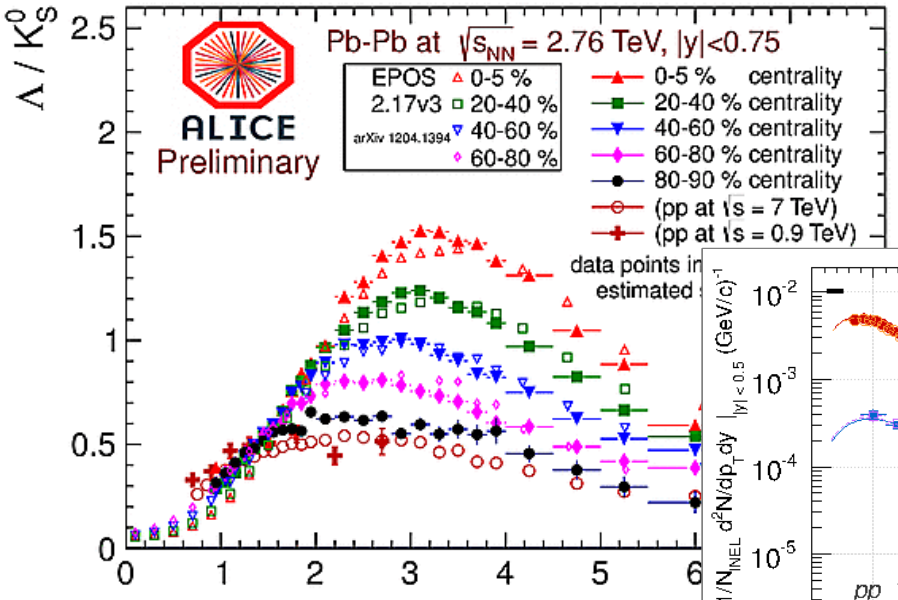
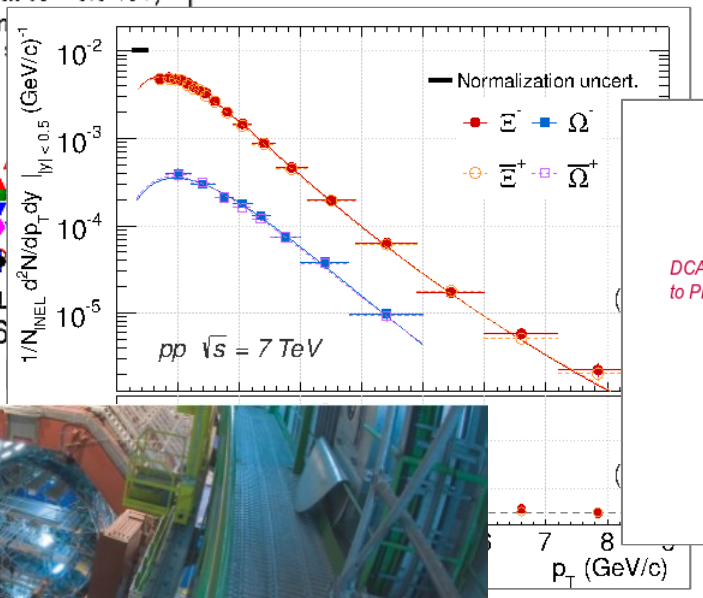
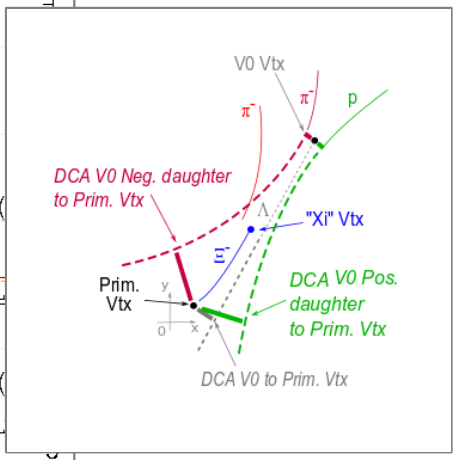
Antonin MAIRE – PI Heidelberg

Strangeness in ALICE :

selected items...
in pp
and Pb-Pb







0.1 – Strange menu : particles and systems

As measured in ALICE :

red = id° implying displaced vertex
gray = id° requiring detector PID only

yellow fill = resonance
orange fill = ground state

	baryons	*mesons*	*« bound states »*
|s| = 0	∅	$\phi(1020)$ → pp: ✓ Pb-Pb: ✓	∅
|s| = 1	$\Lambda, \overline{\Lambda}$ → pp: ✓ / Pb-Pb: ✓ $\Sigma(1385)^-, \Sigma(1385)^+$ → pp: ✓ / Pb-Pb: ✗ $\Lambda(1520)$	K^-, K^+ K^0s $K^*(892)$ → pp: ✓ / Pb-Pb: ✓ D_s^+ → pp: ✓ / Pb-Pb: ✓	(anti)hypertriton : ${}^3_{\Lambda}H$ (pnΛ) (Λn) bound state → pp: ✗ / Pb-Pb: ✓
|s| = 2	$\Xi^-, \overline{\Xi}^+$ → pp: ✓ Pb-Pb: ✓ $\Xi(1530)^0$ → pp: ✓ Pb-Pb: ✗	∅	di-baryon (ΛΛ) → pp: ✗ / Pb-Pb: ✓
|s| = 3	$\Omega^-, \overline{\Omega}^+$ → pp: ✓ / Pb-Pb: ✓		

→ *in this talk...*

0.2 – Strange menu : analyses and $\sqrt{s_{NN}}$

ALICE analyses dealing with strange hadrons...

- basically at $y \approx 0$
  (exception : $\phi(1020) \rightarrow \mu^+\mu^-$ at forward y, *see A.Uras QM2012 poster*)
- $0 < p_T < 20$ GeV/c

	pp 0.9 TeV	pp 2.76 TeV	pp 7 TeV	Pb-Pb 2.76 TeV
1. Spectra, $d^2N/dp_T dy = f(p_T)$	✓	✓	✓	✓
2. Anti-baryon / baryon ratio = $f(p_T)$	✓	✓	✓	✓
3. Strangeness in fragmentation function	✗	✗	*ongoing*	*ongoing*
4. Azimuthal correlations	✗	✗	*ongoing*	*ongoing*
5. Bose-Einstein, femtoscopy, HBT	✗	✗	✓	✓
6. Elliptic flow, v_2	–	–	–	✓

0.3 – Outline : this talk composition ...

