834.
[4] J. W. Cronin et al., Phys. Rev. D, 11:3105, 1975.
[5] F. Arleo et al., Phys. Rev. Lett. 109 (2012) 122301.
[6] R. Vogt, Nucl. Phys. A700 (2002) 539.
[7] C. Lourenco et al., JHEP 0902.014, 2009.
[8] R. Vogt, Phys. Rev. C61 (2000) 035203
[9] E. Ferreiro, arXiv:1411.0549v2

Cosmic rays physics and p-Gas (He) data

- Recent results from AMS-02 exhibit an antiproton excess with respect to expectations from secondary production (p+p → $\bar{p}$X and p+He → $\bar{p}$X) in the interstellar medium, in the O(100 GeV) region
- Possible evidence for Dark Matter Contribution

AMS Coll., Cern 15.04.2015





arXiv:1504.04276

- More conservative estimates on the related uncertainties show that the results could still fit with secondary production
- Largest uncertainty comes from σ(pHe→ $\bar{p}$X)

→ In fixed target mode, proton beam (6.5 TeV) on He at rest suits well the physics case

For more physics opportunities in fixed target collisions at the LHC, see also:
Physics Reports 522 (2013) 239 (AFTER@LHC)

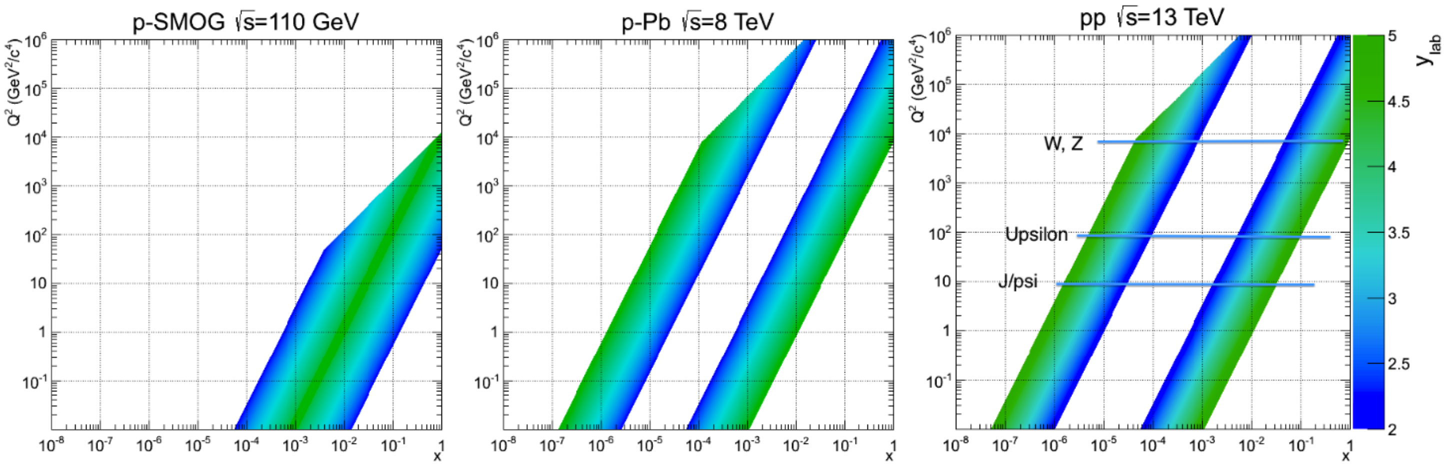
Soft QCD and electroweak measurements in pA / AA

Many open questions in QCD especially in the soft sector which cannot be treated perturbatively

- Perform measurements at different √s , with different setups will allow to investigate:

→ **Nucleon structure of free versus bound nucleons**

- PDFs can be probed via quarkonia, electroweak bosons, Drell Yan measurements
  → Z production in pPb: sensitivity to nuclear PDF at large x_A (10^{-1}), and low x_A (10^{-4})
- Access to very small x (colliding mode) and very large x (fixed target mode)



→ **Dynamic of hadronization process**

- Measurement of toal cross sections, energy flow measurement, particle multiplicities, Bose-Einstein or Fermi-Dirac correlations….

→ **Diffractive scattering**: accessible with new HERSHEL detector

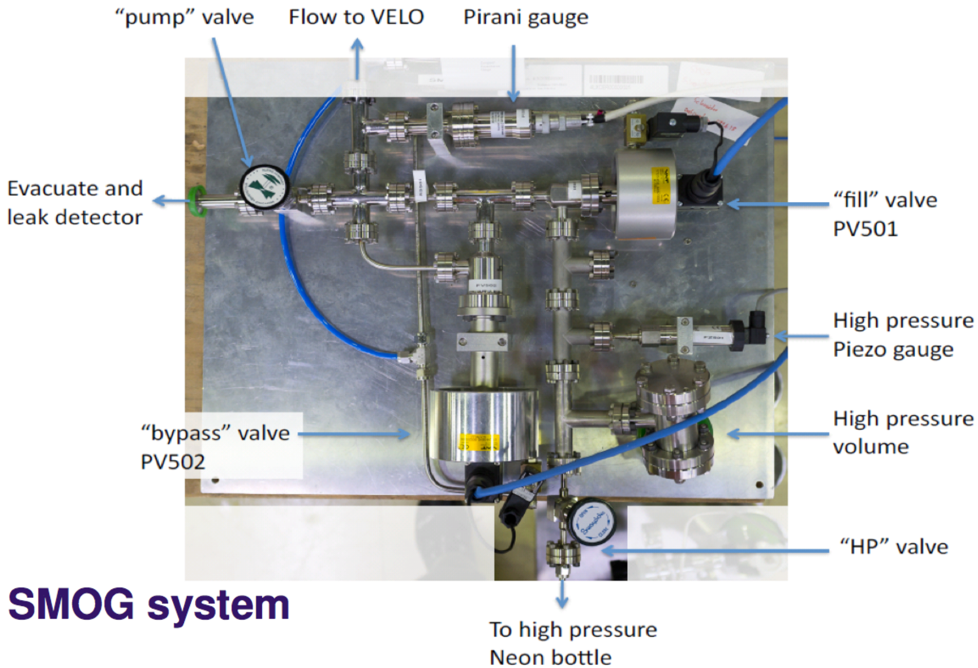
→ **QED at extreme conditions and central exclusive production**

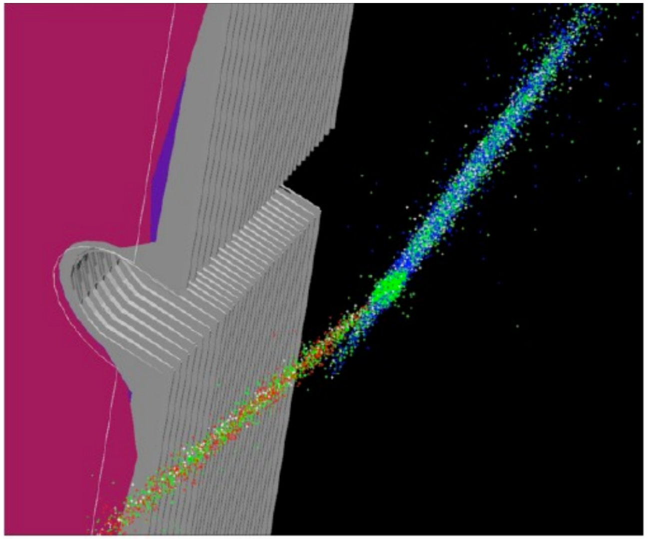
- Ultraperipheral Collisions: measurement of exclusive ρ^0 production, exclusive J/ψ…

Heavy ion studies in fixed target mode

The SMOG system

→ SMOG: System for Measuring Overlap with Gas





Distribution of vertices overlaid on detector display. z-axis is scaled by 1:100 compared to transverse dimensions to see the beam angle.
Beam 1 - Beam 2, Beam 1 - Gas, Beam 2 - Gas.

(Possible) Beam target configurations :

- ❑ Proton and Lead beam
- ❑ Hydrogen and noble gases as target : He, Ne, Ar, Kr, Xe

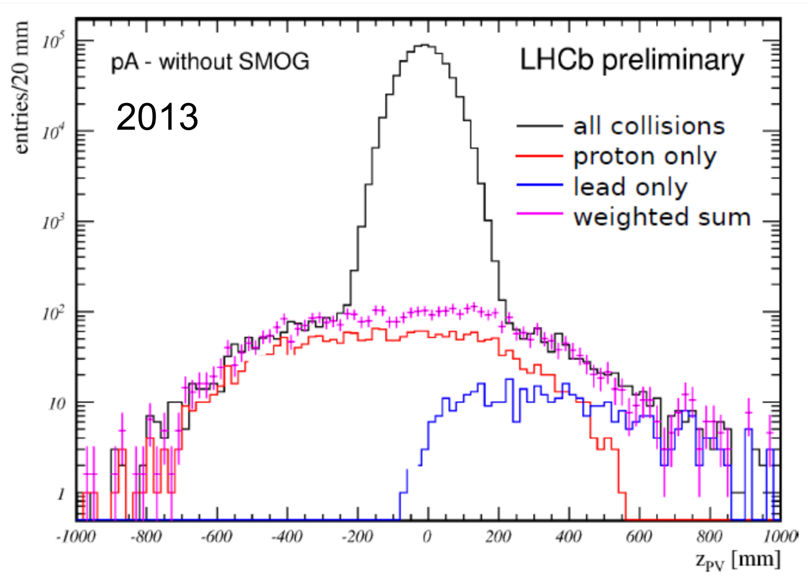
Data taking:

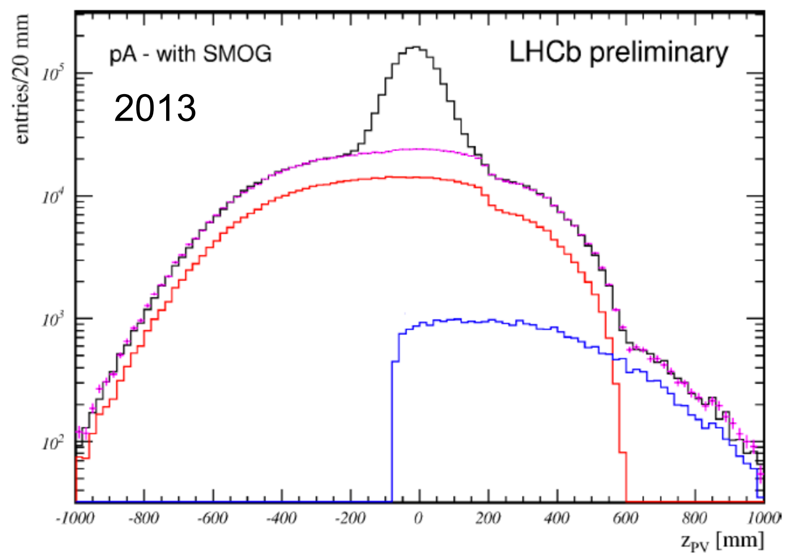
- ❑ pNe pilot run at $\sqrt{s_{NN}}$ = 87 GeV (2012)
- ❑ PbNe pilot run at $\sqrt{s_{NN}}$ = 54 GeV (2013) ~ 30min
- ❑ pNe run at $\sqrt{s_{NN}}$ = 110 GeV (2015) ~ 12h
- ❑ pHe run at $\sqrt{s_{NN}}$ = 110 GeV (2015) ~ 8h
- ❑ pAr run at $\sqrt{s_{NN}}$ = 110 GeV (2015) ~ 3 days
- ❑ pAr run at $\sqrt{s_{NN}}$ = 69 GeV (2015) ~ few hours
- ❑ PbAr run at $\sqrt{s_{NN}}$ = 69 GeV (2015) ~ 1.5 week

- ❑ Low density noble gas injected in the VELO of LHCb, in the interaction region
- ❑ Very simple robust system
- ❑ Main use so far for precise luminosity determination
- ❑ Only local temporary degradation of LHC vacuum

Properties of Fixed target interactions

Z distribution of primary verteces in pPb collisions with and without SMOG





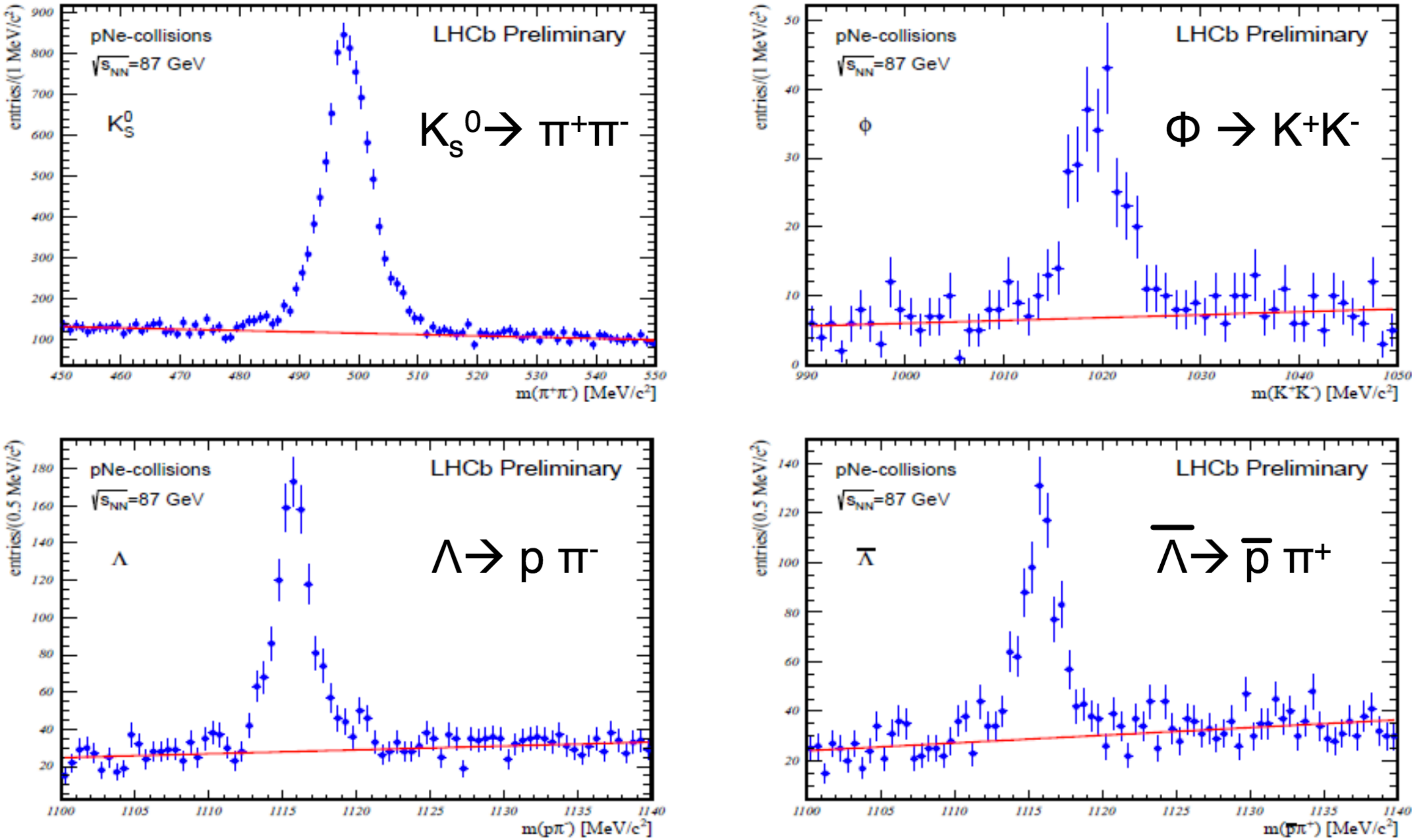
LHCb-CONF-2012-034

- Contributions of beam-beam and beam-gas interactions can be separated by knowing the filling scheme
  → Fixed target collisions can be isolated from regular collisions in collider mode
  No need for dedicated physics runs!
- With SMOG increase of the beam gas rate by two order of magnitudes
  → Gas pressure (~ 1.5×10^{-7} mbar) 2 order of magnitude larger than vacuum pressure
- Strong acceptance effects as a function of Z position

