Resonance and low-mass vector meson production in ALICE

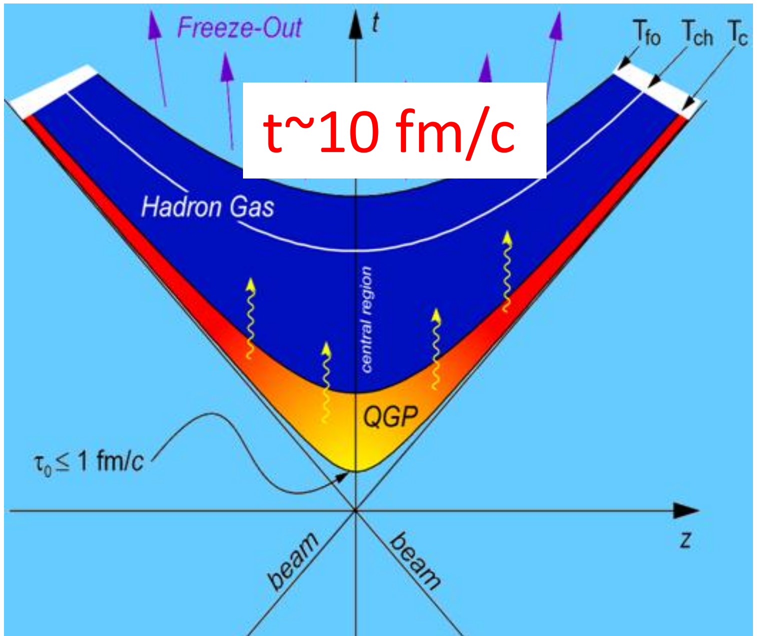
A. Badalà – INFN Sezione di Catania
for the ALICE collaboration

- *Introduction and ALICE performances*
- *Resonances identified by their hadronic decay channel in pp collisions ($\sqrt{s_{NN}}$= 0.9 and 7 TeV)*
- *Resonances identified by their leptonic decay channel in pp collisions ($\sqrt{s_{NN}}$=2.76 and 7 TeV)*
- *Resonance results in Pb-Pb ($\sqrt{s_{NN}}$ =2.76 TeV)*
- *Conclusions and Prospects*

Resonances in heavy-ion collisions

Resonances have lifetimes of about a few tens fm/c $\rightarrow \tau_{resonance} \sim \tau_{fireball}$

	Mass (MeV/c^2)	Width (MeV/c^2)	cτ(fm)	Decay
ρ(770)	770	150.7	1.3	ππ/μμ
φ(1020)	1019	4.26	46	K K/μμ
$\Sigma(1385)^{\pm}$	1385	~33	6	Λ π
$\Xi(1530)^0$	1530	9	22	Ξ π



Space-time evolution of ultrarelativistic heavy ion collision

Resonances may give informations on the nuclear matter dynamics and chiral properties

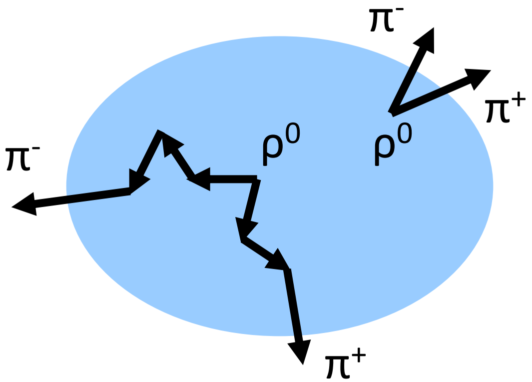
Regeneration and rescattering effects→Timescale chemical-kinetic freeze-out

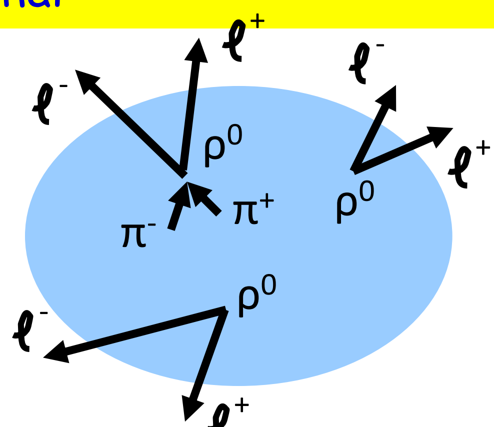
Modification of width, mass and branching ratio