I . Introduction

II. In pp …

→ *production, MC predictions*

III. In Pb-Pb …

→ *production : suppression / enhancement*

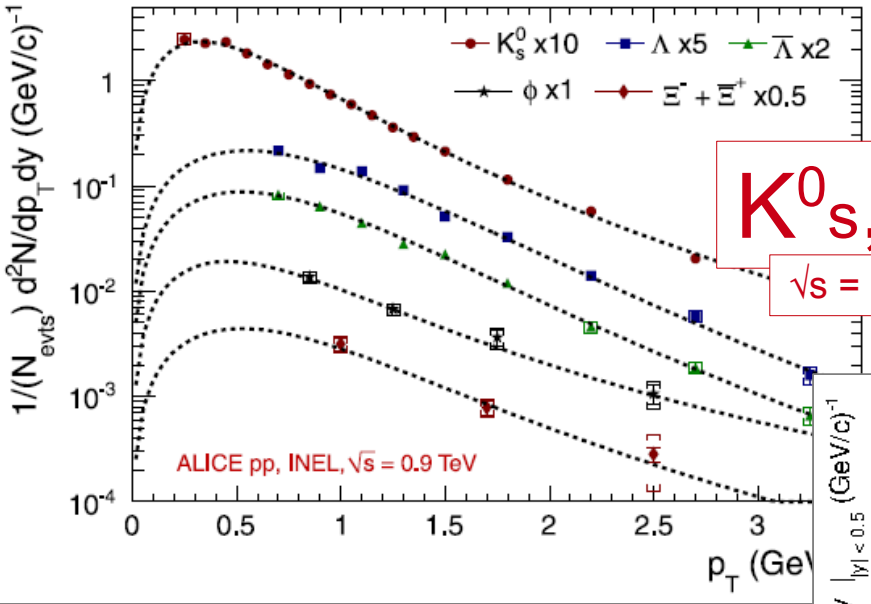
(AA/pp yields, « baryon/meson » ratio, ...)

