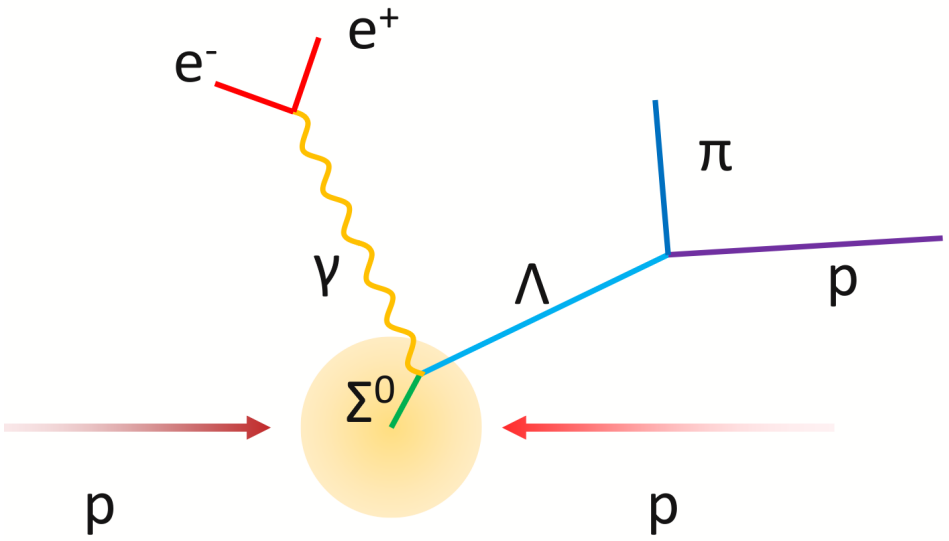
Σ^0 production at LHC with ALICE and search of the new nucleus Σ^0-hypertriton



A.Borissov, Dolgoprudny, MIPT, 10.10.2019

Resonances

A resonance is the peak located around a certain energy found in differential cross sections of scattering experiments (Wikipedia). baryons, upsilon mesons) and their excitations. The width of the resonance (Γ) is related to its lifetime (τ) by the relation $\Gamma = \frac{\hbar}{\tau}$, where $\hbar = \frac{h}{2\pi}$.