Results from p-Ne collisions (2012 pilot run)

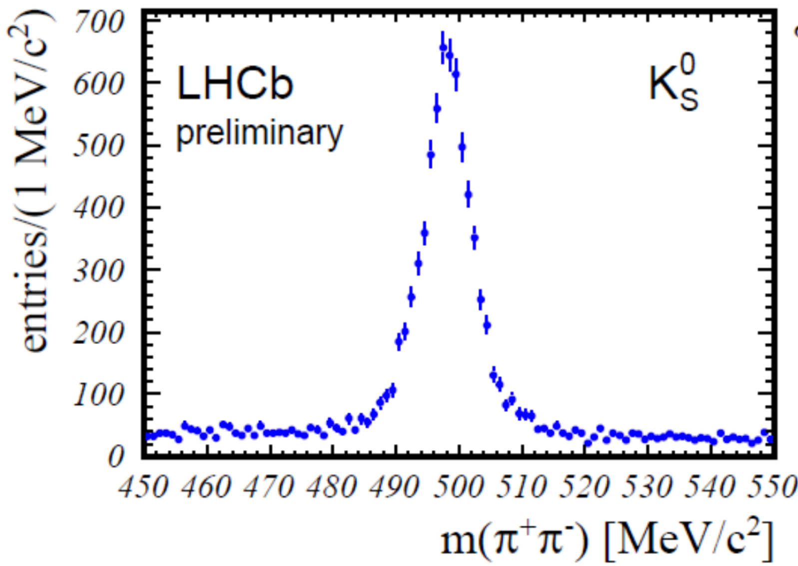
- p-Ne collisions at 87 GeV

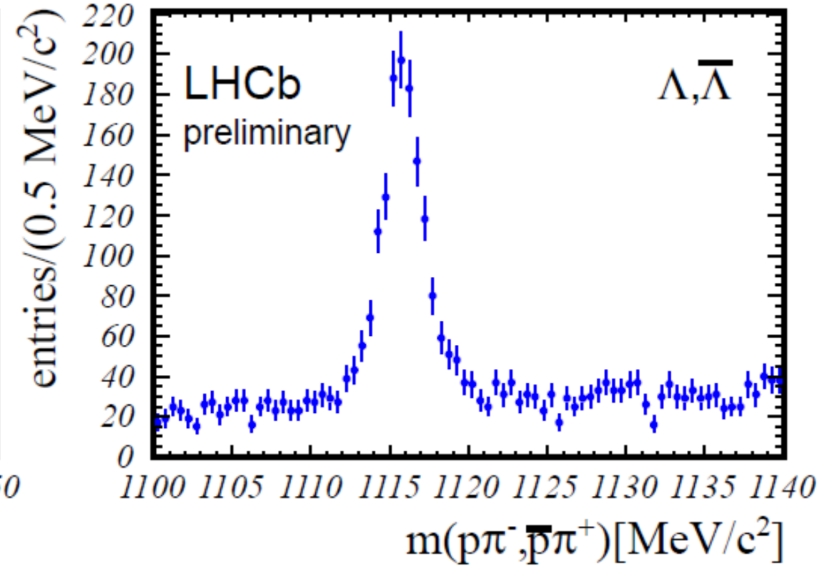
LHCb-CONF-2012-034

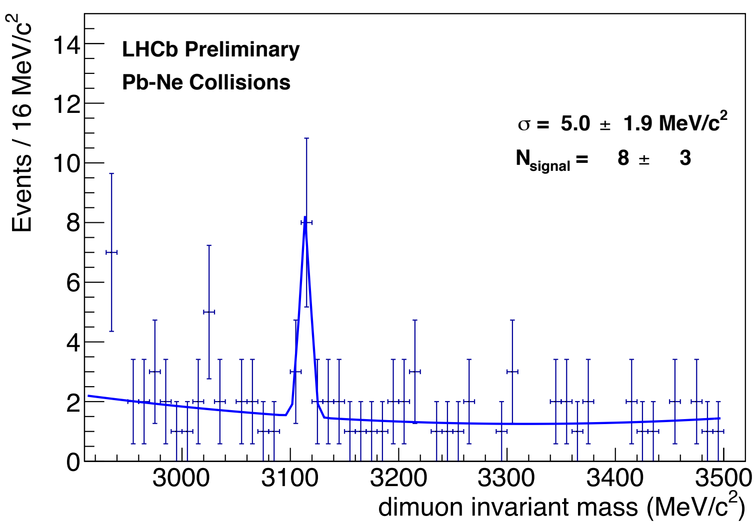


Results from Pb-Ne collisions (2013 pilot run)

- Pb-Ne collisions at 54 GeV
- About 30min of data taking







- $J/\psi \rightarrow \mu^+\mu^-$

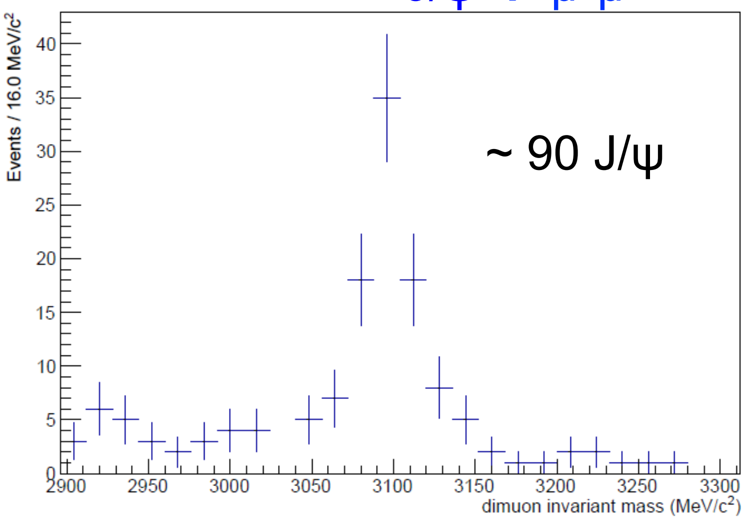
→ ~ 8 J/ψ in the pilot run
→ Only 30min of data taking
→ looking forward to analyse the 1.5 week of Pb-Ar data

Results from p-Ne run at $\sqrt{s_{NN}}$ = 110 GeV (2015)

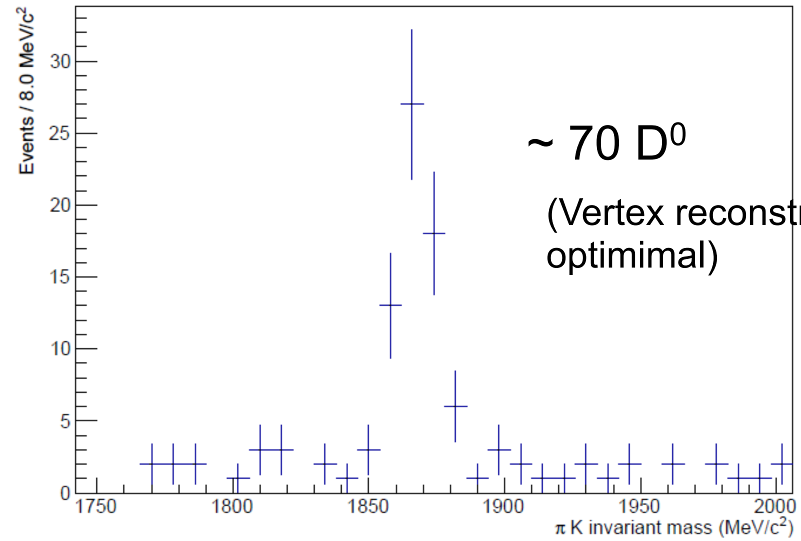
In progress

(Full sample)

- $J/\psi \rightarrow \mu^+\mu^-$



- $D^0 \rightarrow K\pi$

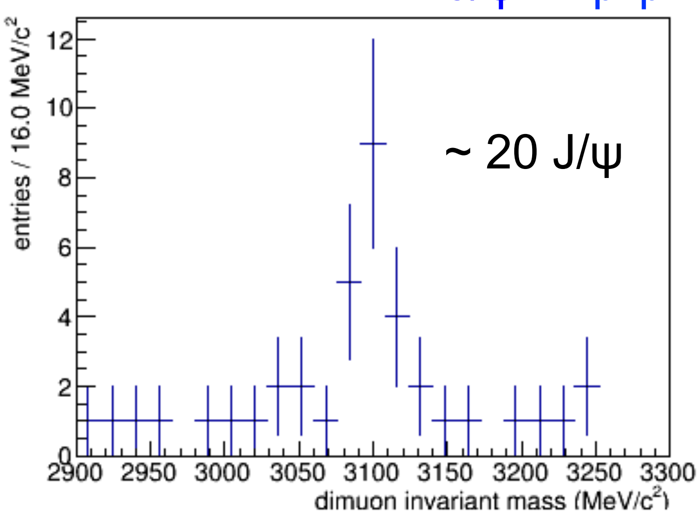


(Vertex reconstruction not optimal)

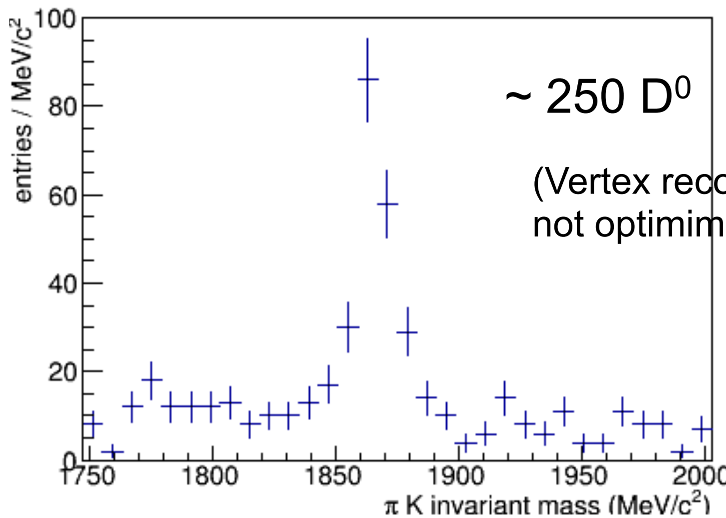
Results from p-He run at $\sqrt{s_{NN}}$ = 110 GeV (2015)

(Full sample)

- $J/\psi \rightarrow \mu^+\mu^-$



- $D^0 \rightarrow K\pi$

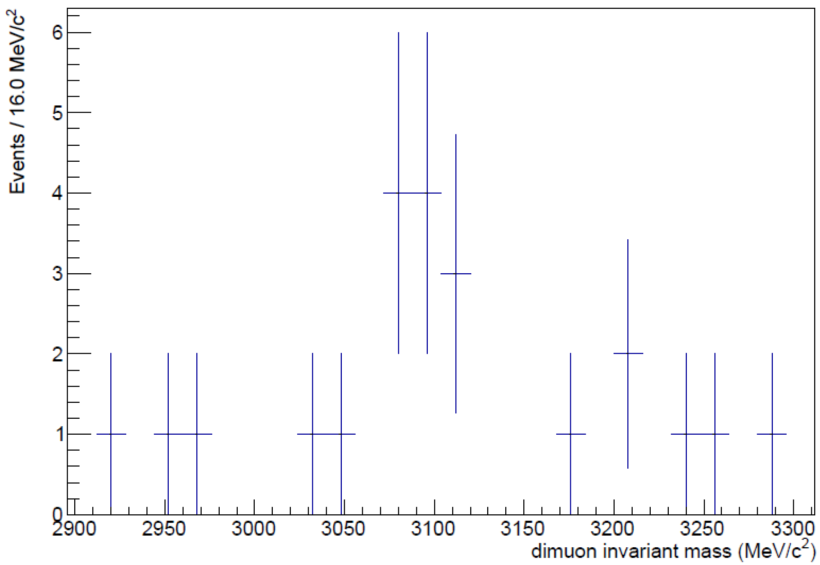


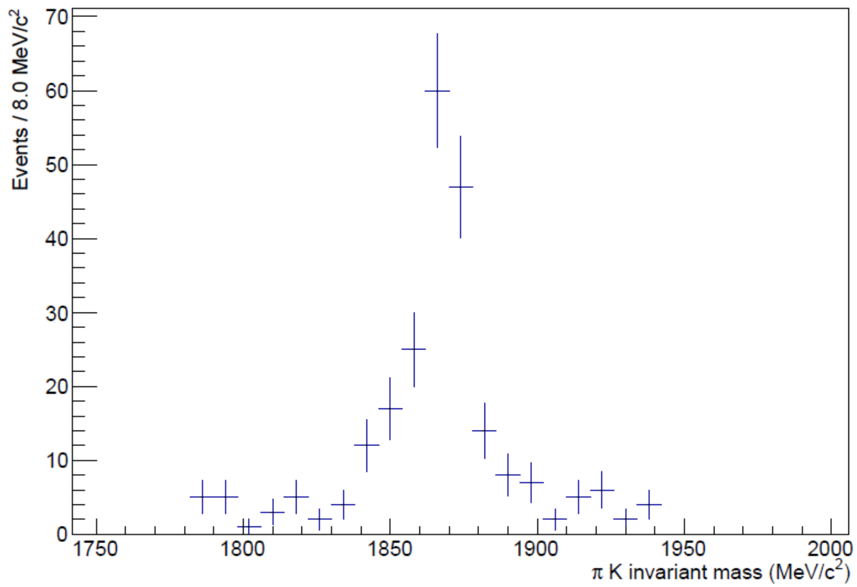
(Vertex reconstruction not optimal)

Results from p-Ar run at $\sqrt{s_{NN}}$ = 110 GeV (2015)

In progress

- $J/\psi \rightarrow \mu^+\mu^-$ few J/ψ counts
- $D^0 \rightarrow K\pi$ ~ 180 D^0