→ *elliptic flow* v_2

IV. Conclusion, Prospects

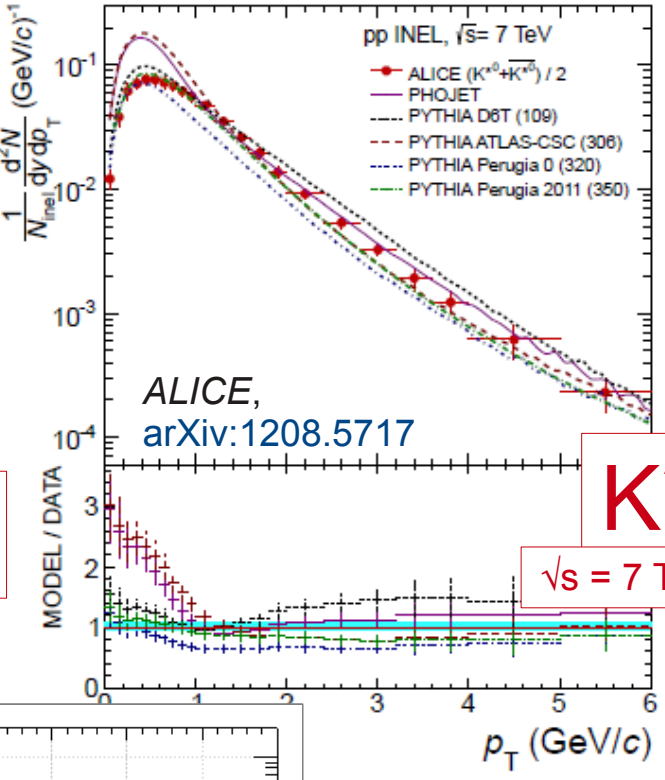
I.1 – pp : various spectra

ALICE, 10.1140/epjc/s10052-011-1594-5



K^0_s, φ, Λ, $\bar{\Lambda}$, $\Xi^{\pm}$

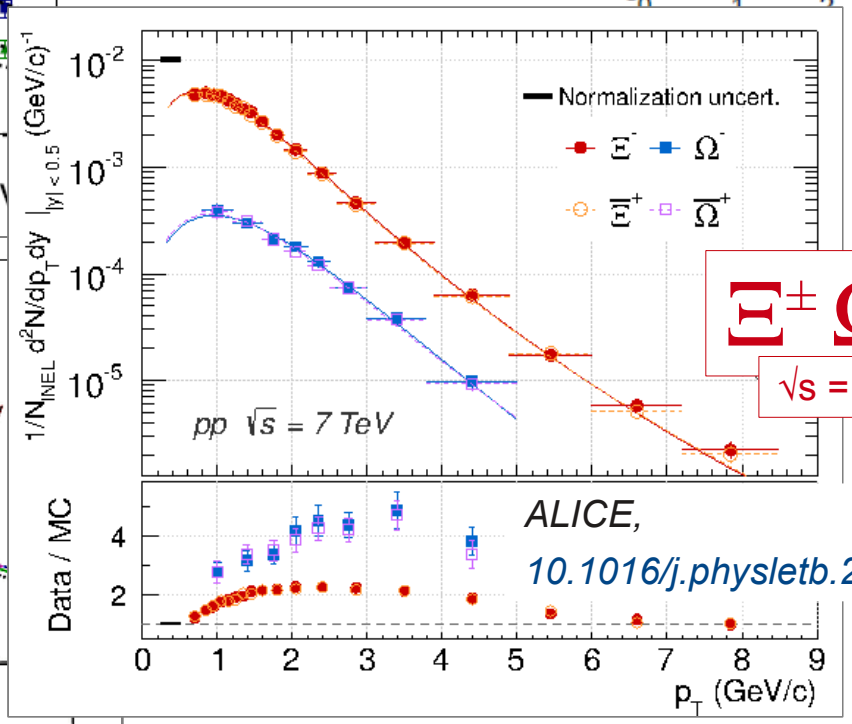
√s = 0.9 TeV



ALICE,
arXiv:1208.5717

K*

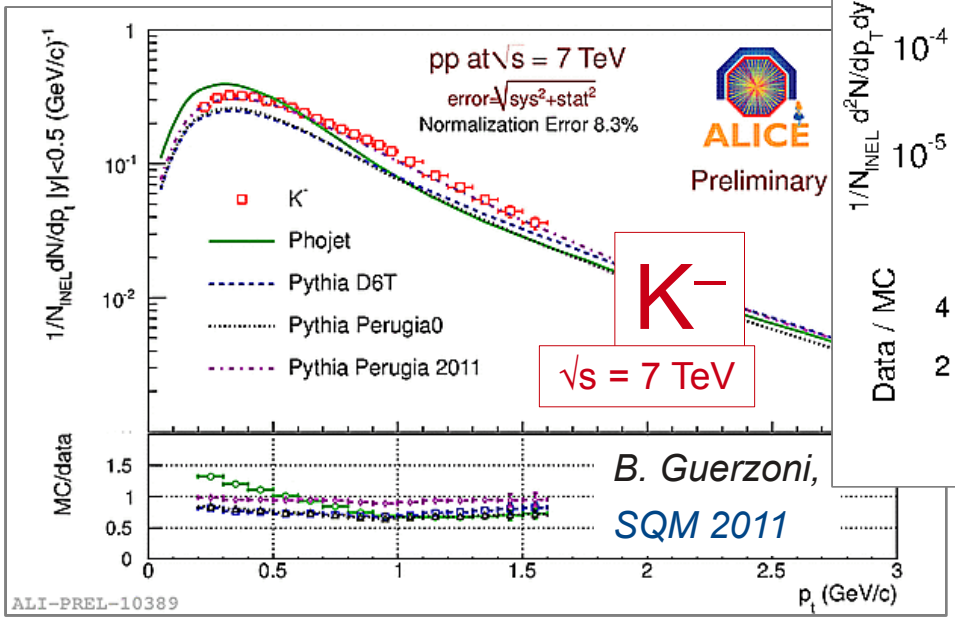
√s = 7 TeV



$\Xi^{\pm}$ $\Omega^{\pm}$

√s = 7 TeV

ALICE,
10.1016/j.physletb.2012.05.011



K⁻

√s = 7 TeV

B. Guerzoni,
SQM 2011

Examples of p_T spectra

I.2 – pp : comparison to pheno. models

- Interest of strangeness for MC models

  1. Extra constraints, with identified particle beyond π,K,p …

  2. Strange hadrons measurable over a rather wide range of p_T.

  = from low p_T (< 3 GeV/*c*) to high p_T (> 6 GeV/*c*)

  → understand the **soft part** of the event + its interplay with the **hard part**, and this way, constrain (strangeness) production mechanisms

- Current MC performances

  Heterogeneous outcome...

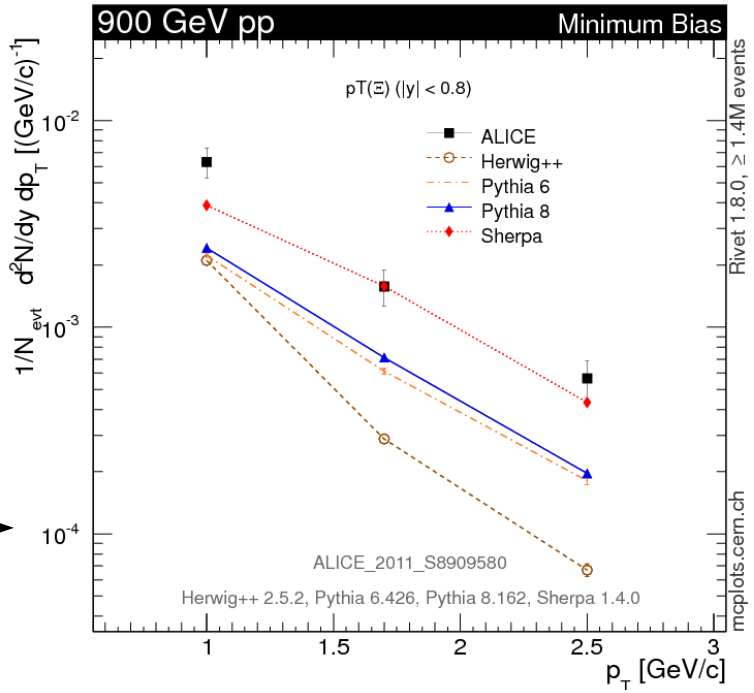
  e.g. PYTHIA Perugia 2011 (P2011) :

  a) for $K^{\pm}$: agreement data/P2011 within 10 % !

  b) for $\Omega^{\pm}$: discrepancy data/P2011~ factor 5...