Resonances and chiral symmetry

To study chiral symmetry restoration in terms of mass shift and width broadening, resonance decays from the early stage of the medium need to be extracted

The best probes are resonances reconstructed by their leptonic decay channel since leptons are less likely to rescatter in the hadronic medium. However regenerated resonances from the late hadronic phase feed down into this signal





Hadronic decay channel probes late stages of the collision

Leptonic decay channel probes all stages of the collision

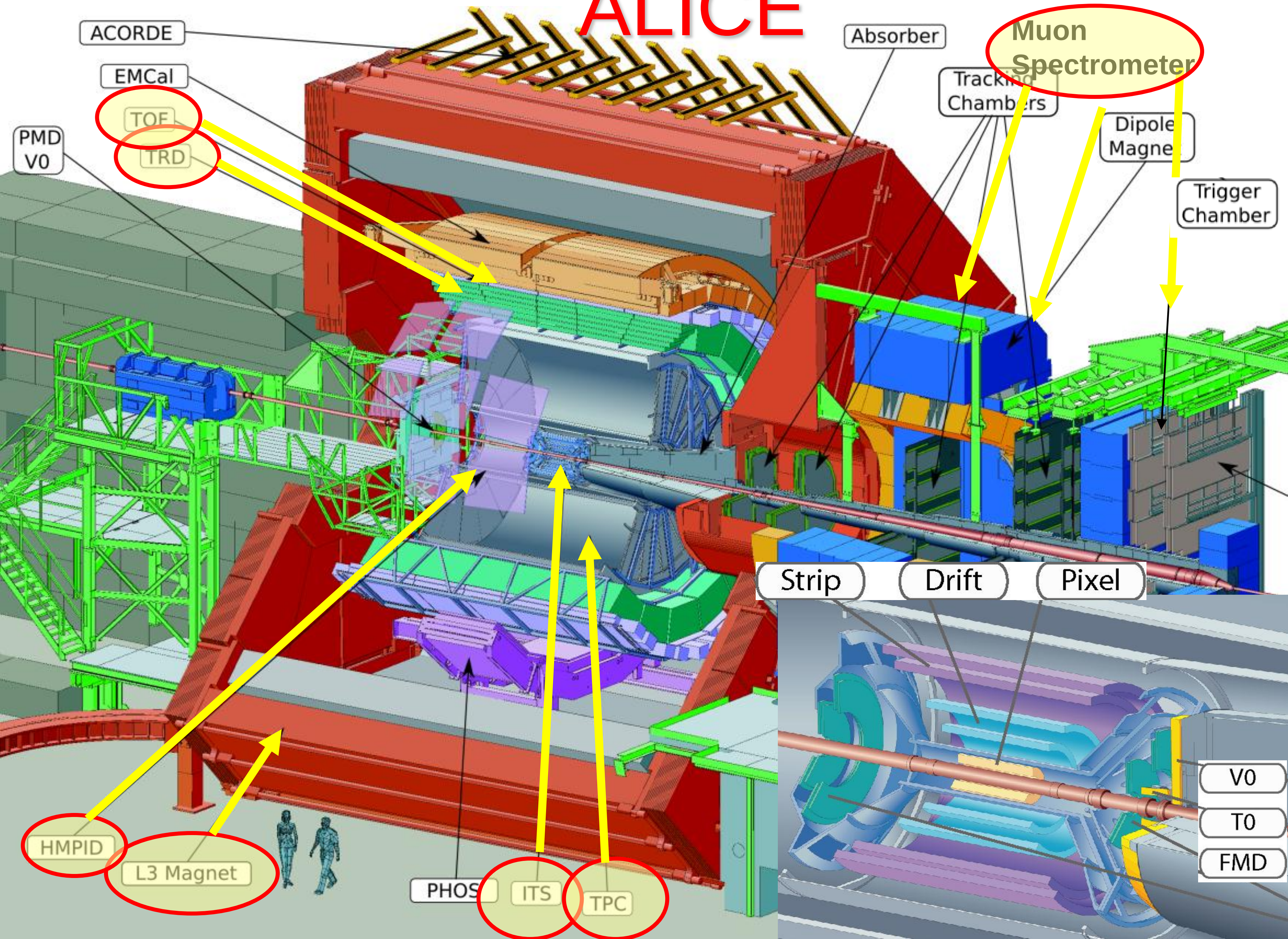
Resonances in pp collisions

Decay of resonances →large fraction of the final-state particles→ early step in understanding pp collisions at LHC, i.e. opportunity to test QCD in a new energy domain