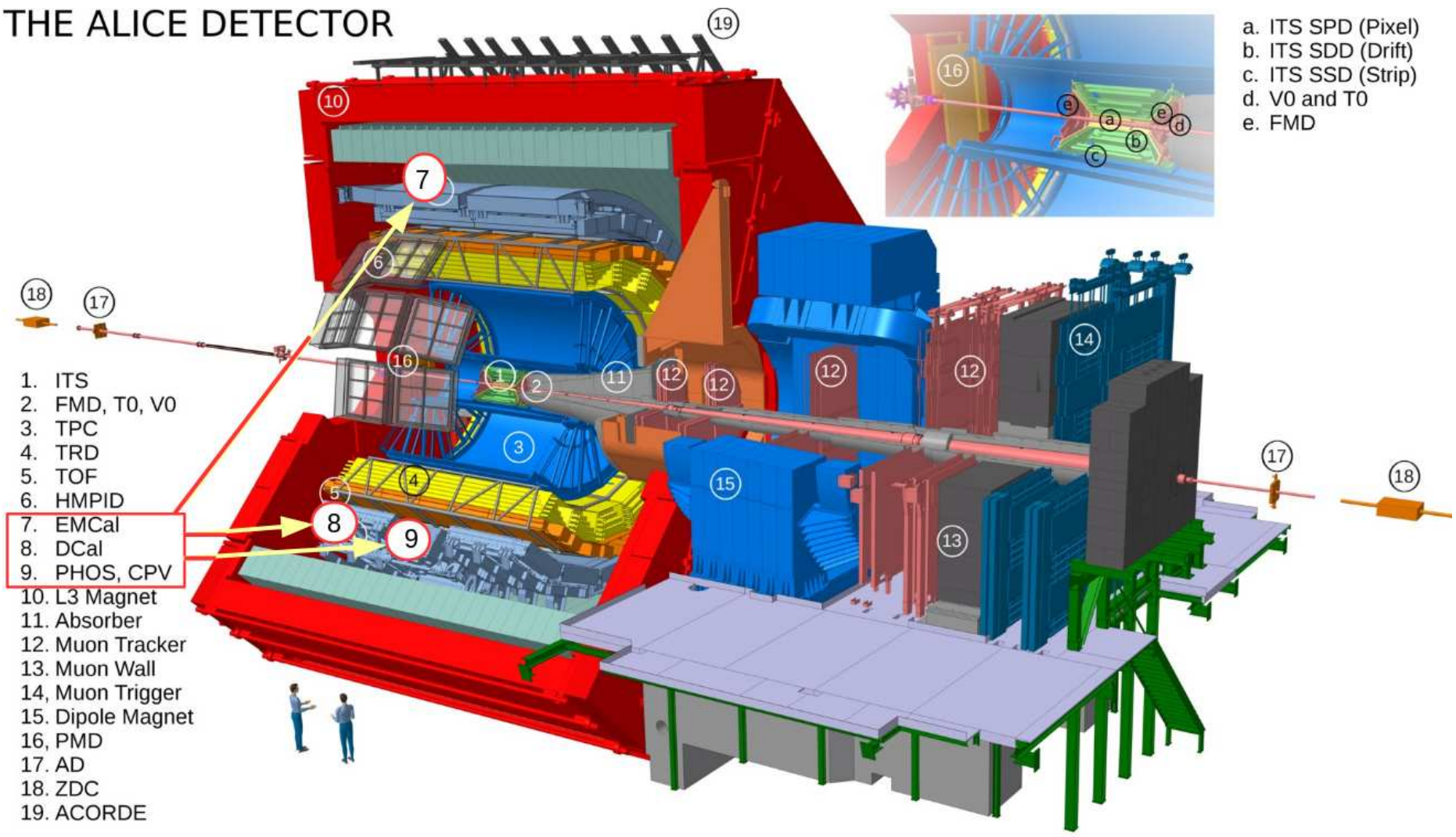
PDG parameters of studied hadronic resonances and ground states

Particle	Quarks	Mass (MeV/c^2)	Width (MeV/c^2)	Lifetime (fm/c)	Decay*	Branching ratio (%)
ρ^0	$(u\bar{u} + d\bar{d})/\sqrt{2}$	770	150	1.3	$\pi^+\pi^-$	100
K^{*0}	$d\bar{s}$	896	47.4	4.17	π^-K^+	66.7
ϕ	$s\bar{s}$	1019	4.27	46.2	K^-K^+	48.9
p	uud	1007.2764	0	inf.	no	no
Λ	uds	1115	~ 0	7.89 cm	p+π^- (1)	63.9
$\Lambda(1520)$	uds	1520	15.7	12.6	K^-p	22
Σ^0	uds	1192	~ 0	22 200	$\Lambda + \gamma$ (2)	100
$\Sigma(1385)^+$	uus	1383	36.0	5.51	$\Lambda + \pi^+$	87.0
$\Sigma(1385)^-$	dds	1387	39.4	5.01	$\Lambda + \pi^-$	87.0
Ξ^-	dds	1321	~ 0	4.91 cm	$\Lambda + \pi^-$ (1)	99.9
$\Xi(1530)^0$	uss	1532	9.1	21.7	$\Xi^- + \pi^+$	42.6