- Prospects

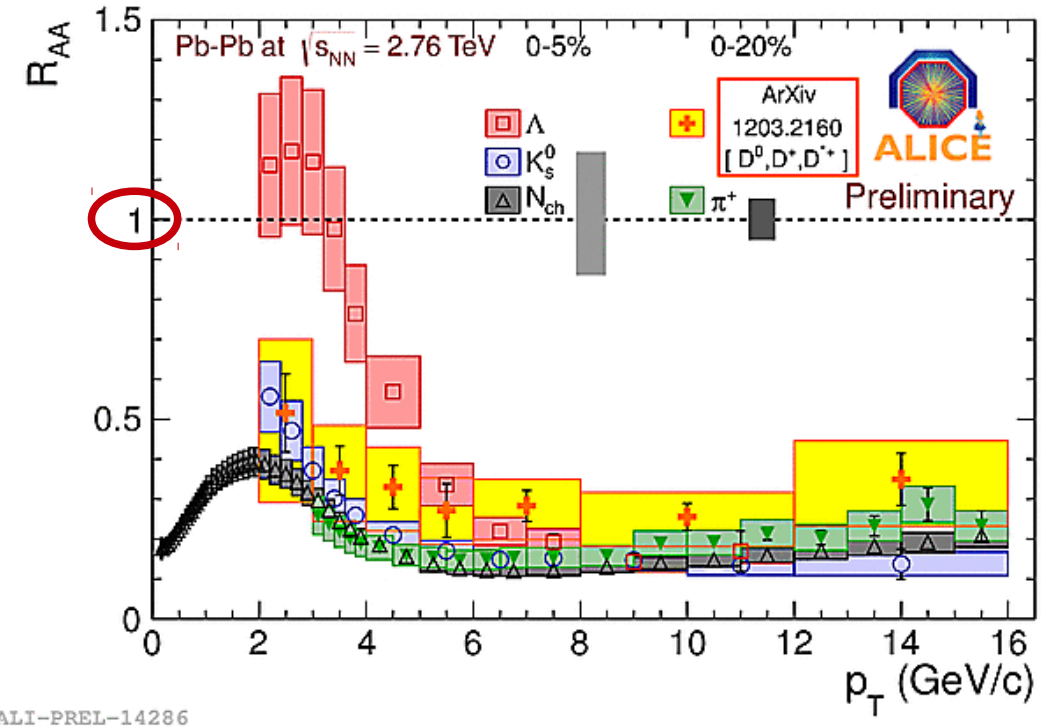
  Improvements expected in the coming years, with systematic consideration of data (Rivet, Professor + MC plots)



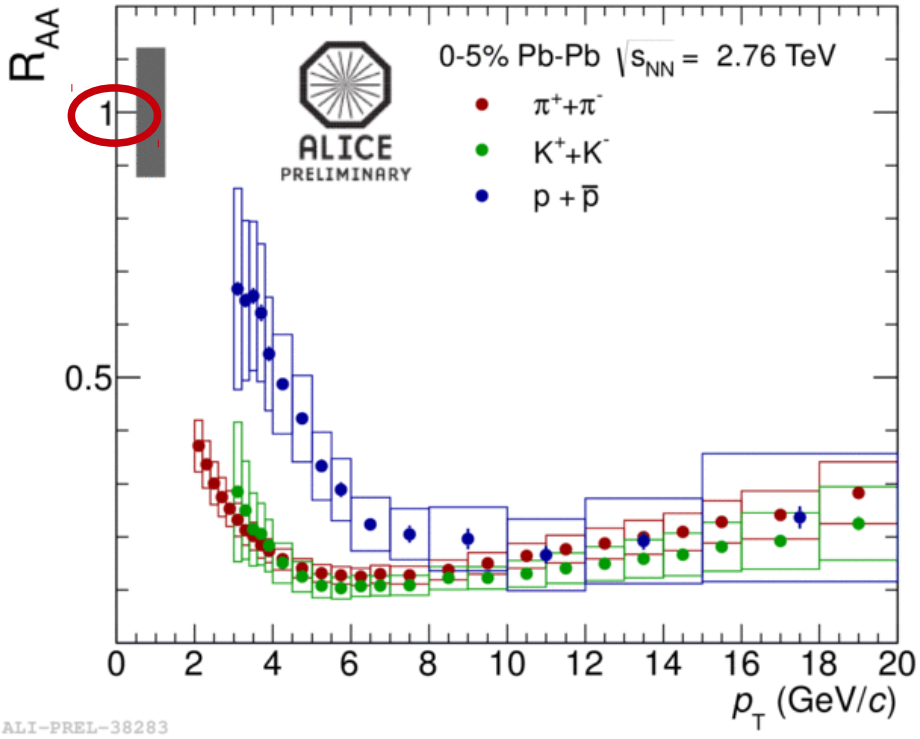
II.1 – Pb-Pb : R_{AA} = f(p_T) for $K^{\pm}$, K^0s, Λ

Nuclear modification factor : $$R_{AA}^{\Lambda}(p_T) = \frac{d^2 N_{AA}(\Lambda)/dp_T\,dy/\langle N_{PART}\rangle}{d^2 N_{pp}(\Lambda)/dp_T\,dy/2}$$