In general, resonance production in pp collisions helps in

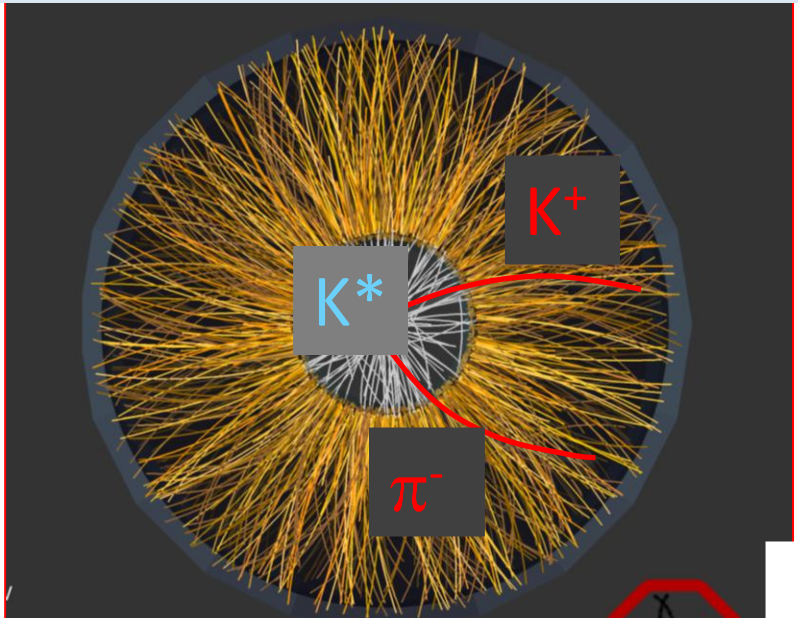
- establishing the underlying event structure and the baseline for heavy-ion collisions
- constraining QCD-inspired models (PYTHIA, PHOJET,etc…)
- understanding hadronic production processes
- strangeness production is accessed via strange resonance production

ALICE


ACORDE
EMCal
TOF
TRD
PMD
V0
Absorber
Muon Spectrometer
Tracking Chambers
Dipole Magnet
Trigger Chamber
Strip
Drift
Pixel
V0
T0
FMD
HMPID
L3 Magnet
PHOS
ITS
TPC

Resonance reconstruction

Reconstruction based on *primary* tracks or particles (cut on DCA)