*Decay: strong if no label, 1 - weak, 2 - electromagnetic

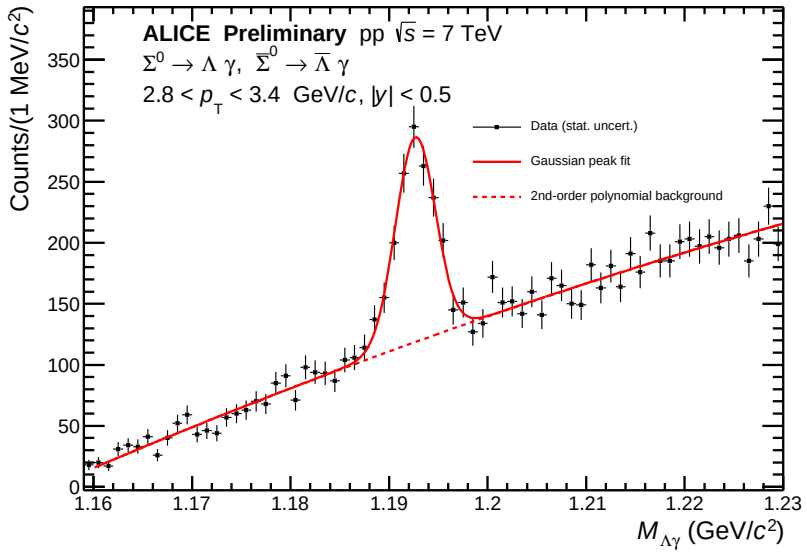
Measured in pp (0.9, 2.76, 5.02, 7.0, 8.0, 13.0 TeV), p-Pb (5.02 TeV), and Pb-Pb (2.76, 5.02 TeV) collisions at ALICE

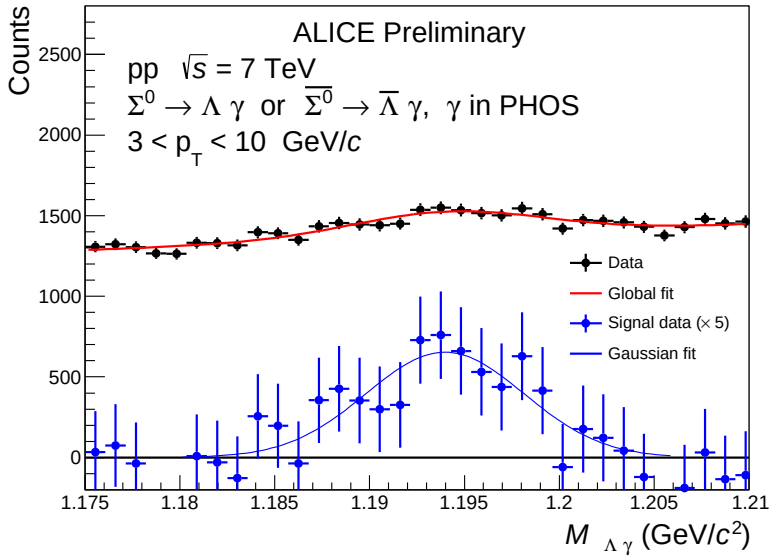
The ALICE detector in LHC runs 1 and 2



ITS and TPC and used for the reconstruction of the decay products of resonances.
Unique particle identification, high granularity, tracking down to p_{T} 0.1 GeV/c.
Total size of ALICE 16× 26 meters, weight $\sim$ 10000 tons.

$\Sigma^0 \to \Lambda + \gamma$ and $\bar{\Sigma}^0 \to \bar{\Lambda} + \gamma$ decays