B. Hippolyte, SQM 2011



A. Ortiz, QM2012

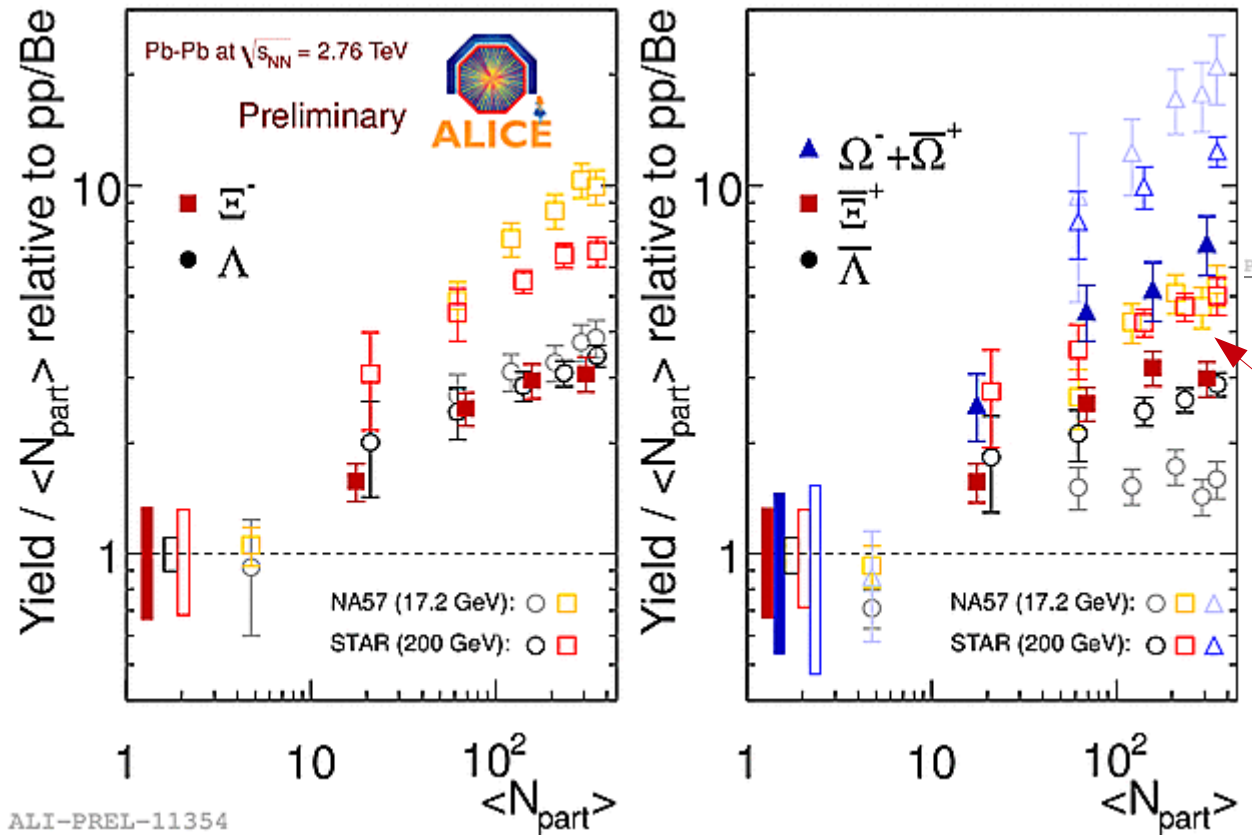


- From 7 GeV/*c* on, looks like any hadron experiences ~ the same suppression, independently of its nature.
- Note the similar trend for p and Λ for p_T < 7 GeV/*c*.

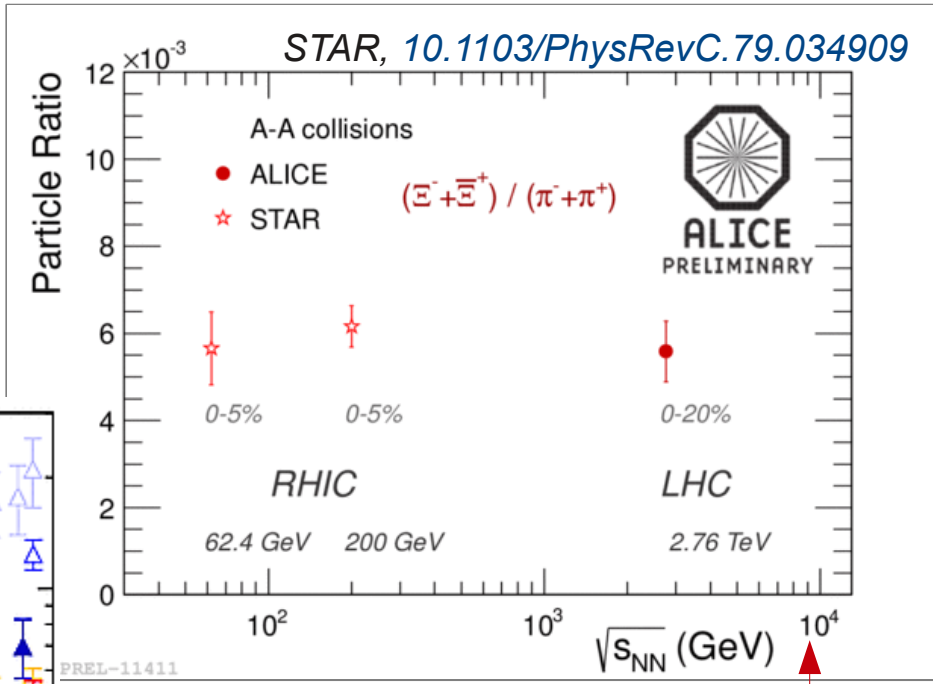
II.2 – Pb-Pb : « strangeness enhancement »

Enhancement : $E_i(\Xi) = \dfrac{dN_{AA}(\Xi)/dy/\langle N_{PART}\rangle}{dN_{pp}(\Xi)/dy/2}$

M. Nicassio, SQM 2011



STAR, 10.1103/PhysRevC.79.034909

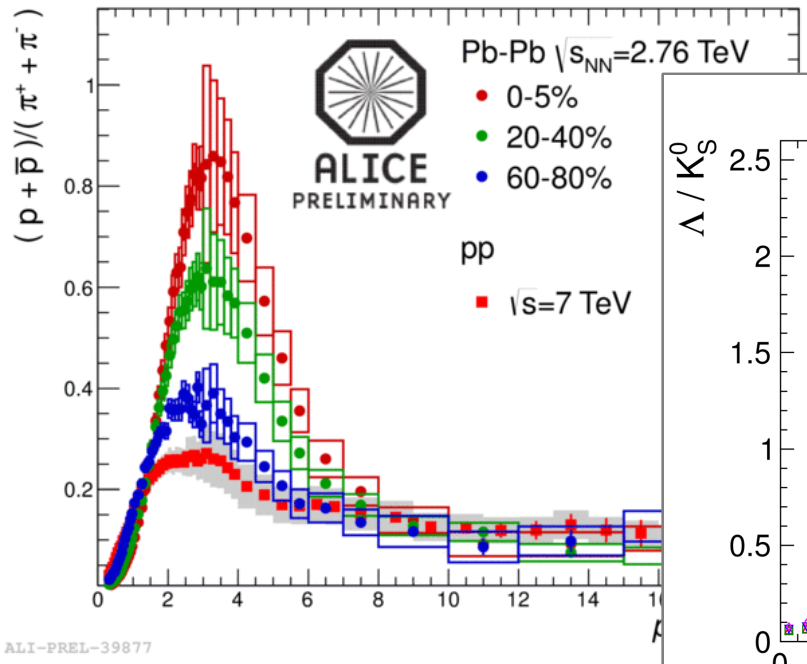


"Strangeness enhancement" decreases from SPS to LHC...