(Vertex reconstruction optimized)

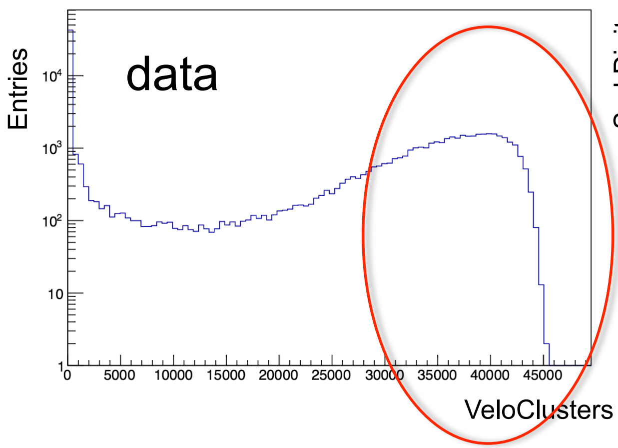
(Only one run of reconstructed data ~ 1h)

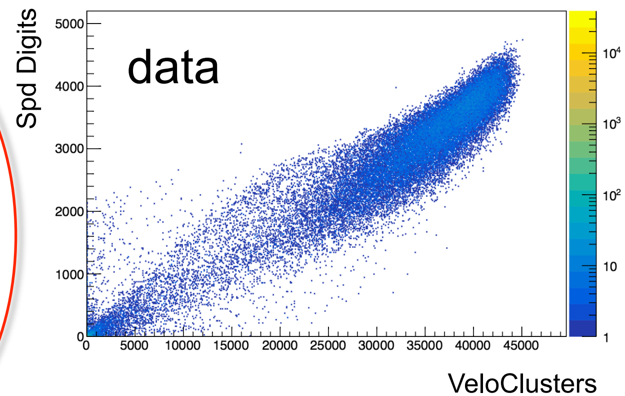
→ Looking forward to analyse the full sample (~ 3 days)

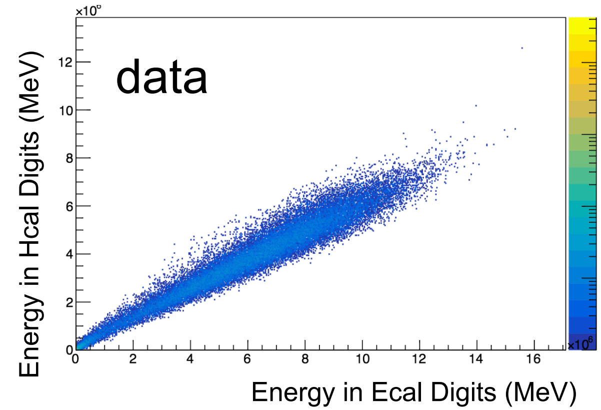
First look at Pb-Ar data (december 2015)

In progress

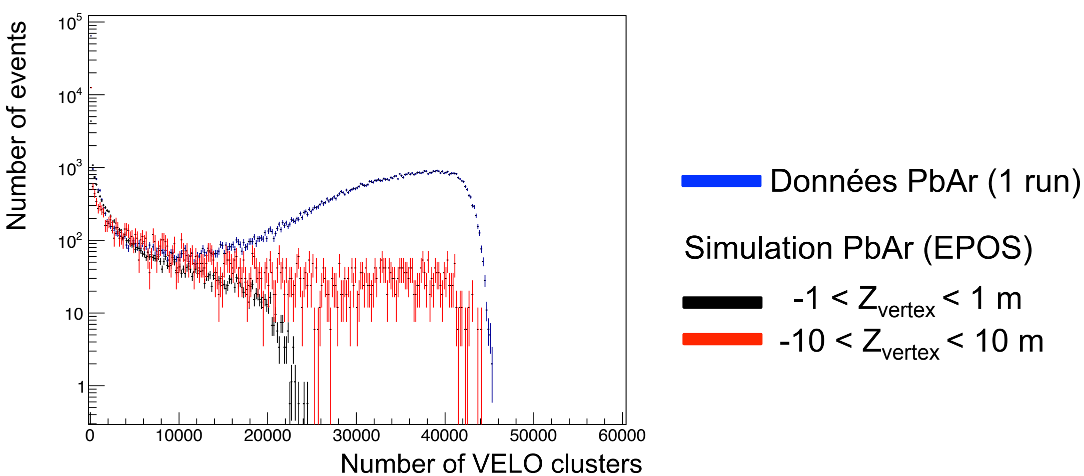
- Work on the reconstruction of the data ongoing
- First look at multiplicities in the detectors in raw data (1 run)







- SMOG was turned off 1 week during the Pb-Pb run to understand the unexpected large amount of high multiplicity events (multiplicities similar as in Pb-Pb collisions)



High multiplicity events in Pb-Ar seems related to interactions in the material upstream the VELO

Heavy ion studies in collider mode

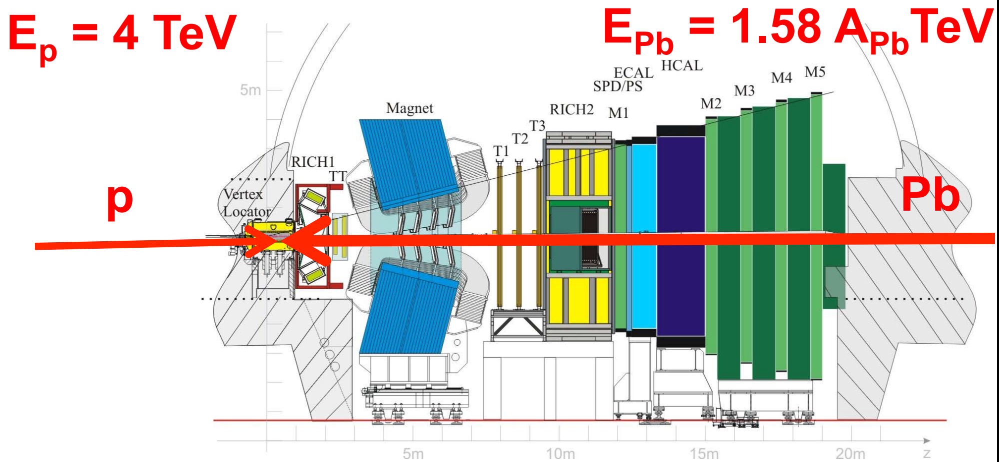
➡ p-Pb and Pb-p collisions

Results from 2013 data taking

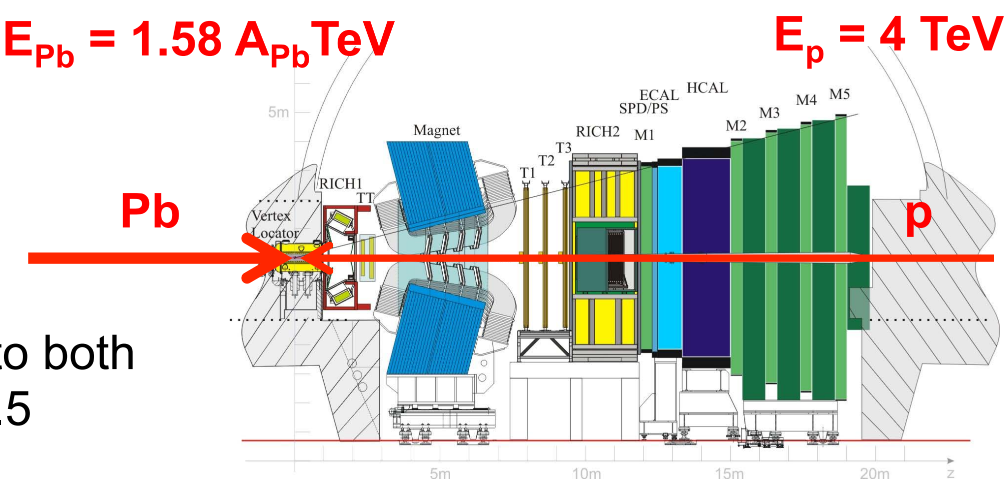
The p-Pb and Pb-p data taking

- p-Pb and Pb-p data collected at a nucleon-nucleon center of mass energy $\sqrt{s_{NN}} = 5$ TeV
- Asymmetric beams: nucleon-nucleon center-of-mass system shifted by $\Delta y = 0.47$ in the direction of the p beam

p + Pb collisions (forward)
Rapidity coverage: $1.5 < y_{CMS} < 4.5$
2013 data sample: $L_{int} = 1.1\ nb^{-1}$
→ Applies to all analyses unless specified



Pb + p collisions (backward)
Rapidity coverage: $-5.5 < y_{CMS} < -2.5$
2013 data sample: $L_{int} = 0.5\ nb^{-1}$
→ Applies to all analyses unless specified



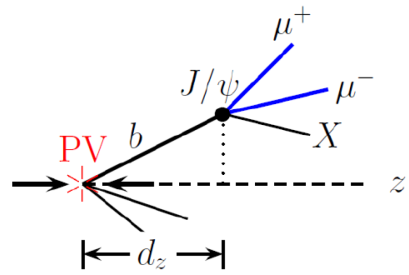
→ Rapidity coverage in common to both configurations: $2.5 < |y_{CMS}| < 4.5$

J/ψ production in p-Pb and Pb-p

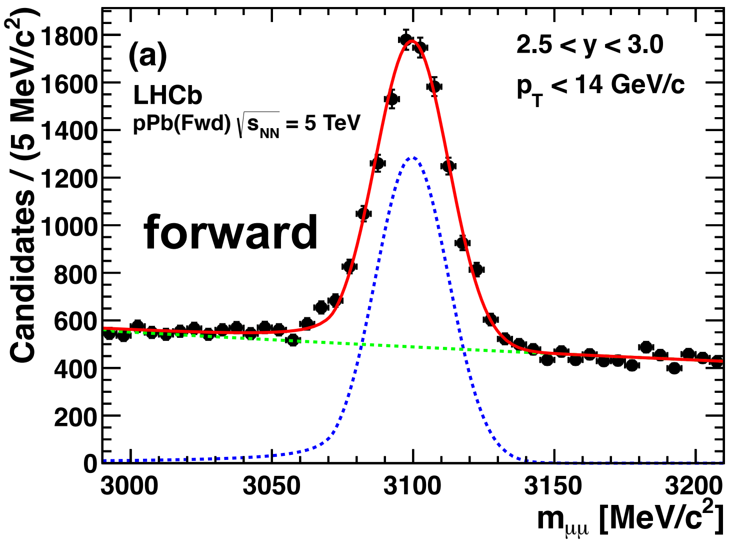
JHEP 02 (2014) 072

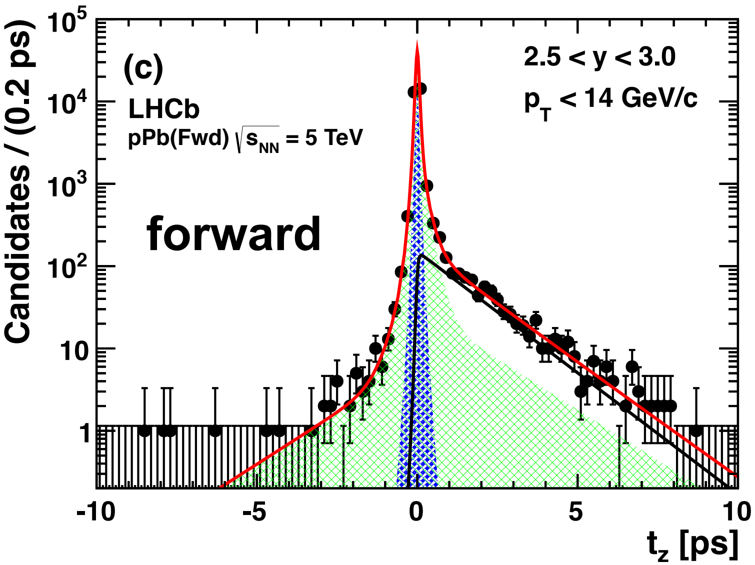
- J/ψ are reconstructed from two well identified muons
- Disentangle prompt J/ψ from J/ψ from b using pseudo-proper time:

$$t_Z = \frac{(Z_{J/\Psi} - Z_{PV}) \times M_{J/\Psi}}{p_z}$$



- Yields of prompt J/ψ and J/ψ from b extracted from simultaneous fit of mass and pseudo-proper time





Mass distribution:

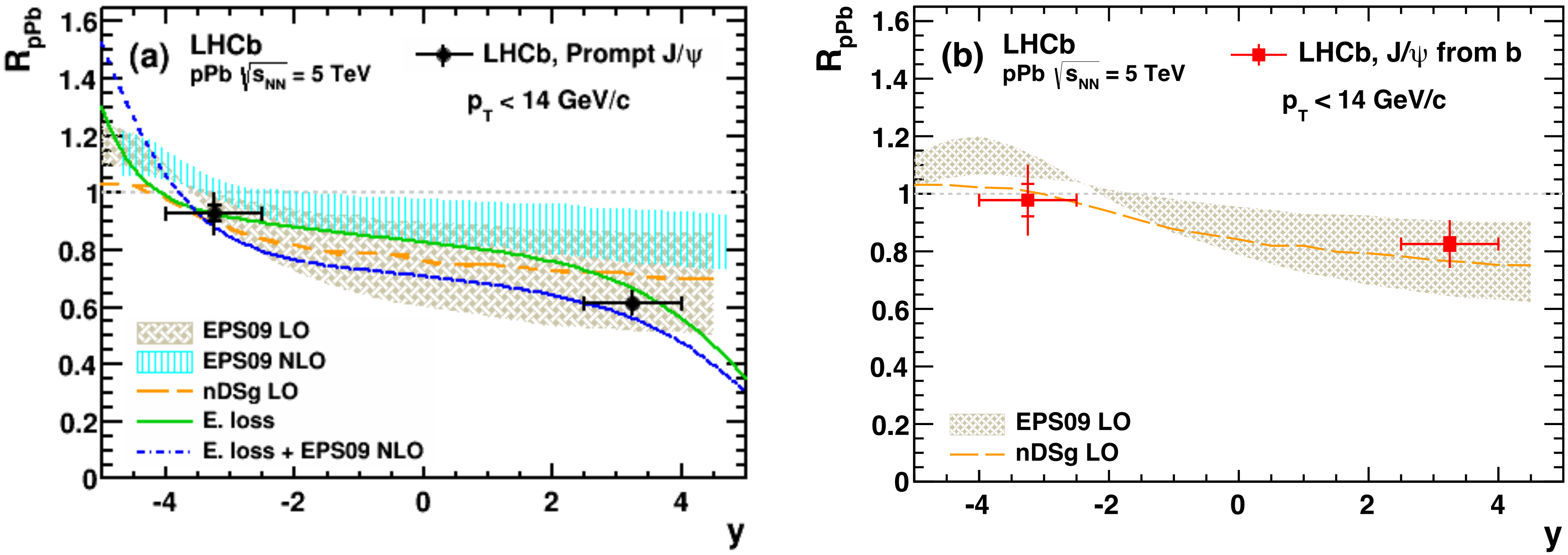
- Signal: Crystal-Ball function
- Background: Exponential

t_Z distribution:

- Signal: - $\delta(t_z)$ for prompts J/ψ (blue curve)
  - Exponential for J/ψ from b (black line)
- Background: Empirical function from sideband (green hatched)

J/ψ nuclear modification factor (R_{pPb}) JHEP 02 (2014) 072

- $R_{pPb}(y) = (1/A) \times (\mathrm{d}\sigma_{\mathrm{pA}}/\mathrm{d}y)/(\mathrm{d}\sigma_{\mathrm{pp}}/\mathrm{d}y)$

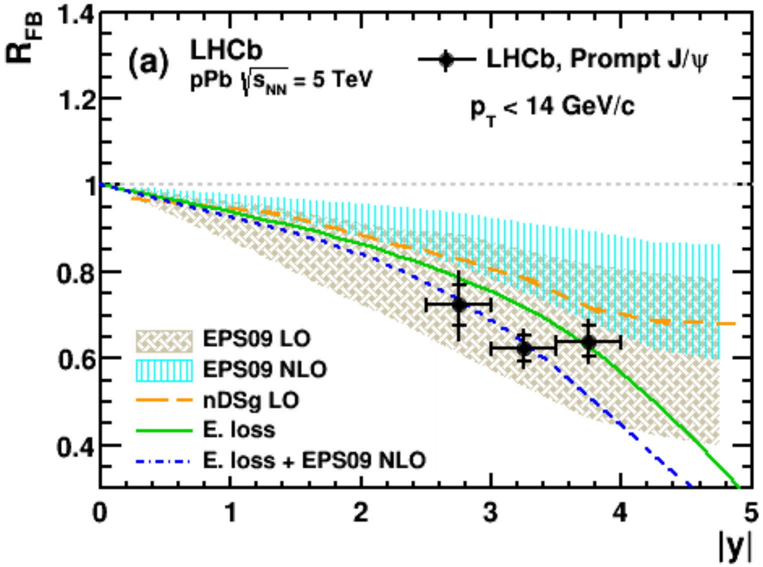


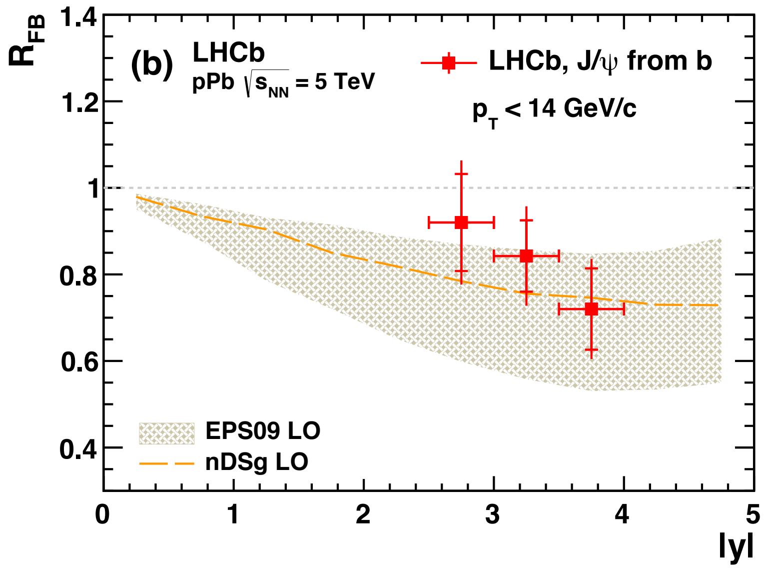
Prompt J/ψ: strong suppression at forward y (strong CNM effect)
→ Data well described by coherent energy loss models (w and w/o shadowing)
J/ψ from b: small suppression in the forward region
→ first indication of suppression of b hadron production

Models: EPS09LO (CSM): PRC88 (2013) 047901; NPA 926 (2014) 236
EPS09LNO (shadowing + CEM): IJMP E22 (2013) 1330007
Energy Loss: JHEP 03 (2013) 122; JHEP 05 (2013) 155
nDSg LO: PRC88 (2013) 047901

J/ψ forward to backward ratio (R_{FB}) JHEP 02 (2014) 072

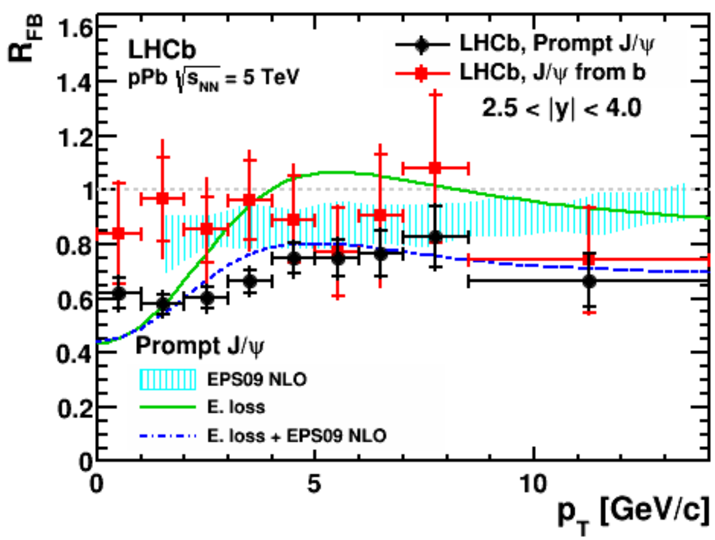
- $R_{FB}(y) = (d\sigma_{pA}/dy)/(d\sigma_{Ap}/dy)$ in common range $2.5 < |y_{CMS}| < 4.0$





Rapidity dependence:
Prompt J/ψ: Clear forward-backward asymmetry
→ More statistics needed to distinguish between models
J/ψ from b: Small forward-backward asymmetry

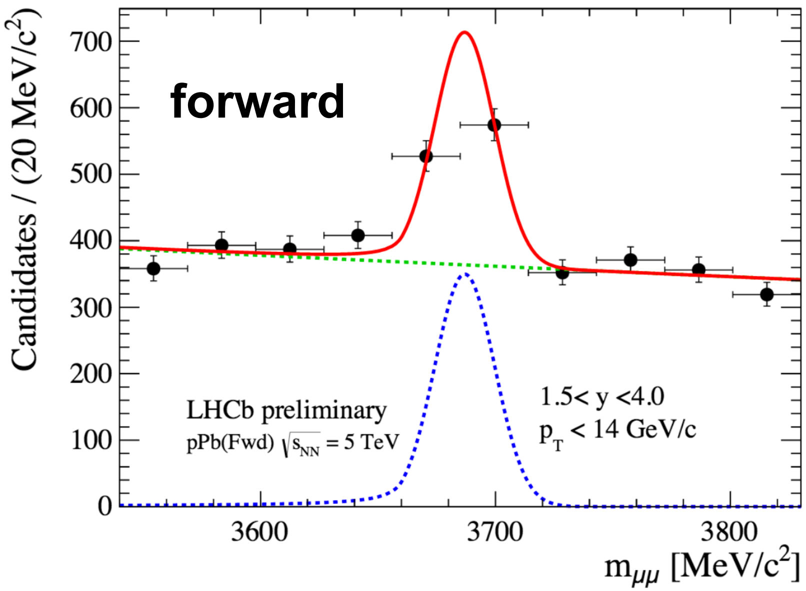
p_T dependence:
Prompt J/ψ : forward backward asymmetry agrees best with eloss + shadowing (except at low p_T)
J/ψ from b: R_{FB} close to 1

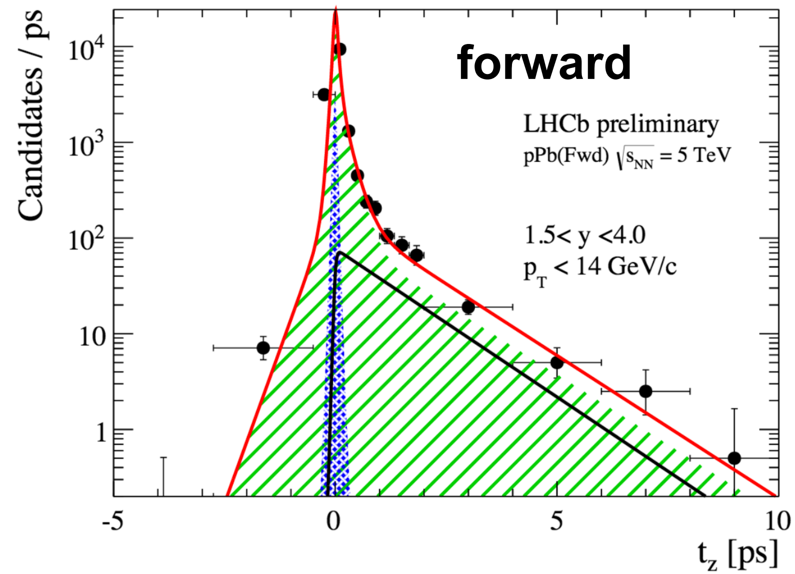


Ψ(2S) production in p-Pb and Pb-p

LHCb-CONF-2015-005

- Similar analysis strategy as for the J/ψ
- Yields of prompt ψ(2S) and ψ(2S) from b extracted from simultaneous fit of mass and pseudo-proper time





Mass distribution:

- Signal: Crystal-Ball function
- Background: Exponential

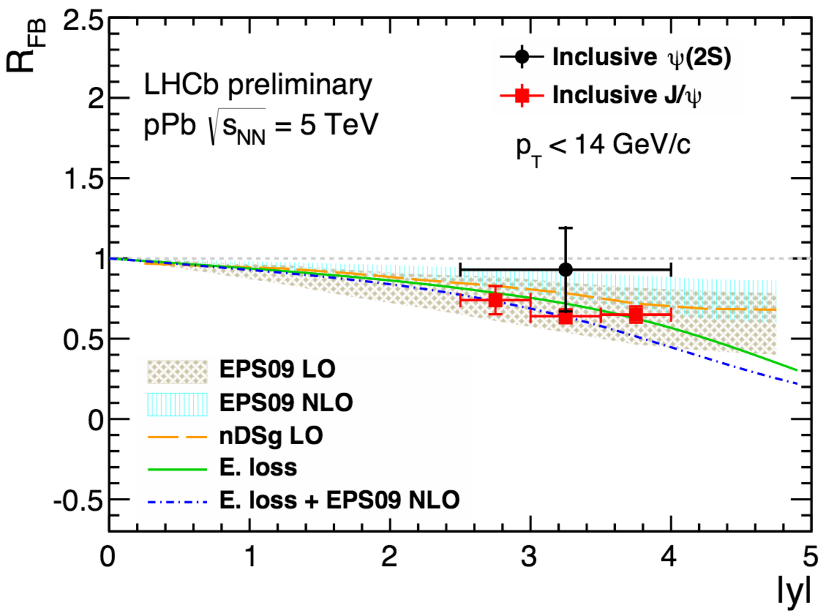
t_z distribution:

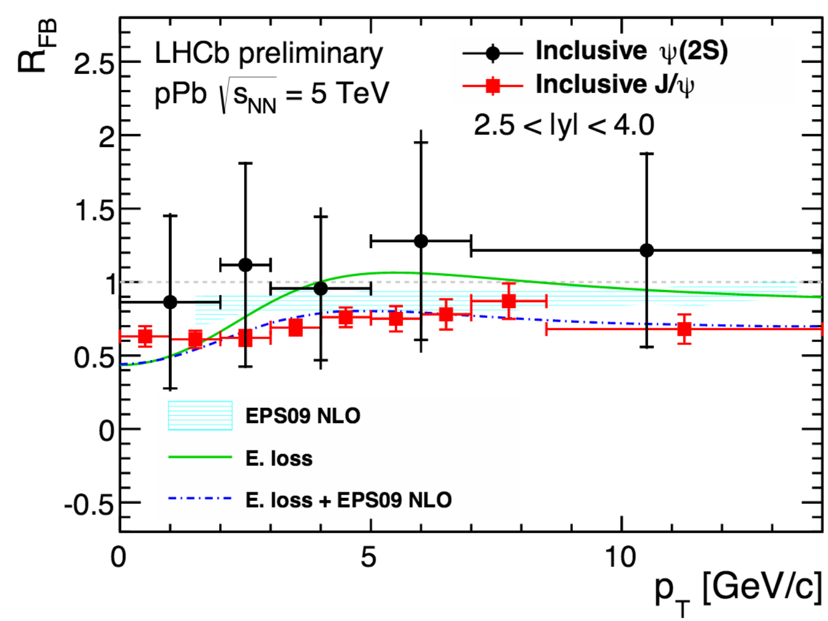
- Signal: - $\delta(t_z)$ for prompts ψ(2S) (blue curve)
  - Exponential for ψ(2S) from b (black line)
- Background: Empirical function from sideband (green hatched)

Ψ(2S) forward to backward ratio

LHCb-CONF-2015-005

- R_{FB} as a function of p_T and rapidity in common range $2.5 < |y_{CMS}| < 4.0$
- No need of pp refence cross section, part of experimental and theoretical uncertainties cancel





Large experimental uncertainties → more statistics needed to get a trend (R_{FB} of inclusive ψ(2S) compatible both with unity and with suppression of inclusive J/ψ)

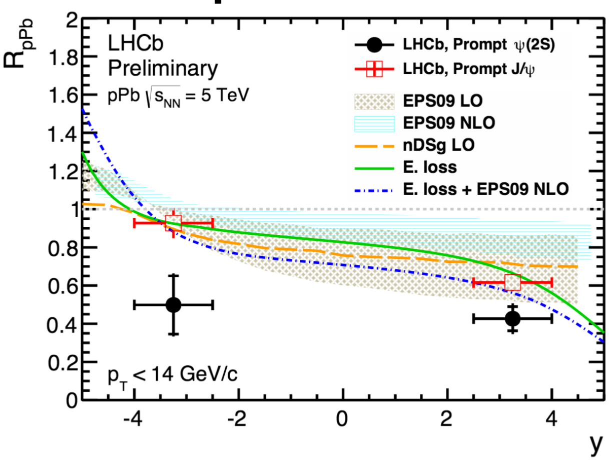
Ψ(2S) nuclear modification factor

LHCb-CONF-2015-005

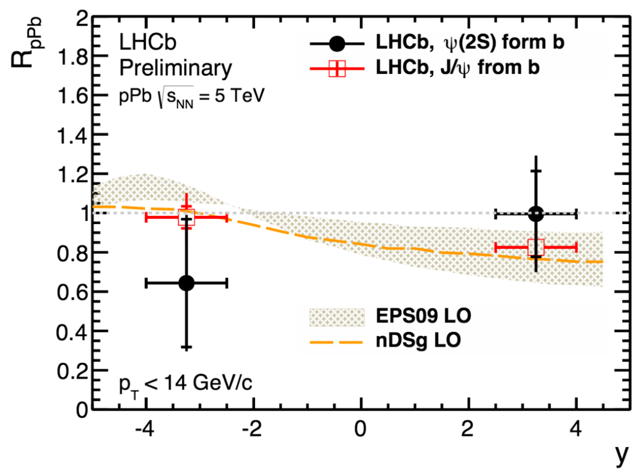
- Ψ(2S) nuclear modification factor is calculated from J/Ψ nuclear modification factor

$$\Rightarrow \quad R_{pPb}^{\Psi(2S)} \approx R_{pPb}^{J/\Psi} \times R \qquad \text{Assuming} \qquad \frac{\sigma_{pp}^{J/\Psi}(5\text{ TeV})}{\sigma_{pp}^{\Psi(2S)}(5\text{ TeV})} \approx \frac{\sigma_{pp}^{J/\Psi}(7\text{ TeV})}{\sigma_{pp}^{\Psi(2S)}(7\text{ TeV})}$$