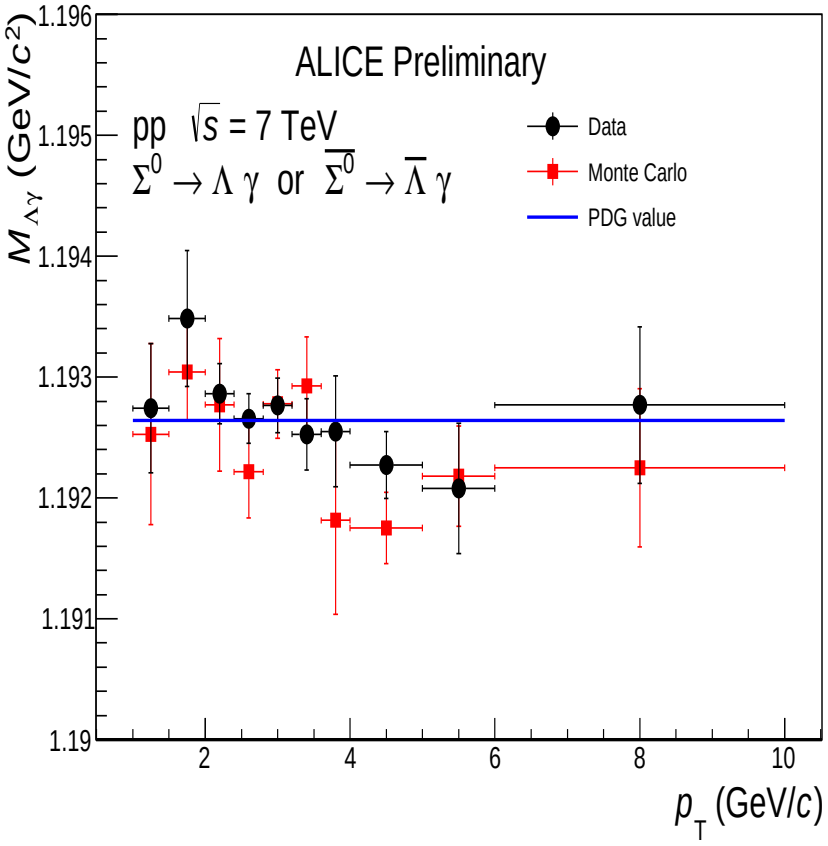
- Σ^0 invariant mass is calculated from the mass of the selected Λ and γ candidates. Note low $E_\gamma \approx 300$ MeV.

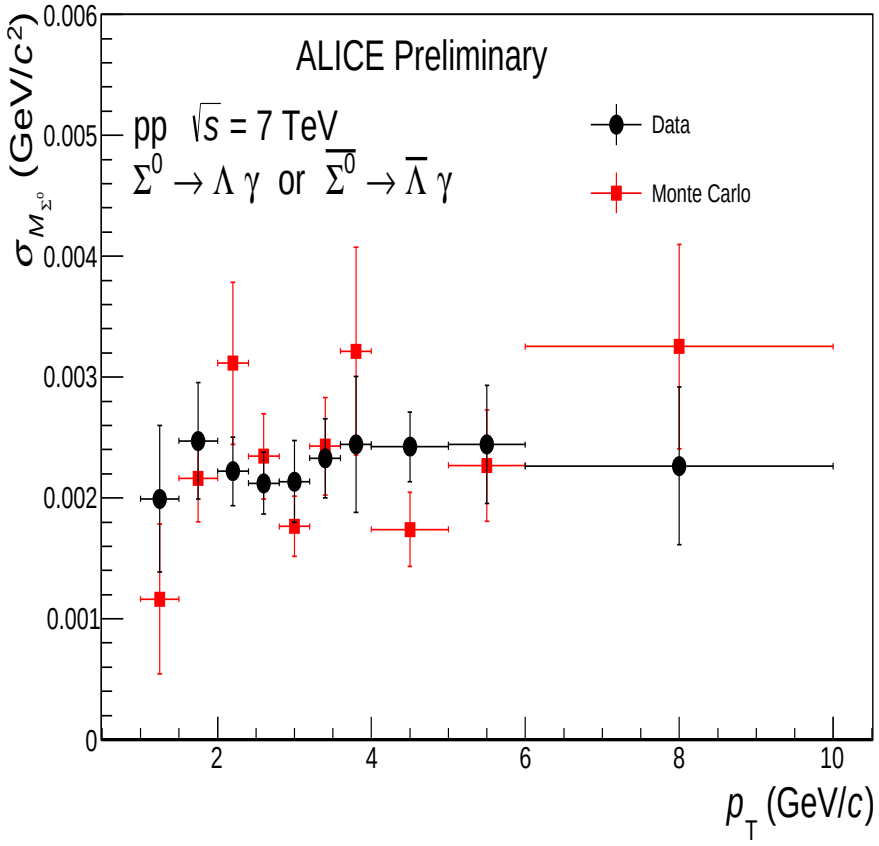
  $\Longrightarrow$ Clean Σ^0 invariant mass peak.