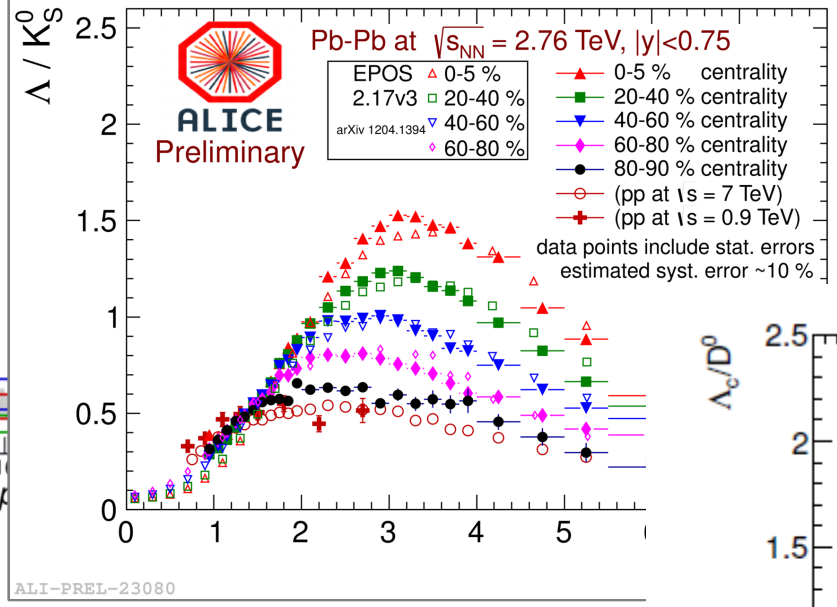
While relative d*N* /d*y* in AA stays ~constant from RHIC to LHC → the pp production baseline may change ...

II.3 – Pb-Pb : baryon to meson ratios

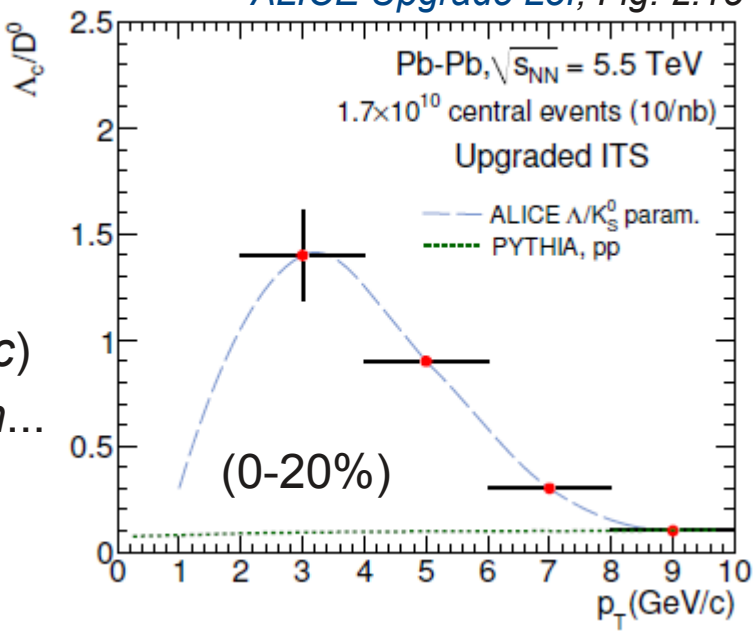
A.Ortiz, QM2012



I. Belikov, QM2011
+ K. Werner, 10.1103/PhysRevLett.109.102301



ALICE Upgrade LoI, Fig. 2.15



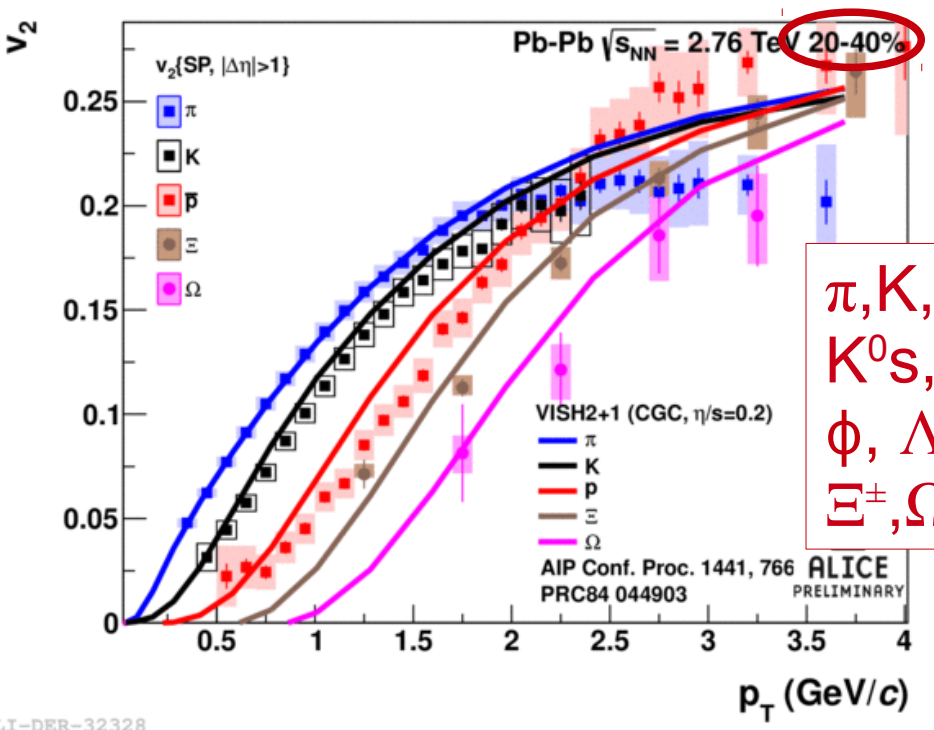
Increase of baryon/meson ratios at intermediate p_T (2-6 GeV/*c*)
= seen for *light flavours,* seen for *strangeness* Wait for *charm*...