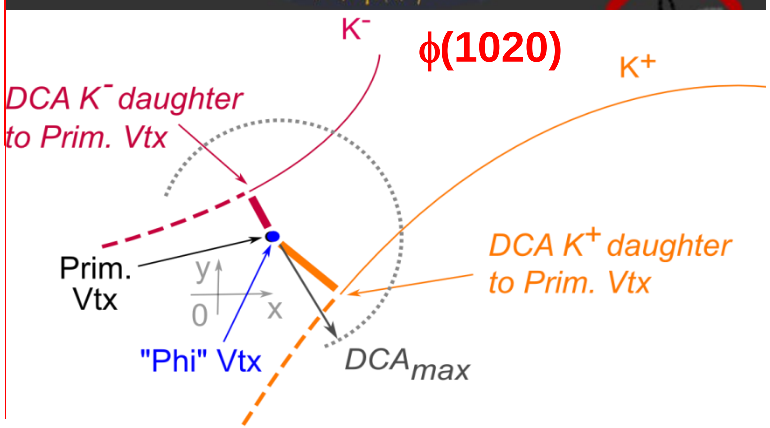


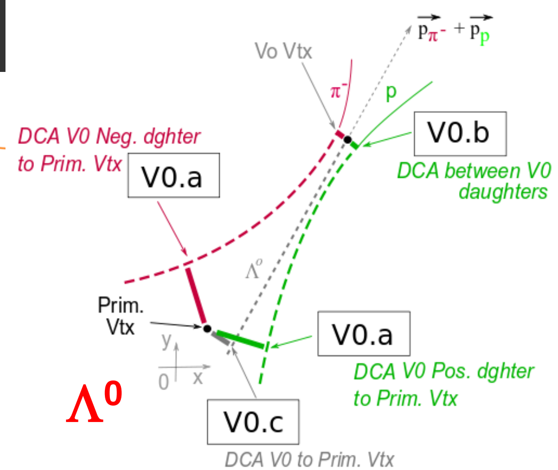
π, K, p identified via *PID detectors (ITS, TPC, TOF)*

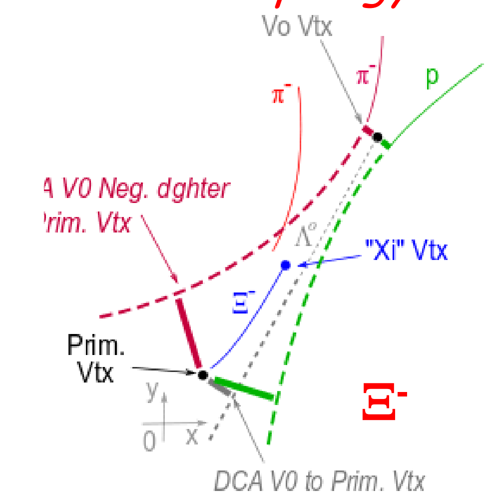
$K(892)^0$	$\rightarrow \pi^- + K^+$
$\phi(1020)$	$\rightarrow K^+ + K^-$
$\Sigma(1385)^\pm$	$\rightarrow \Lambda^0 + \pi^\pm$
$\Xi(1530)^0$	$\rightarrow \Xi^- + \pi^+$

Λ identified by *secondary* tracks, with opposite charges, within a fiducial volume, + "*V0 topology*"

Ξ identified by three *secondary* tracks, within a fiducial volume, + "*Cascade topology*"