- Proof-of-principle: Σ^0 peak is also observed with photon detected in PHOS calorimeter, but with worse mass resolution.

- No Σ^0 invariant mass peak observed with photon in EMCAL due to the noise and resolution

Σ^0 mass and width



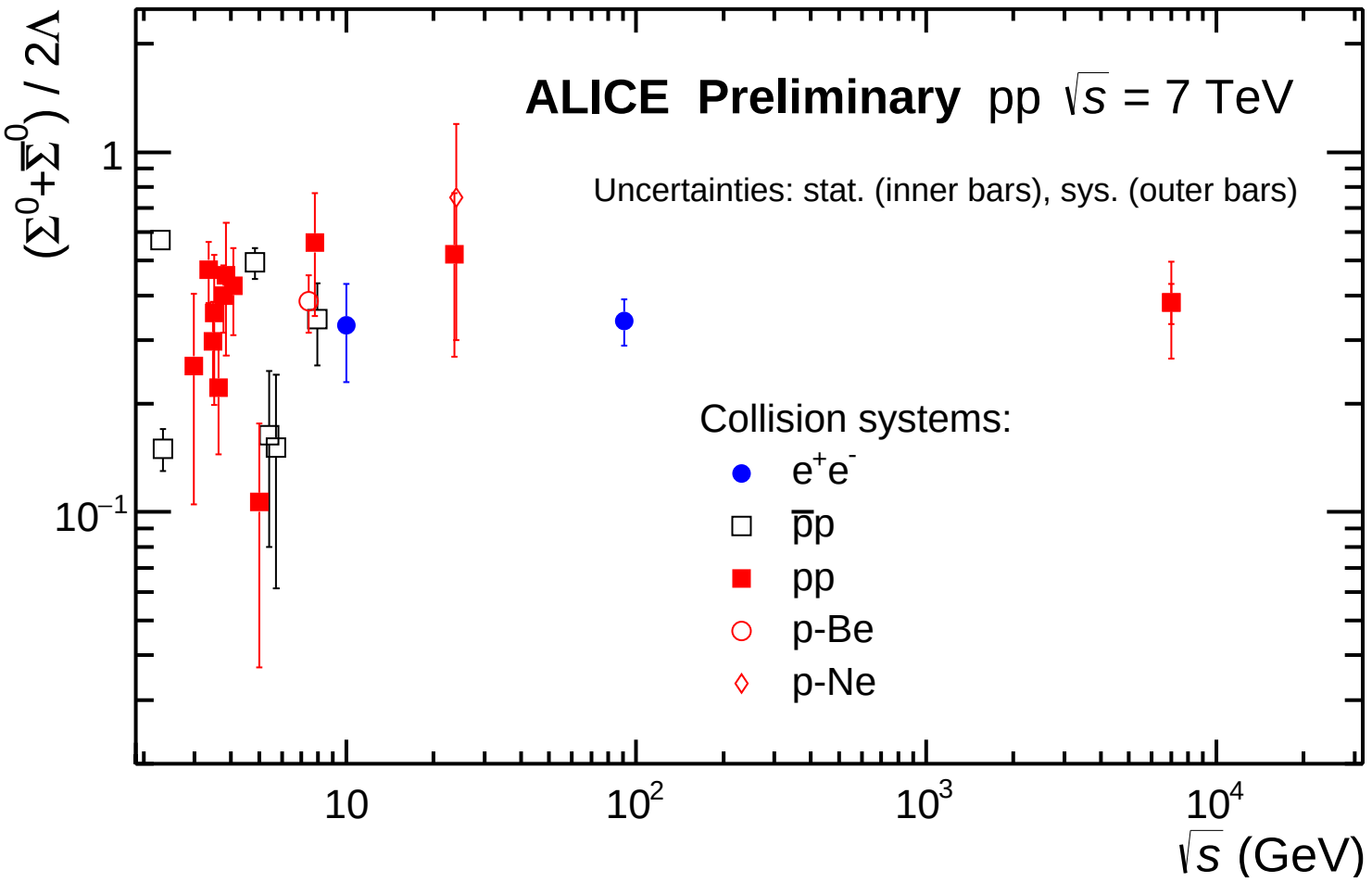


$\Longrightarrow$ Reconstructed peak position is in good agreement with the PDG value.