Explanation ?

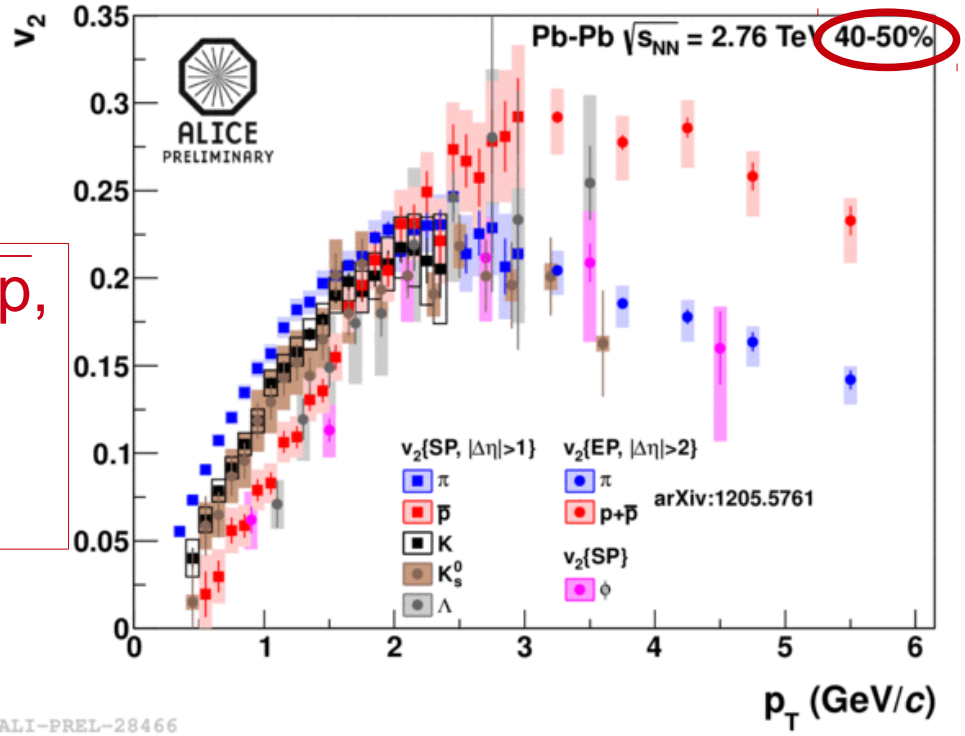
- flow (AMPT),
- recombination (*Fries et al*),
- interplay between flow and jets (EPOS)

II.4 – Pb-Pb : elliptic flow, v_2

Z. Yin, ISMD2012
Y. Zhou, poster QM2012
F. Noferini, QM2012



π,K,p,p̄,
K^0s,
ϕ, Λ,
$\Xi^{\pm}$,$\Omega^{\pm}$



1. **Mass splitting** in $v_2 = f(p_T)$:

« the heavier the particle is, the higher the shift towards high p_T will be. »

2. Compared to **STAR data** at $\sqrt{s_{NN}}$ = 200 GeV, stronger radial flow at LHC energies

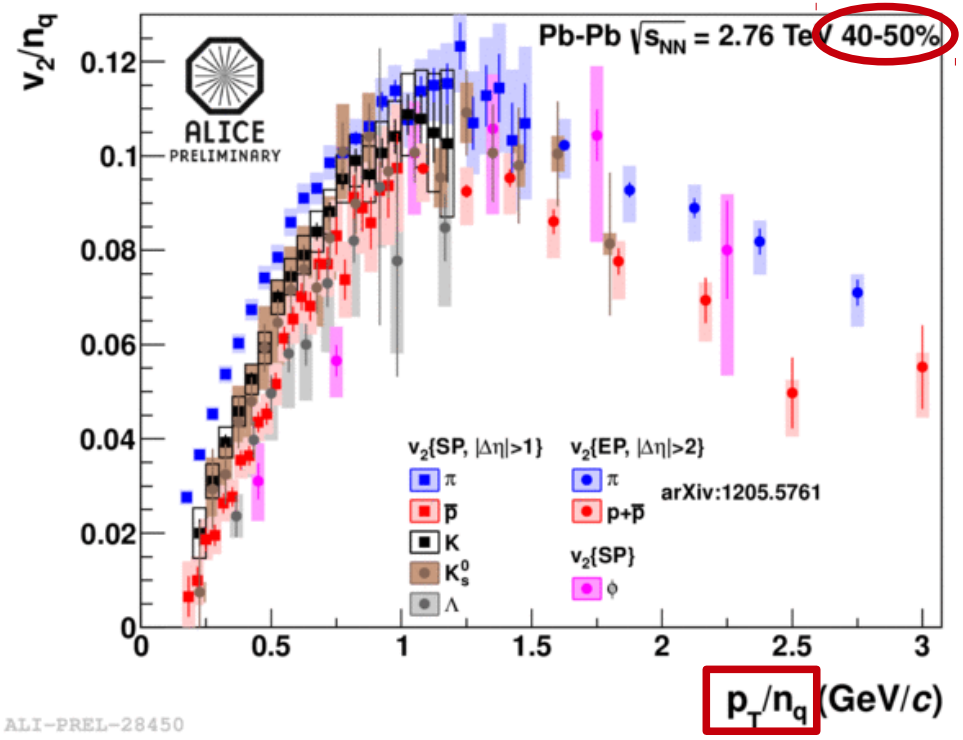
→ shift towards higher p_T + higher max(v_2) values