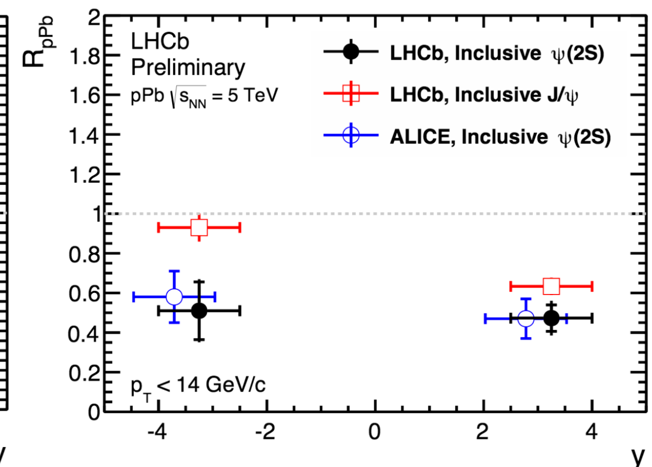
Prompt



From b



Inclusive



ALICE: JHEP 12 (2014) 073

Prompt ψ(2S) more suppressed than prompt J/ψ
Eloss + shadowing don't explain the ψ(2S) suppression in the backward region (other mechanism at play?)
Suppression of ψ(2S) from b consistent with that of J/ψ from b
Suppresion of inclusive ψ(2S) consistent with ALICE results

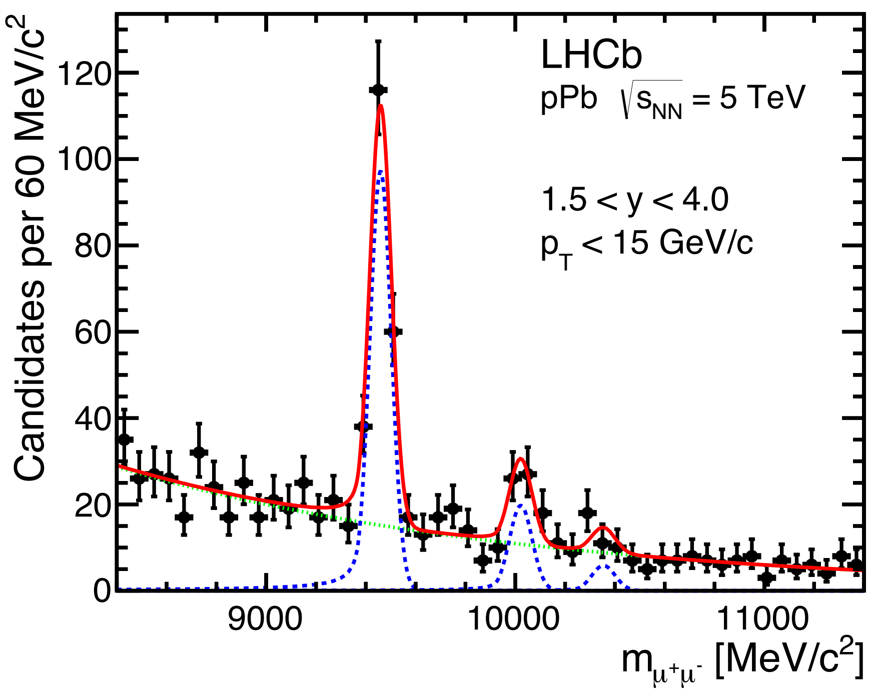
Υ(nS) production in p-Pb and Pb-p

JHEP 07 (2014) 094

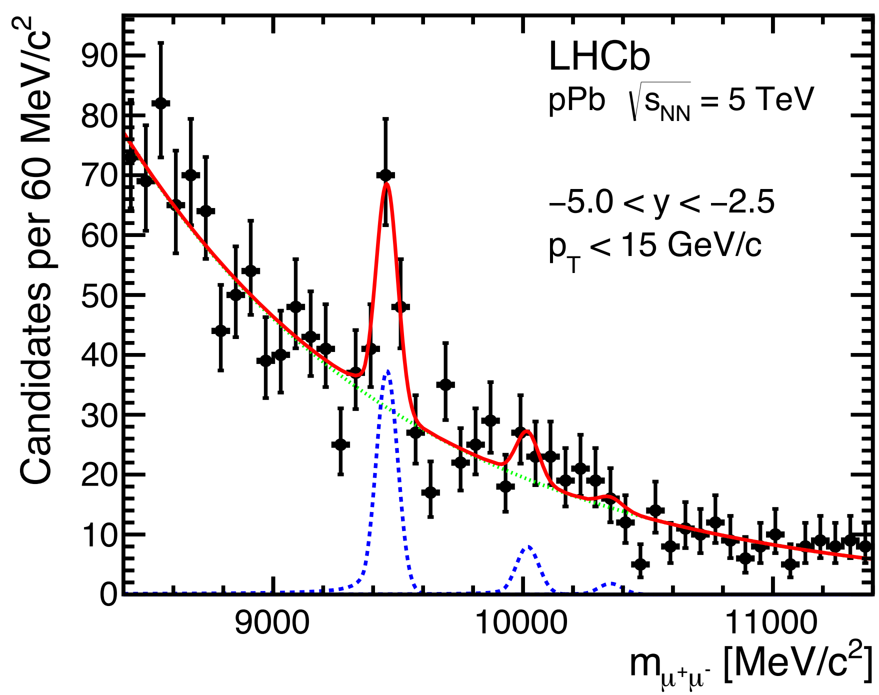
- Υ states in the dimuon decay channel
- Forward: $1.5 < y_{CMS} < 4.0$, backward: $-5.0 < y_{CMS} < -2.5$; $p_T < 15$ GeV/c
- Fit performed with 3 Crystal Balls for signal and an exponential for background

➡ Limited statistics do not permit to do a differential measurement

Forward production



Backward production

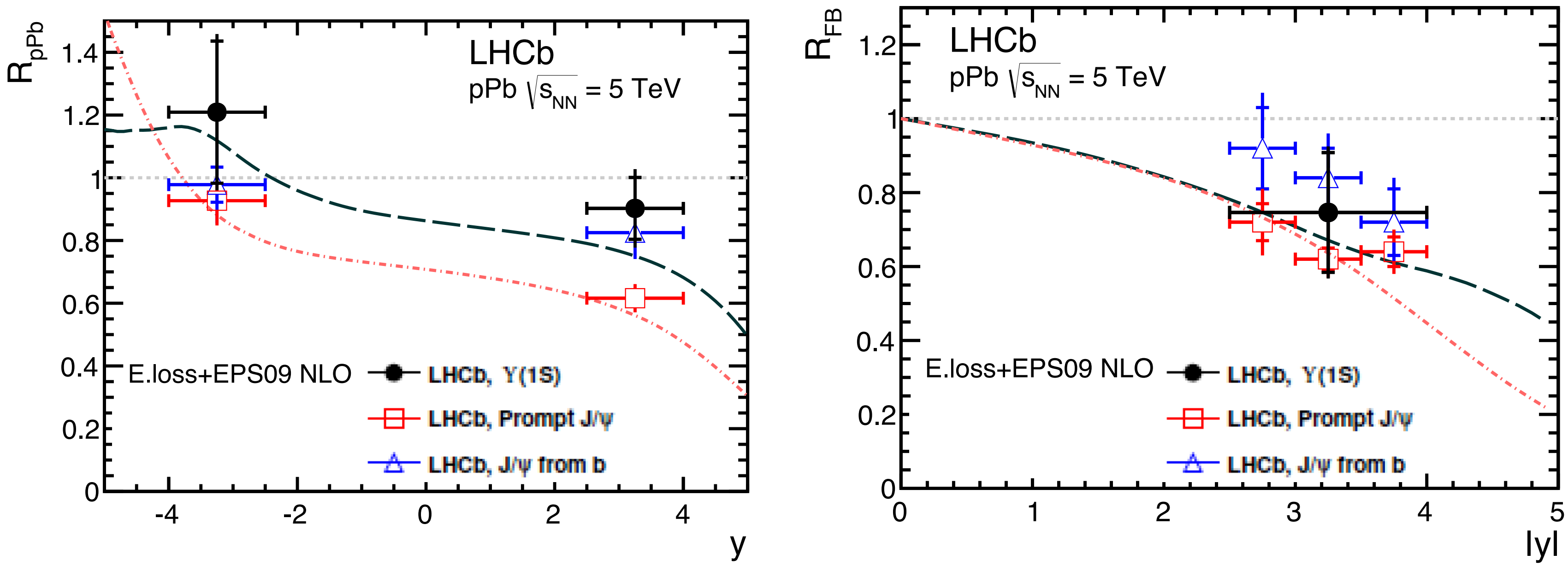


$\Upsilon(1S)$ R_{pA} and R_{FB}

JHEP 07 (2014) 094

- In common range $2.5 < |y_{CMS}| < 4.0$
- Measurement of $\Upsilon(1S)$ R_{pPb} and R_{FB} is complementary to the one of J/ψ

➡ Probing different x_A



$\Upsilon(1S)$ is also sensitive to CNM effets

R_{pPb} versus rapidity:

Suppression in forward region is smaller than for J/ψ

Central value in forward region close to that of J/ψ from b → CNM effects on b hadrons

Indication of enhancement in the backward region → could be attributed to anti-shadowing

R_{FB} versus rapidity:

Ratio in agreement with predictions of energy loss + shadowing (EPSO9 NLO)

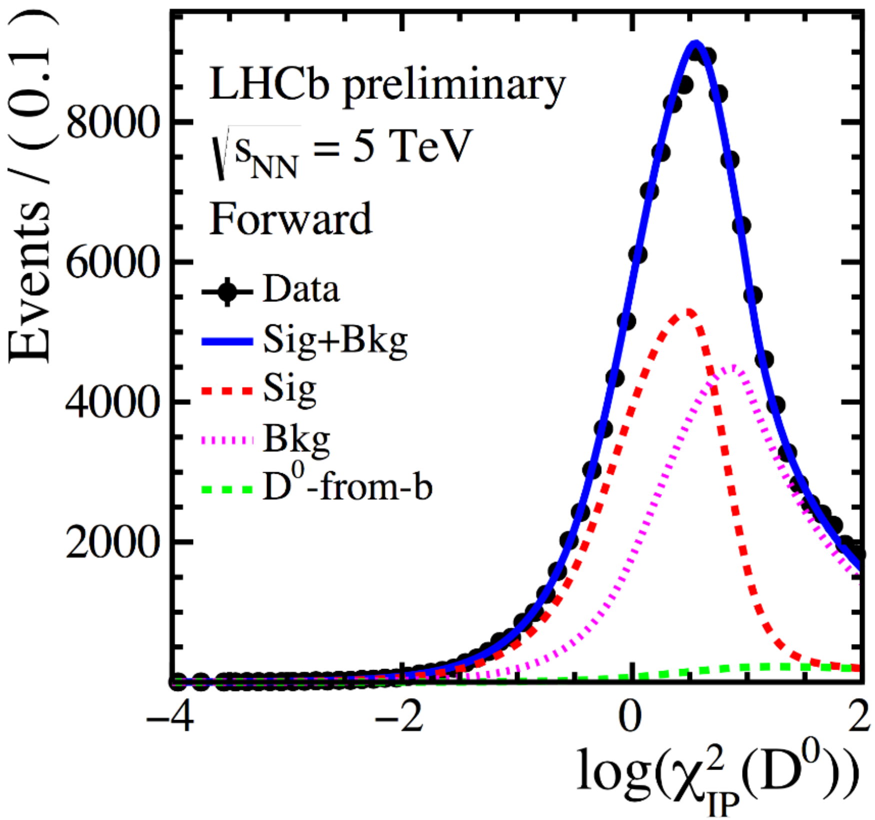
Prompt D^0 production in p-Pb/Pb-p

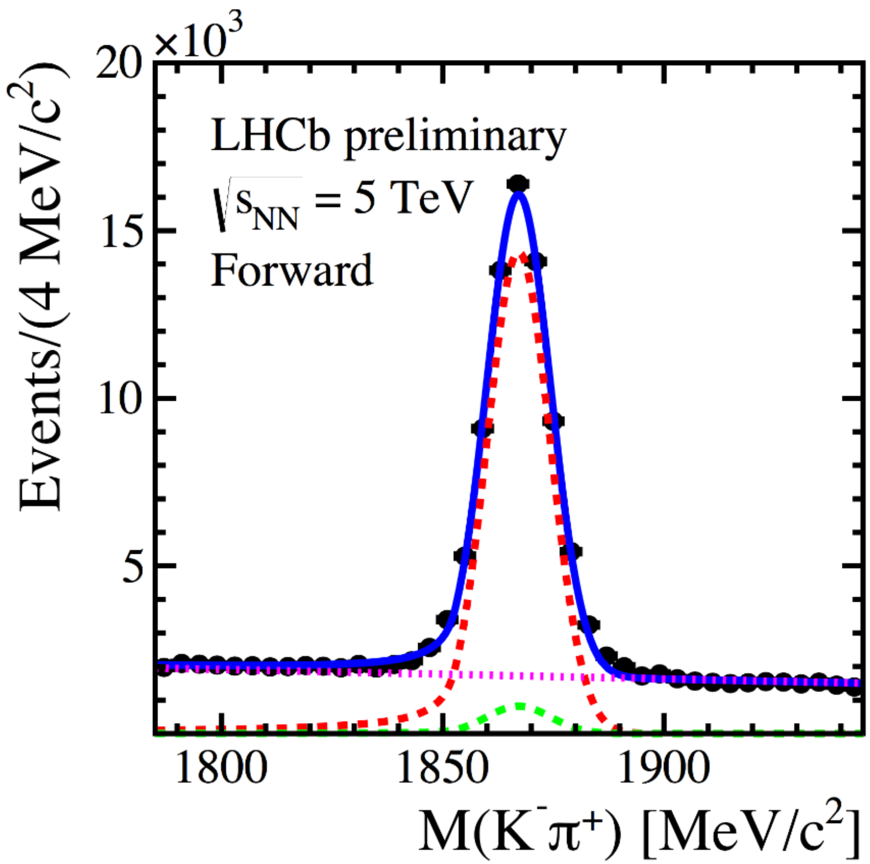
NEW

LHCB-CONF-2016-003-001

- ❑ D^0 reconstructed in $D^0 \rightarrow K^- \pi^+$ decay channel
- ❑ Lint = 0.11 nb^{-1} (forward), Lint = 0.05 nb^{-1} (backward)
- ❑ Prompt D^0 yields obtained from 2D fit of D^0 invariant mass and χ^2 of Impact Parameter