PDG: $\Sigma^{0PDG} = 1192.642 \pm 0.024$ MeV

The Σ^0 mass resolution is determined only by the detector resolution due to the long lifetime of the Σ^0 and is in agreement with the simulations

$\Longrightarrow$ Σ^0 mass resolution $\sigma_M^{PCM} = 2$ MeV at $2.8 < p < 3.4$ GeV/c

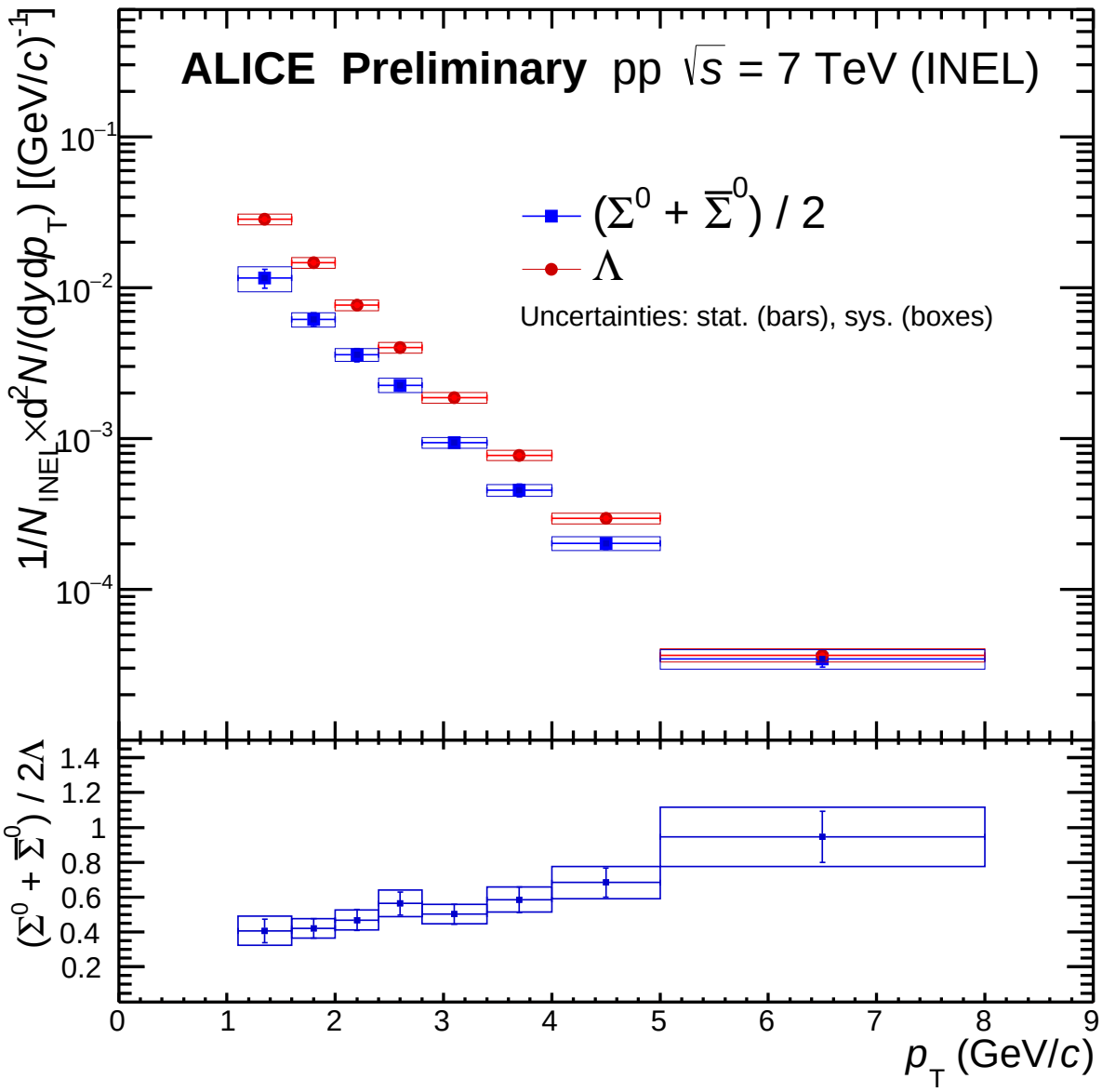
ALICE measurement and world data → new point