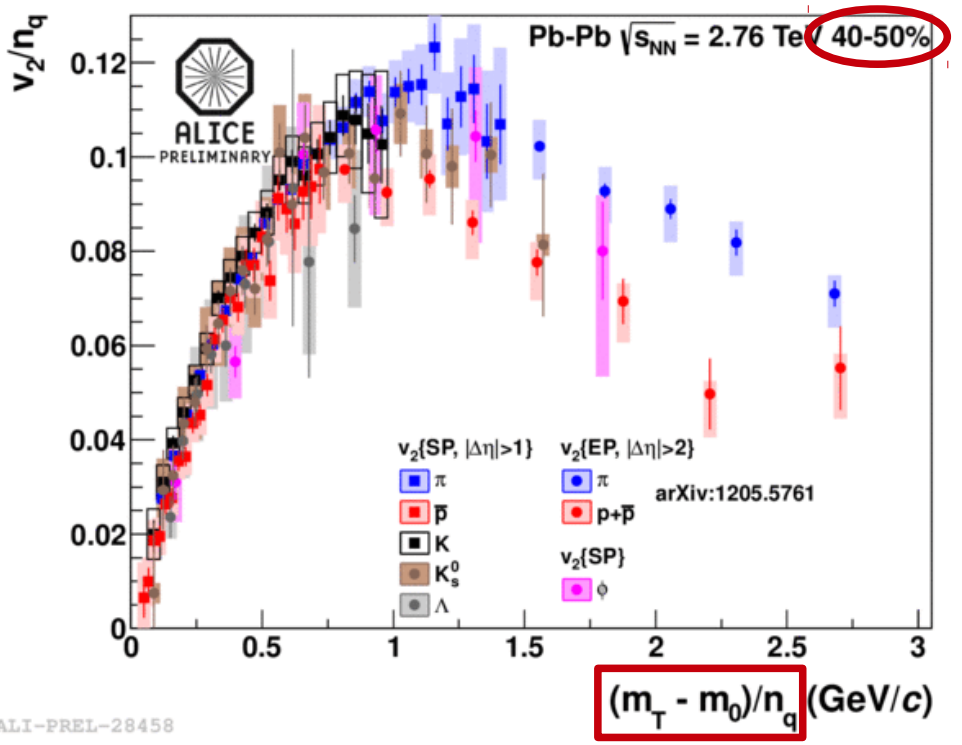
II.5 – Pb-Pb : elliptic flow and quark scaling

Z. Yin, ISMD2012

Y. Zhou, poster QM2012

F. Noferini, QM2012





1. Constituent quark scaling or not ?

→ $v_2/n_q = f(p_T/n_q)$ or $v_2/n_q = f([m_T - m_0]/n_q)$

Current conclusion :

at LHC energies, if such a scaling holds, only valid **within 20%**

Conclusions and Prospects

- Conclusions : ALICE measurements related to strangeness = advanced :
  from $K^{\pm}$ to Ω^{-} via D^{+}_{S} and anti-hypertriton...

  The key question : similar behaviour in medium for light to heavy flavours ?
  s quarks = in the middle of the picture *u,d,s,c,b* (bare mass)...

- Prospects :

  → push forward more differential analyses ...
  Will we close the historical studies related to :
  - strangeness enhancement ?
  - baryon to meson anomaly ?
  - quark scaling in flow ?

  (profiting from RHIC Beam Energy Scan + LHC programme)

  p-Pb : - $d^2N/dp_T dy$ measurements seem within reach (pA run 2013...)

  pp : - multiplicity dependence in production, e.g. $dN/dy(\Xi) = f(p_T, dN_{ch}/d\eta)$

  pp/Pb-Pb : - multiplicity dependence in correlations ($\Xi,\Omega - h^{\pm}$) or ($\phi - h^{\pm}$)
  - strangeness in jets/in UE in Pb-Pb (fragmentation function in medium)

Appendices

A. Strangeness measured by ATLAS, CMS, LHCb

B. Further ALICE results on strangeness

A.1 – pp : ATLAS, CMS, LHCb and strangeness

Some input available only in pp.
There is nothing that
I could spot in Pb-Pb...

- **ATLAS :** K^0s, Λ, $\overline{\Lambda}$ yields
  in pp collisions at $\sqrt{s}$ = 0.9 and 7 TeV
  10.1103/PhysRevD.85.012001

- **CMS :** K^0s, $(\Lambda + \overline{\Lambda})$, $(\Xi^- + \overline{\Xi}^+)$ yields
  in pp collisions at $\sqrt{s}$ = 0.9 and 7 TeV
  10.1007/JHEP05(2011)064

- **CMS :** π,K,p yields
  in pp collisions at $\sqrt{s}$ = 0.9, 2.76, 7 TeV,
  at low p_T (< 1-1.7 GeV/*c*)
  arxiv:1207.4724 (submitted to EPJC)

- **LHCb :** K^0s production cross-section
  in pp collisions at $\sqrt{s}$ = 0.9 TeV
  10.1016/j.physletb.2010.08.055

- **LHCb :** K^0s, Λ, $\overline{\Lambda}$ particle ratios
  in pp collisions at $\sqrt{s}$ = 0.9 and 7 TeV
  10.1007/JHEP08(2011)034

- **LHCb :** $\phi(1020)$ production cross-section
  in pp collisions at $\sqrt{s}$ = 7 TeV
  10.1016/j.physletb.2011.08.017

- **LHCb :** π,K,p particle ratios
  in pp collisions at $\sqrt{s}$ = 0.9 and 7 TeV
  arxiv:1206.5160 (submitted to EPJC)

B.1 – further ALICE results : ...

- **Bose-Einstein correlations**
  1) $K_{ch}K_{ch}$, K^0s-K^0s in pp and Pb-Pb
     = Matthew Steinpreis, poster QM2012

  2) p-Λ, p-$\bar{p}$, Λ-$\bar{\Lambda}$
     = Jai Salzwedel, poster QM2012

  3) Summary
     = Maciej Szymanski, talk QM2012

- **Anti-baryon / baryon ratios** ($\bar{p}/p$, $\bar{\Lambda}/\Lambda$, $\bar{\Xi}^+/\Xi^-$)
  = Michal Broz, talk QM2012

- **Hypermatter + exotic strange bound states** (hypertriton, $\Lambda\Lambda$ di-baryon)
  = Benjamin Doenigus, talk QM2012

- **Resonances in pp** ($\phi(1020)$, $\Sigma(1385)^-$, $\Sigma(1385)^+$, $\Lambda(1520)$, $\Xi(1530)^0$)
  = Dhevan Gangadharan, talk SQM 2011