→ LHCb unique to measure prompt D^0 down to zero p_T



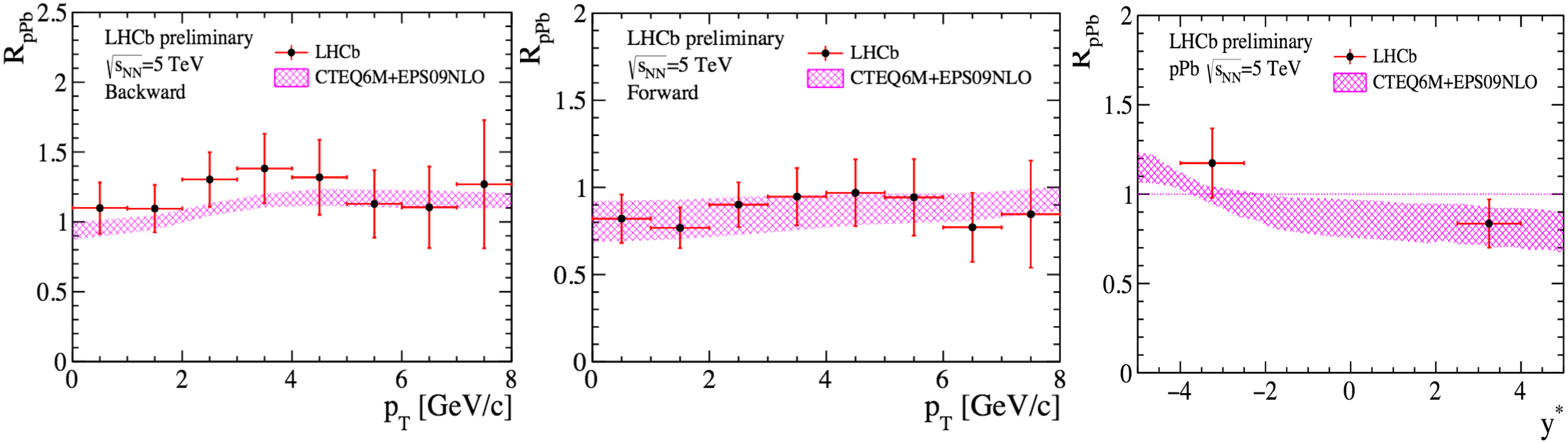


Prompt D^0 production in p-Pb/Pb-p

NEW

LHCB-CONF-2016-003-001

- D^0 nuclear modification factor: $$R_{pPb}(y^*,\sqrt{s_{NN}}) = \frac{1}{A}\frac{\frac{d\sigma_{pPb}}{dy^*}(y^*,\sqrt{s_{NN}})}{\frac{d\sigma_{pp}}{dy^*}(y^*,\sqrt{s_{NN}})}$$
- D^0 pp reference cross section at $\sqrt{s}$ = 5 TeV obtained from extrapolation of LHCb measurements at $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 13 TeV



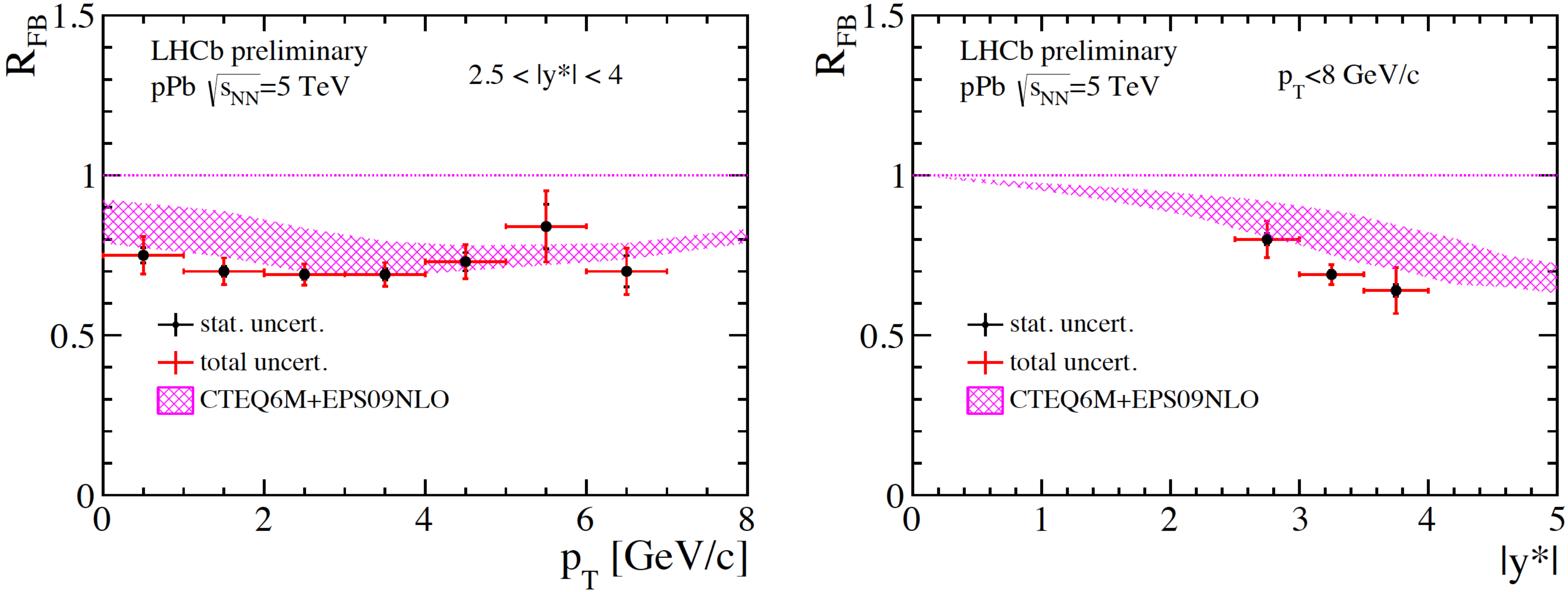
- No strong p_T dependence of the D^0 R_{pPb} at forward and backward rapidities
- Nuclear modification factor smaller at forward rapidity
- Measurement consistent with theoretical predictions from NLO MNR with CTEQ6M + EPS09NLO → Nucl. Phys. B.373 (1992) 295, JHEP 10 (2003) 046, JHEP 04 (2009) 065

Prompt D^0 production in p-Pb/Pb-p

NEW

LHCB-CONF-2016-003-001

- D^0 forward to backward ratio: $R_{FB}(y^*) = R_{pPb}(+|y^*|) / R_{pPb}(-|y^*|)$
- Cancellation of pp reference cross section and of part of the uncertainties



- Clear forward-backward asymmetry → CNM effect
- No strong p_T dependence of the R_{FB}
- Asymmetry more important at larger rapidity
- Measurement consistent with theoretical predictions from NLO MNR with CTEQ6M + EPS09NLO → Nucl. Phys. B.373 (1992) 295, JHEP 10 (2003) 046, JHEP 04 (2009) 065

Heavy ion studies in collider mode

➡ Prospects for Pb-Pb data taking

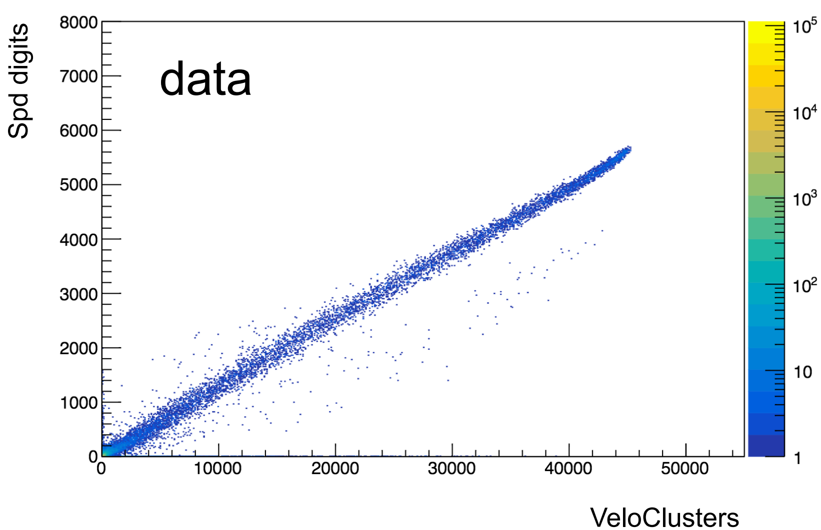
Estimation of collected luminosity : $L_{int} \sim 3\text{-}5\ \mu b^{-1}$

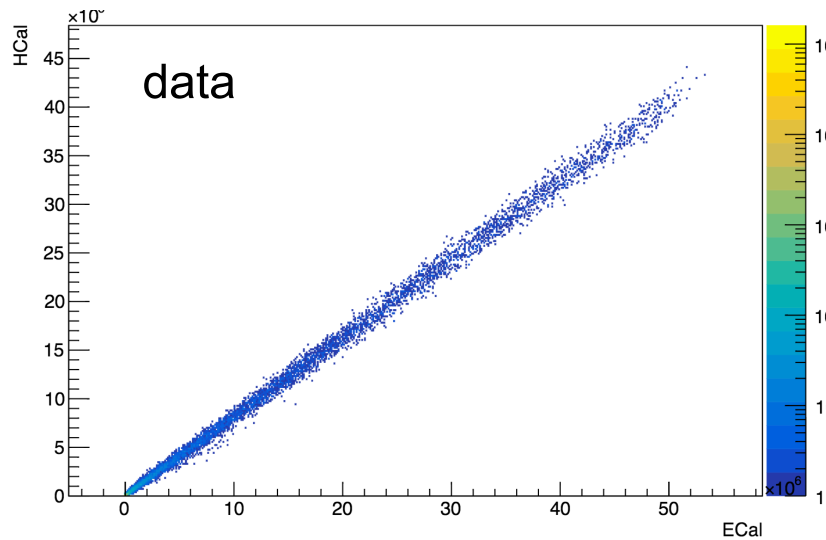
First LHCb Pb-Pb data taking (december 2015)

In progress

- LHCb was switch on slowly and carefully during Pb-Pb data taking
- We had 24 colliding bunches only in LHCb
- After few days of data taking, all LHCb detectors were running in stable conditions
- Estimate of the integrated luminosities: 3-5 μb^{-1}
- We had one week of pure Pb-Pb collisions (without SMOG on) and the rest of the data taking was Pb-Pb and Pb-Ar in parallel
- Pb-Pb data without cut on the centrality are on tape
  - → We won't be able to reconstruct all of them (for timing reason, low tracking efficiency, large number of ghost rate)
  - → But we should be able to measure the collision centrality

Multiplicity in the detectors in the raw data (1 run, without SMOG)

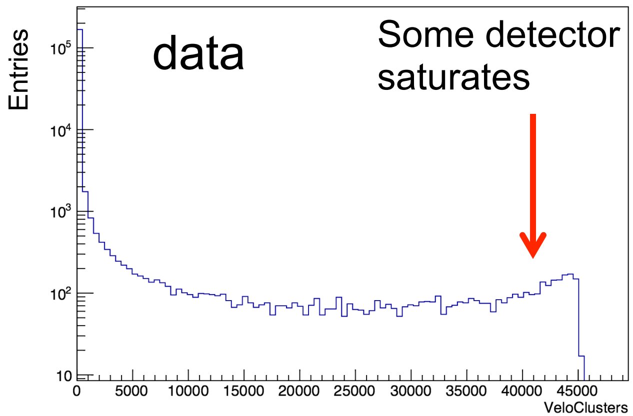


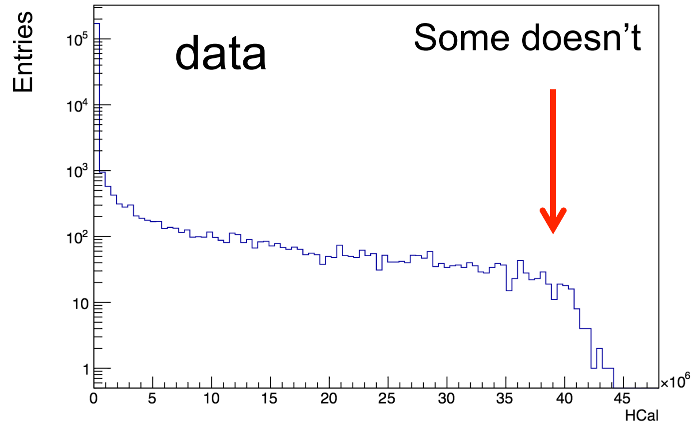


First LHCb Pb-Pb data taking (december 2015)

In progress

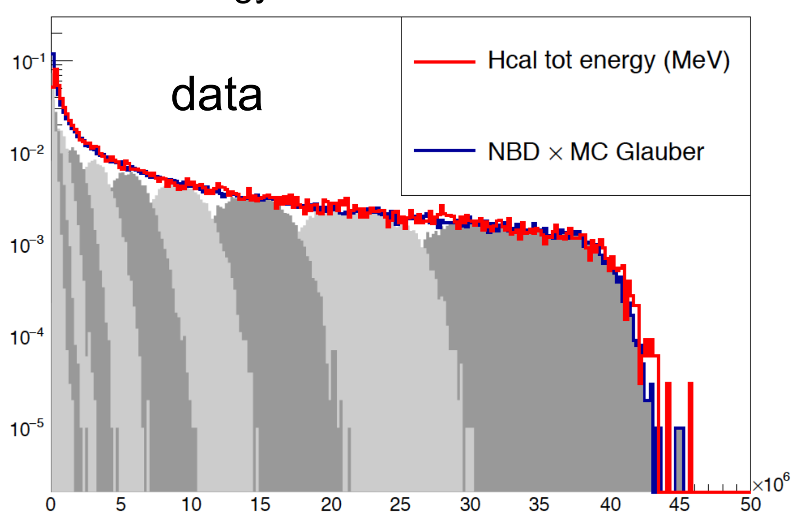
Multiplicity in the detectors in the raw data (1 run, without SMOG)