- First measurement at LHC of $\frac{\Sigma^0}{\Lambda}$ cross section ratio complements world data from lower energies, including pp collisions at $\sqrt{s} \approx 10$ GeV

- e^+e^- data at $\sqrt{s} = 91$ GeV from L3 at LEP reported $\frac{\Sigma^0}{\Lambda} = 0.33 \pm 0.03$, where both Σ^0 and Λ were detected in hadronic Z decays

p_{T} -differential $(\Sigma^0 + \bar{\Sigma}^0)/2\Lambda$ ratio



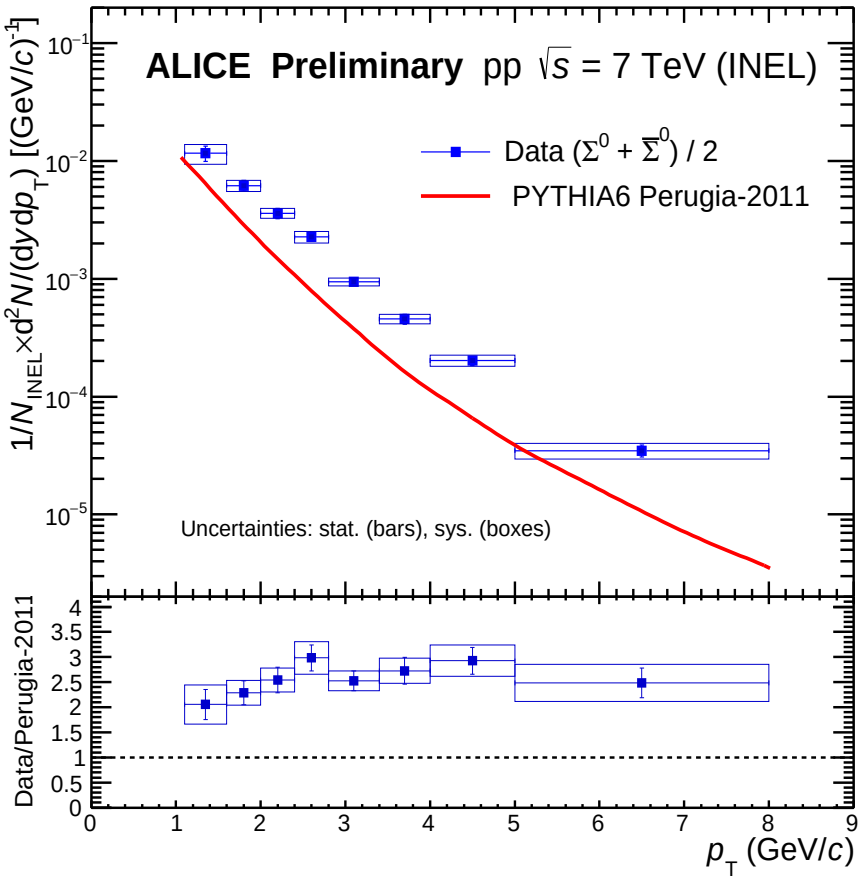
$\Longrightarrow$ NEW: Increasing trend of the $(\Sigma^0 + \bar{\Sigma}^0)/2\Lambda$ ratio with p_{T}