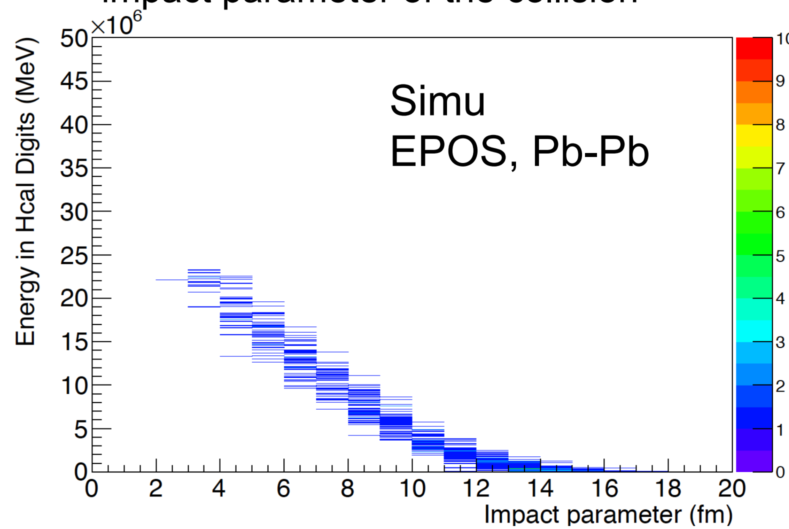


Energy deposition in the hadronic calorimeter could be a good centrality estimator

Glauber MC (a la ALICE) overlayed with total energy measured in hcal



Correlation between energy in hcal and impact parameter of the collision

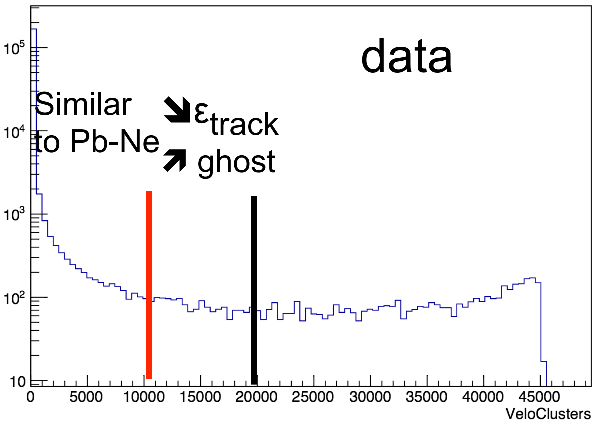


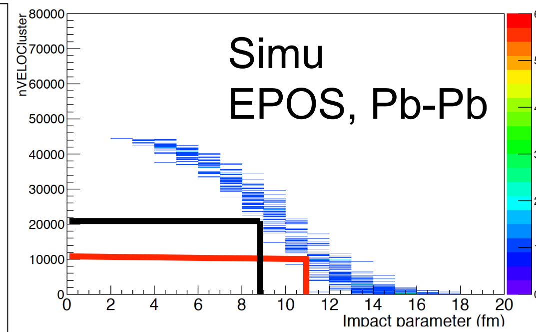
First LHCb Pb-Pb data taking (december 2015)

In progress

Up to which centrality will we reconstruct the data?

Reconstruction will be performed for events with nVeloClusters < 20000





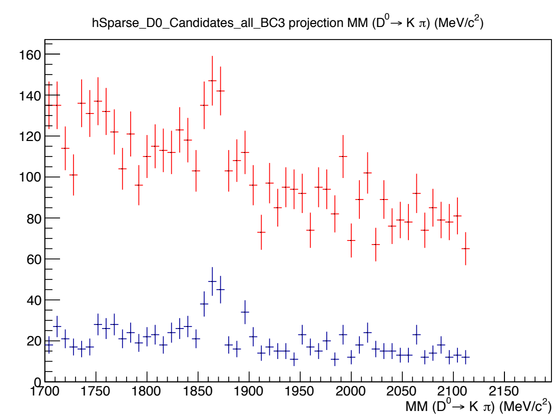
ALICE centrality paper: http://arxiv.org/abs/1301.4361

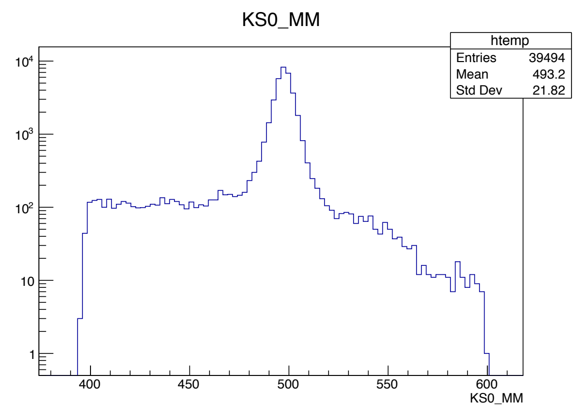
Table 1: Geometric properties (N_{part}, N_{coll}, T_{AA}) of Pb–Pb collisions for centrality classes defined by sharp cuts in the impact parameter b (in fm). The mean values, the RMS, and the systematic uncertainties are obtained with a Glauber Monte Carlo calculation.

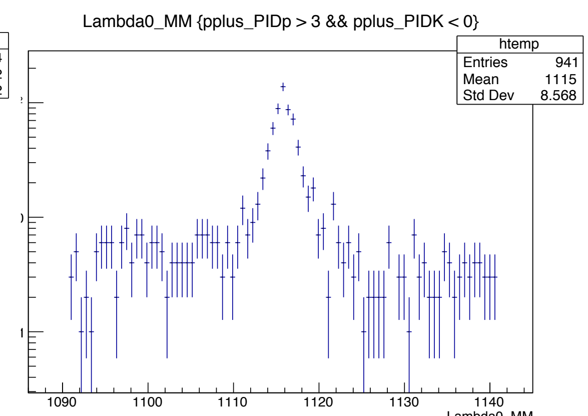
Centrality	b_{min} (fm)	b_{max} (fm)	$\langle N_{part} \rangle$	RMS	(*sys.*)	$\langle N_{coll} \rangle$	RMS	(*sys.*)	$\langle T_{AA} \rangle$ 1/mbarn	RMS 1/mbarn	(*sys.*) 1/mbarn
0–1%	0.00	1.57	403.8	4.9	1.8	1861	82	210	29.08	1.3	0.95
1–2%	1.57	2.22	393.6	6.5	2.6	1766	79	200	27.6	1.2	0.87
2–3%	2.22	2.71	382.9	7.7	3.0	1678	75	190	26.22	1.2	0.83
3–4%	2.71	3.13	372.0	8.6	3.5	1597	72	180	24.95	1.1	0.81
4–5%	3.13	3.50	361.1	9.3	3.8	1520	70	170	23.75	1.1	0.81
5–10%	3.50	4.94	329.4	18	4.3	1316	110	140	20.56	1.7	0.67
10–15%	4.94	6.05	281.2	17	4.1	1032	91	110	16.13	1.4	0.52
15–20%	6.05	6.98	239.0	16	3.5	809.8	79	82	12.65	1.2	0.39
20–25%	6.98	7.81	202.1	16	3.3	629.6	69	62	9.837	1.1	0.30
25–30%	7.81	8.55	169.5	15	3.3	483.7	61	47	7.558	0.96	0.25
30–35%	8.55	9.23	141.0	14	3.1	366.7	54	35	5.73	0.85	0.20
35–40%	9.23	9.88	116.0	14	2.8	273.4	48	26	4.272	0.74	0.17
40–45%	9.88	10.47	94.11	13	2.6	190.4	41	19	3.115	0.64	0.14
45–50%	10.47	11.04	75.3	13	2.3	143.1	34	13	2.235	0.54	0.11
50–55%	11.04	11.58	59.24	12	1.8	100.1	28	8.6	1.564	0.45	0.082
55–60%	11.58	12.09	45.58	11	1.4	68.46	23	5.3	1.07	0.36	0.060
60–65%	12.09	12.58	34.33	10	1.1	45.79	18	3.5	0.7154	0.28	0.042
65–70%	12.58	13.05	25.21	9.0	0.87	29.92	14	2.2	0.4674	0.22	0.031
70–75%	13.05	13.52	17.96	7.8	0.66	19.08	11	1.3	0.2981	0.17	0.020
75–80%	13.52	13.97	12.58	6.5	0.45	12.07	7.8	0.77	0.1885	0.12	0.013
80–85%	13.97	14.43	8.812	5.2	0.26	7.682	5.7	0.41	0.12	0.089	0.0088
85–90%	14.43	14.96	6.158	3.9	0.19	4.904	4.0	0.24	0.07662	0.062	0.0064
90–95%	14.96	15.67	4.376	2.8	0.10	3.181	2.7	0.13	0.0497	0.042	0.0042
95–100%	15.67	20.00	3.064	1.8	0.059	1.994	1.7	0.065	0.03115	0.026	0.0027

Signal already seen in 3 reconstructed runs!

nVeloCluster < 20000
nVeloCluster < 6000

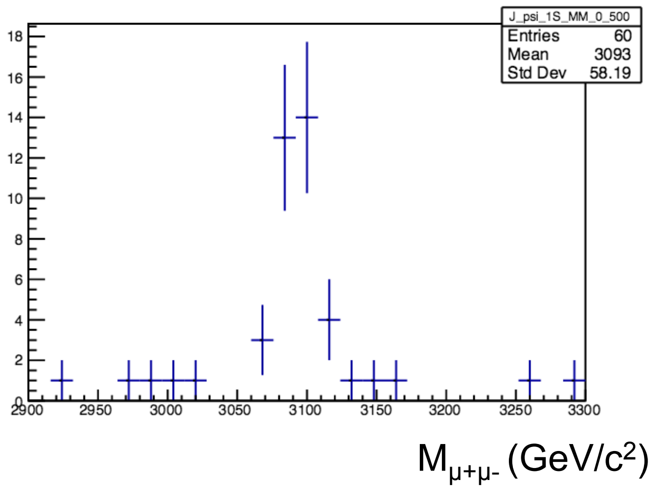




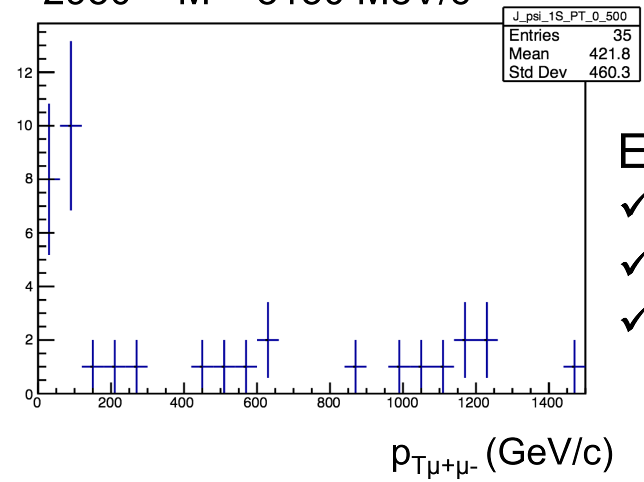


Prospects for J/ψ photoproduction in Pb-Pb UPC

- ❑ Private reconstruction of 5 runs (~ 5h of data taking)



$2950 < M < 3150$ MeV/c^2

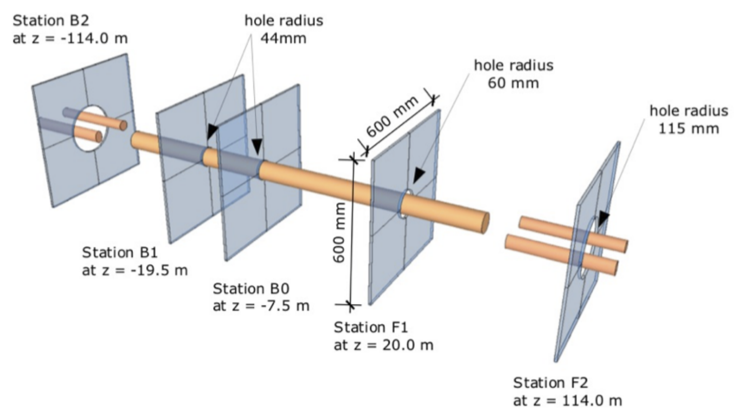


Events mainly with:

- ✓ No PV reconstructed
- ✓ only 2 LongTracks
- ✓ only 2 VeloTracks

➡ Evidences for coherently photoproduced J/ψ in very low activity Pb-Pb events (probably UPC)

- ❑ New HERSHEL detector installed in LHCb:
  - Forward detector $5 < |\eta| < 8$
  - Possibility to define rapidity gaps



Conclusions

- **LHCb is in the unique position to do fixed target physics**
  - Exploit the SMOG system with different noble gases (p-Ne, p-He, p-Ar and Pb-Ar runs already collected)
  - Bridge the physics gap from SPS to LHC with a single experiment

- **LHCb succesfully participated to the proton-Pb data taking in 2013**
  - Measurement of J/ψ, ψ(2S) and ϒ production
    → Cold nuclear matter effects visible in J/ψ, ψ(2S) and ϒ(1S) production
  - New measurement of prompt D^0 production (down to zero p_T)
    → Analysis will be updated with full statistics and pp reference cross section measurement

- **LHCb has collected PbPb data end of 2015**
  - Rich program on heavy flavour physics, EW, (soft) QCD and QGP studies
  - Measurement of centrality, D^0 production in peripheral events, J/ψ photoproduction in Pb-Pb UPC foreseen

LHCb is more than a pp heavy flavour experiment
LHCb is a truly general purpose detector in the forward region

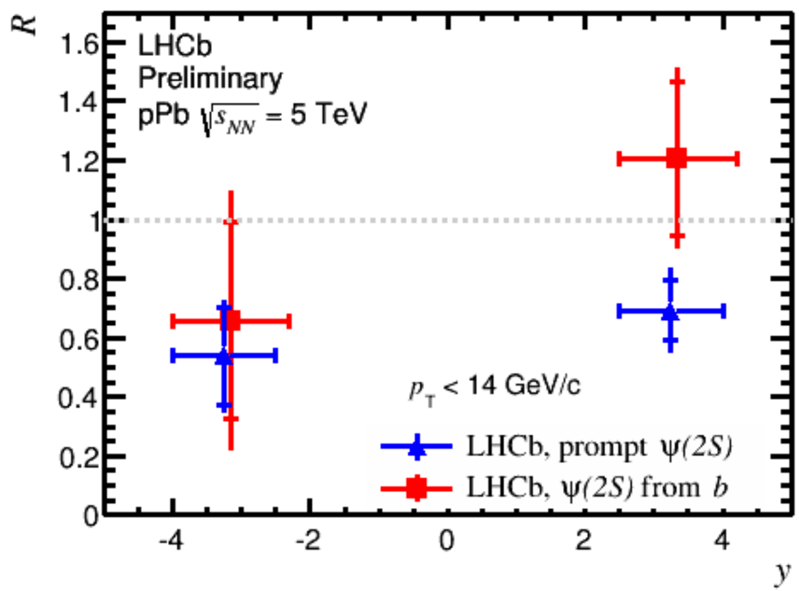
BACK UP

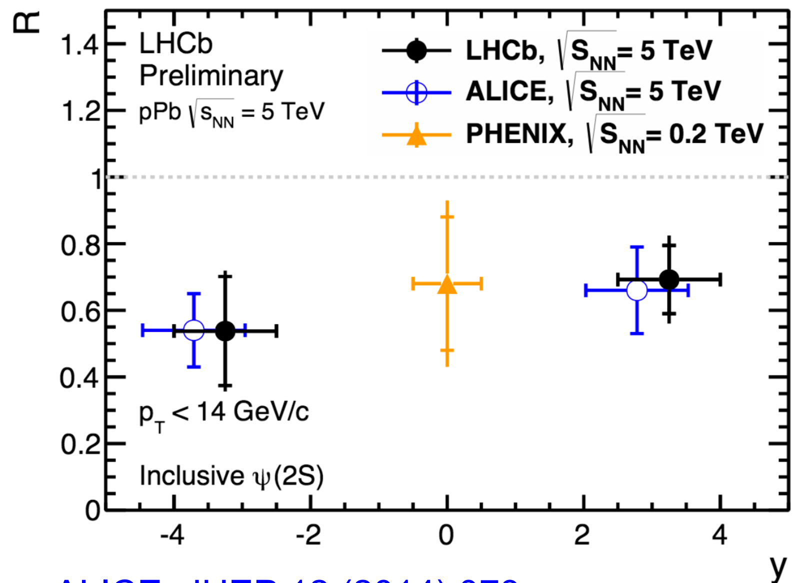
Ψ(2S) relative suppression wrt J/ψ

LHCb-CONF-2015-005

- Relative suppression is calculated as:

$$R = \frac{R_{pPb}^{\psi(2S)}}{R_{pPb}^{J/\Psi}} = \frac{\sigma_{pPb}^{\psi(2S)}(5\mathrm{TeV})}{\sigma_{pPb}^{J/\Psi}(5\ \mathrm{TeV})} \frac{\sigma_{pp}^{J/\Psi}(5\ \mathrm{TeV})}{\sigma_{pp}^{\Psi(2S)}(5\ \mathrm{TeV})} \approx \frac{\sigma_{pPb}^{\psi(2S)}(5\mathrm{TeV})}{\sigma_{pPb}^{J/\Psi}(5\ \mathrm{TeV})} \frac{\sigma_{pp}^{J/\Psi}(7\ \mathrm{TeV})}{\sigma_{pp}^{\Psi(2S)}(7\ \mathrm{TeV})}$$





ALICE: JHEP 12 (2014) 073
PHENIX: Phys. Rev. Lett. 111 (2013), no. 20 (202301)

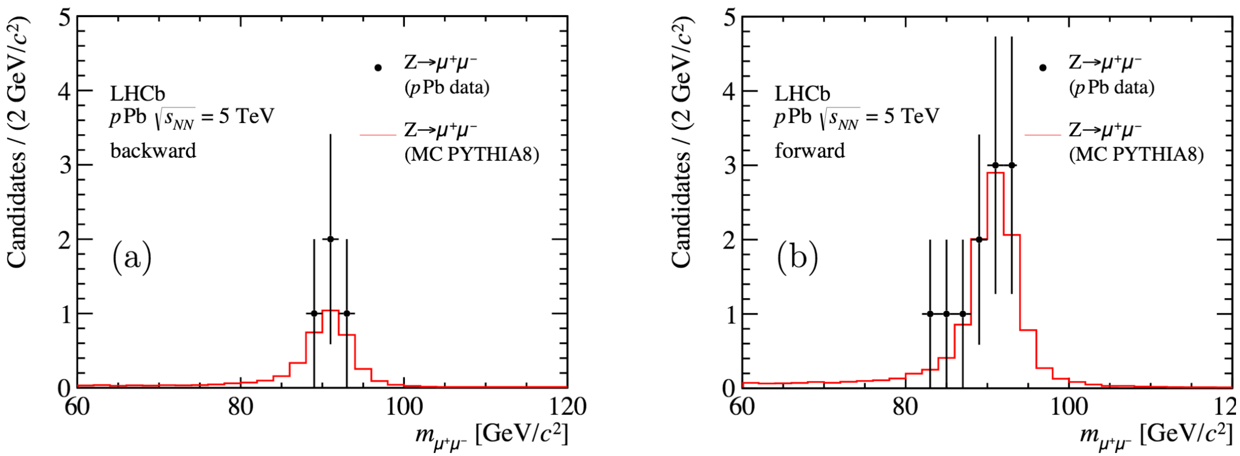
Intriguing stronger suppression of prompt ψ(2S) than that of prompt J/ψ
Similar suppression for ψ(2S) from b and J/ψ from b
→ R compatible with 1 within large uncertainties
Results for inclusive ψ(2S) compatible with ALICE measurement

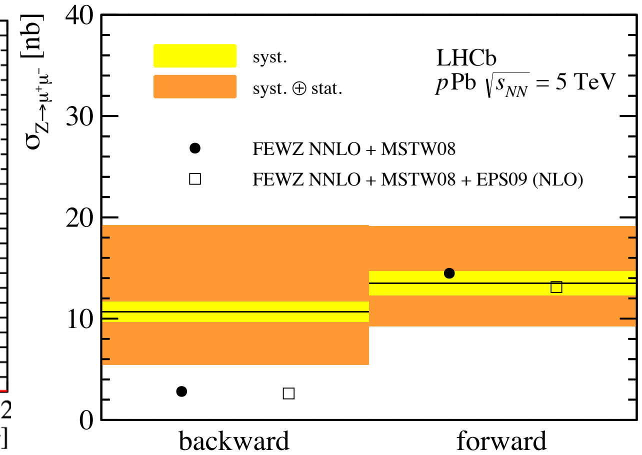
Z production in p-Pb and Pb-p

JHEP 09 (2014) 030

Muon selection: p_T > 20 GeV/c, 2.0 < η < 4.5, 60 < $M(\mu^+\mu^-)$ < 120 GeV/c^2
Backgrounds: very small, purity > 99% determined from data

➡ Clean signal: 11 forward candidates, 4 backward candidates





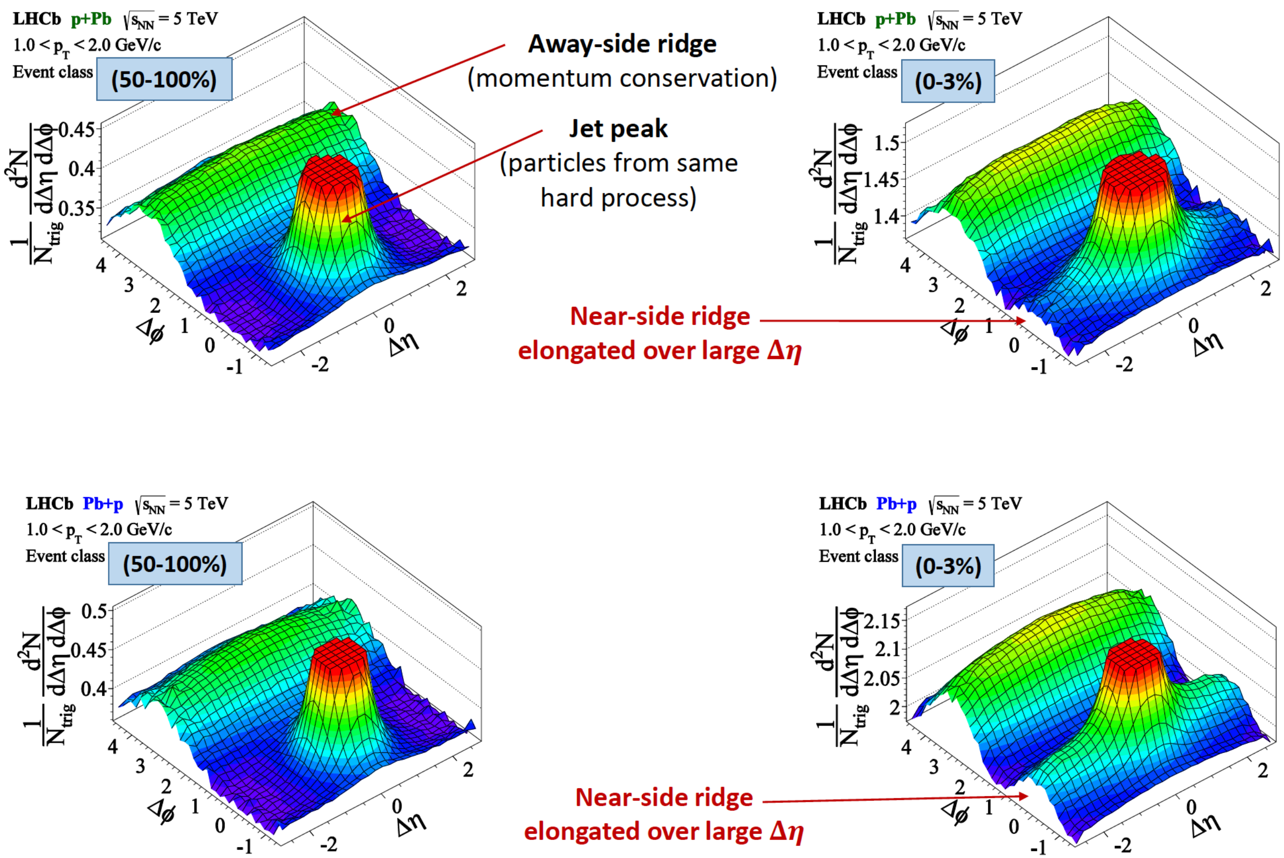
Cross sections in agreement with predictions, although the production of Z in the backward region appears slightly higher than prediction
R_{FB} calculated in the common rapidity range is lower than expectations
→ deviation of 2.2σ from R_{FB} = 1
Statistical precision of measured cross sections prevents conclusions on the presence of CNM
Looking forward to take more data during run II

Two particle correlations in p-Pb and Pb-p

LHCB-CONF-2015-004

- Measurement of angular (Δη,Δϕ)-correlations of prompt charged particles
- Both beam configurations analyzed separately: L_{int} = 0.46nb^{-1} (p+Pb), L_{int} = 0.30nb^{-1} (Pb-p)
- Rapidity range 1.5 < y_{CMS} < 4.4 (forward), -5.4 < y < -2.5 (backward)
- Correlation function is decribed as a per-trigger particle associated yield:

$$\frac{1}{N_{trig}}\frac{d^2N_{pair}}{d\Delta\eta d\Delta\varphi} = \frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)} \times B(0,0)$$



p-Pb configuration
Δϕ=0 near-side ridge clearly visible **in high event activity class** (however not very pronounced)

Pb-p configuration
Δϕ=0 very pronounced near-side ridge in Pb-p in **high activity event class**

Two particle correlations in p-Pb and Pb-p

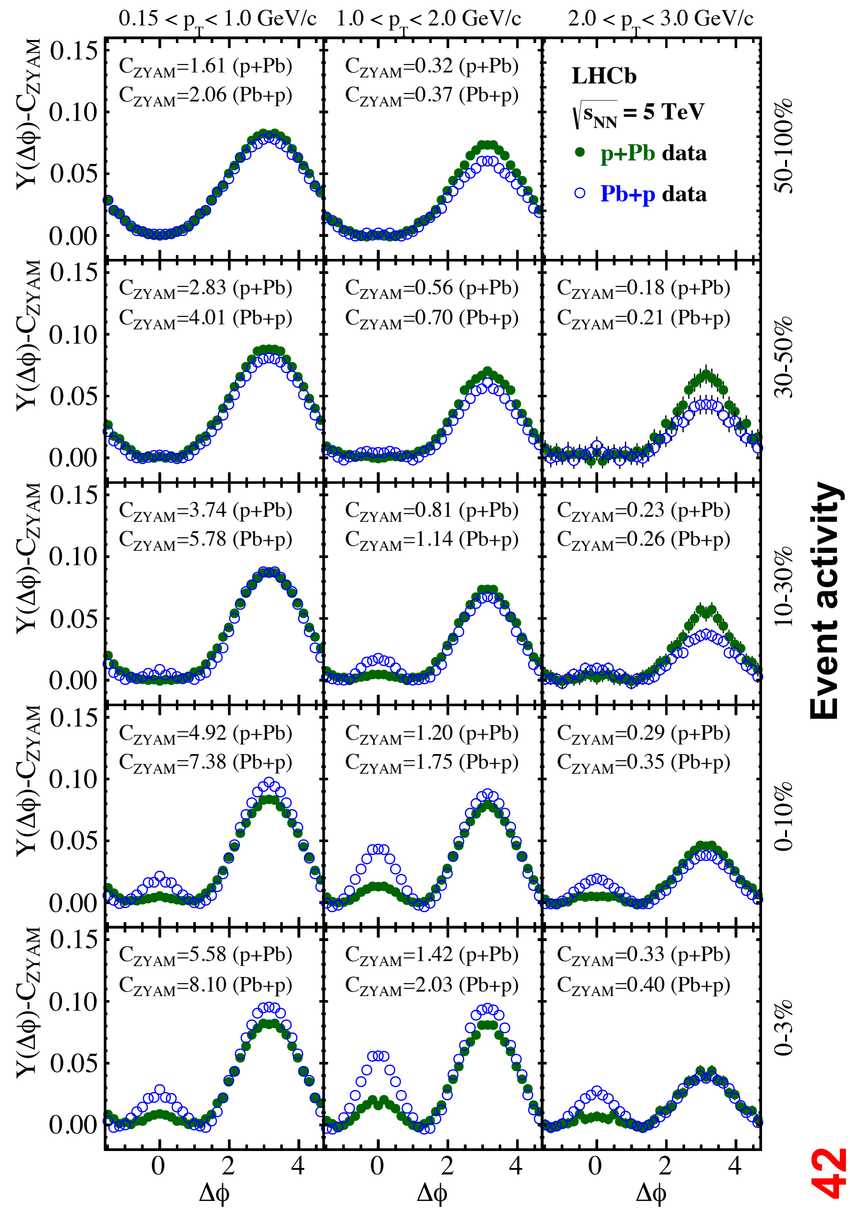
- To study the evolution of the long-range correlations on the near and away sides in more details, correlation function on Δϕ are calculated:

$$Y(\Delta\phi) \equiv \frac{1}{N_{trig}}\frac{dN_{pair}}{d\Delta\phi} = \frac{1}{\Delta\eta_b - \Delta\eta_a}\int_{\Delta\eta_a}^{\Delta\eta_b}\frac{1}{N_{trig}}\frac{d^2N_{pair}}{d\Delta\eta d\Delta\phi}d\Delta\eta$$

- 2D-yield averaged in the range 2.0 < η < 2.9 to exclude short range correlations (jet peak)

- Subtraction of the zero yield at minimum (ZYAM)

LHCB-CONF-2015-004



Correlation yield increases with event activity
Away-side ridge decreases towards higher p_T
On the near side the ridge emerges (from 10-30% event activity class in Pb-p, from 0-10% event activity class in p-Pb) with a maximum in 1 < p_T < 2 GeV/c
Near-side ridge is more pronounce in Pb-p than in p-Pb