Indication on different contributions of primordial and final Σ^0 and Λ production.

$\Longrightarrow$ More data are needed! LHC run II data are under analysis.

Σ^0 and Λ vs PYTHIA6

(D.D.Chinellato arXiv:1211.7298 [hep-ex])



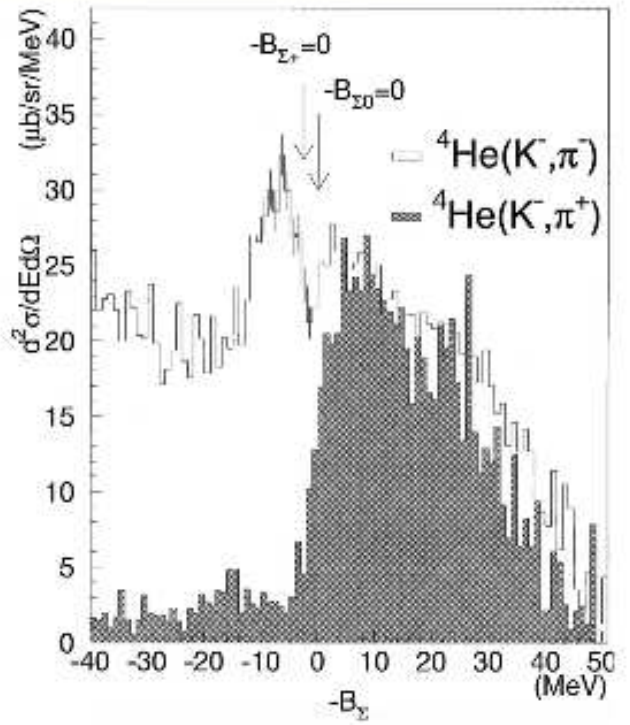
$\Longrightarrow$ PYTHIA6 Perugia-2011 clearly underestimates the production of both ground-state hyperons in the intermediate p_{T} -range

$\Longrightarrow$ Further investigations are very interesting and more students needed!

Search of the NEW nucleus ${}^{3}_{\Sigma^0}\mathrm{H} = (\mathrm{p}, \mathrm{n}, \Sigma^0)$ in LHC runs 3 & 4 (2021–2026)

on the base of the strategy of Σ^0 and ${}^{3}_{\Lambda}\mathrm{H} = (\mathrm{p}, \mathrm{n}, \Lambda)$ detection in LHC runs 1 and 2

Scarce data indicate hypernucleus ${}^{4}_{\Sigma^0}\mathrm{He}$



T. Nagae et al., PRL 80 (1998), 1605.

$\Longrightarrow$ Large statistics for ${}^{3}_{\Lambda}\mathrm{H}$ $({}^{3}_{\overline{\Lambda}}\overline{\mathrm{H}})$ for LHC runs 3 & 4

LHC Report "Future physics opportunities for high-density QCD at the LHC with heavy-ion and proton beams", arXiv:1812.06772


Σ^0

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