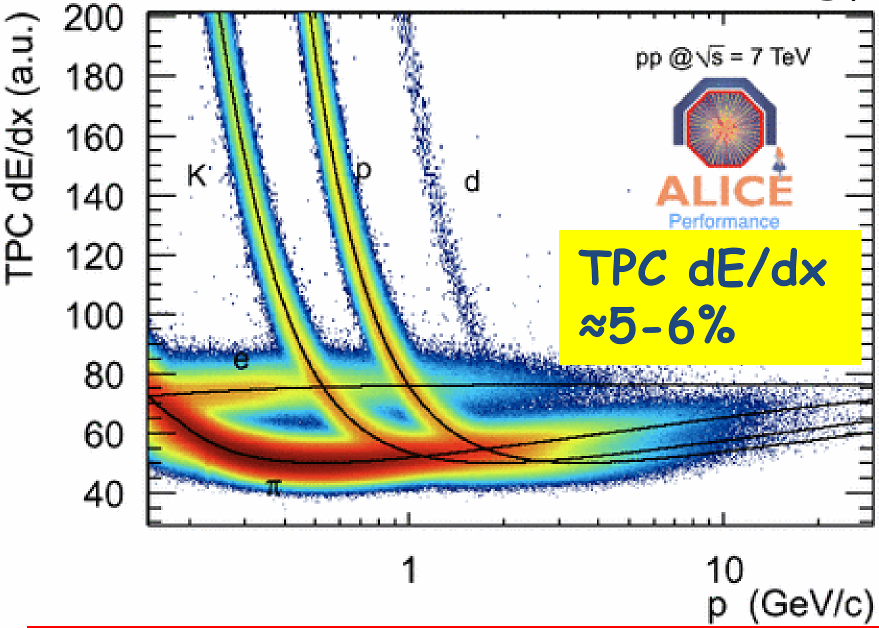


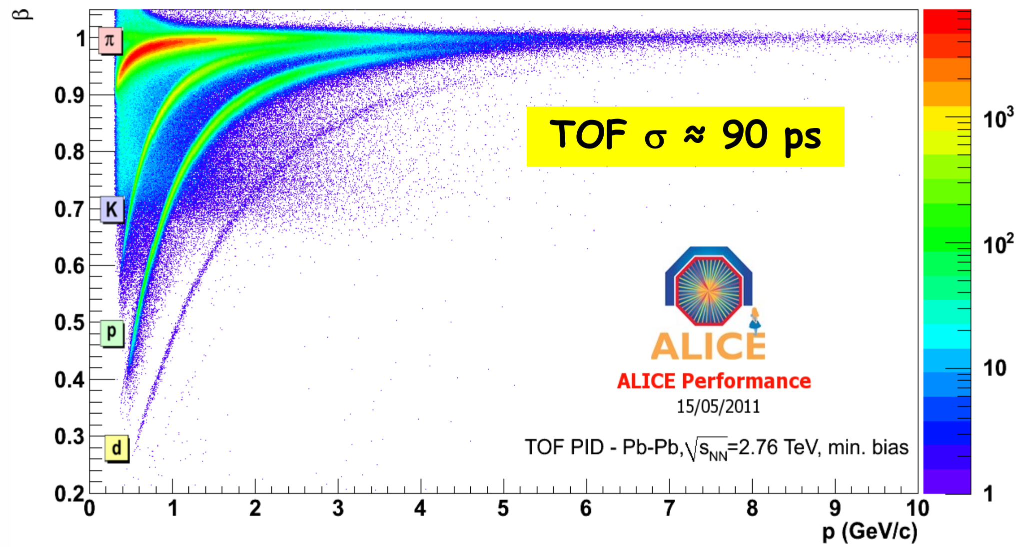




Particle identification

: Basic identification strategy: fit response function in p_T bin



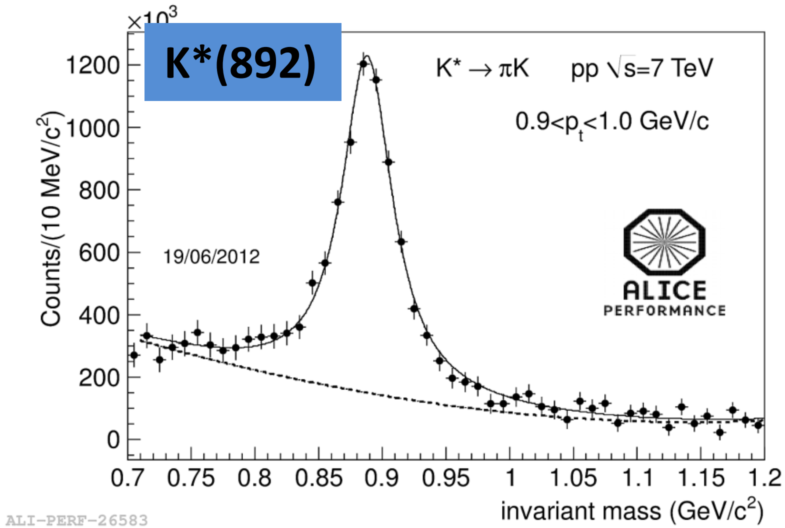


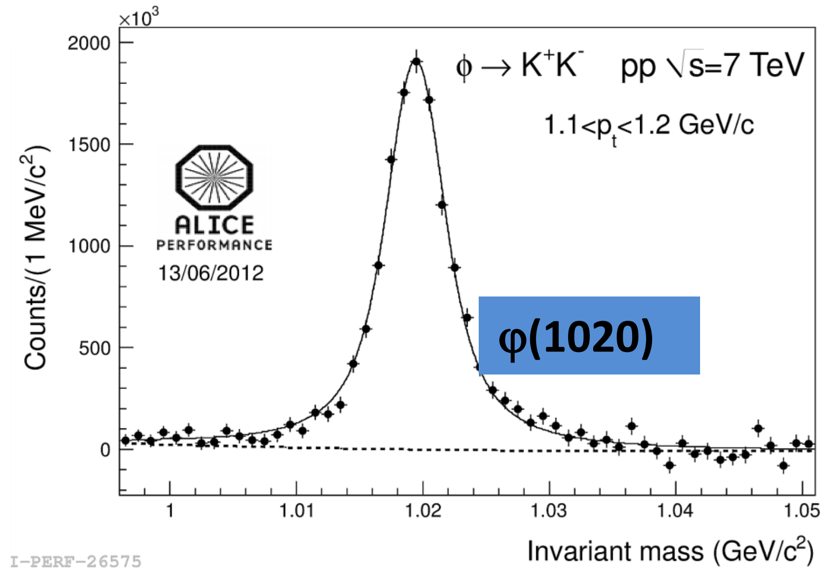
For resonances, V0 and cascade analysis PID by a cut (3-5 σ) on the relative difference between:

- TPC signal and Bethe-Bloch function
- TOF signal and integrated time

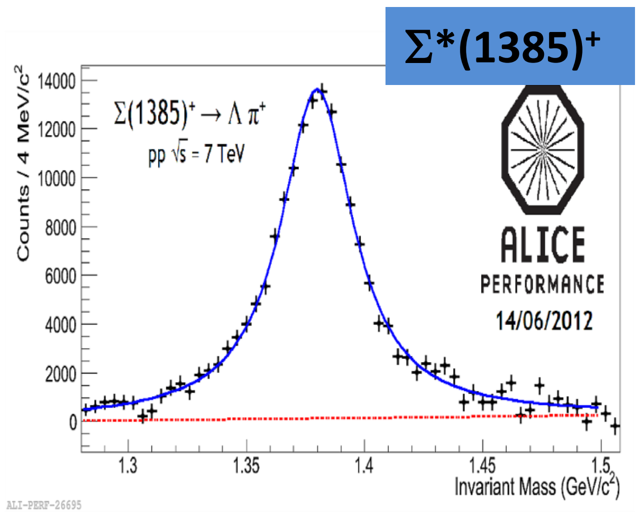
p_T range of separation within 3σ (GeV/c)	TPC	TOF
π	0.2 ÷ 0.7	0.5 ÷ 2.0
K	0.3 ÷ 0.6	0.5 ÷ 2.0
p	0.5 ÷ 1.0	0.5 ÷ 2.5

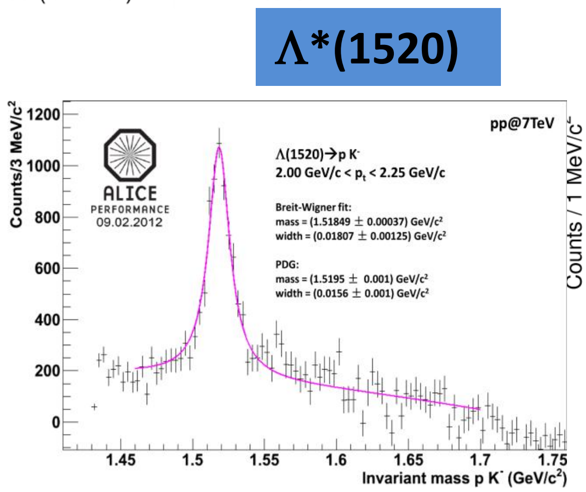
Invariant mass signal pp 7 TeV

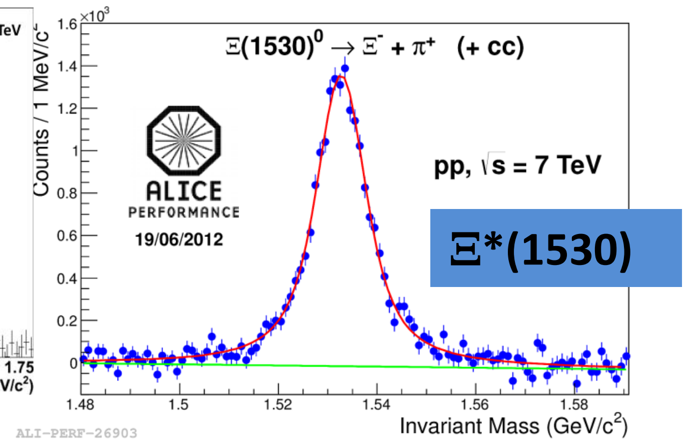




60-155 M MB events

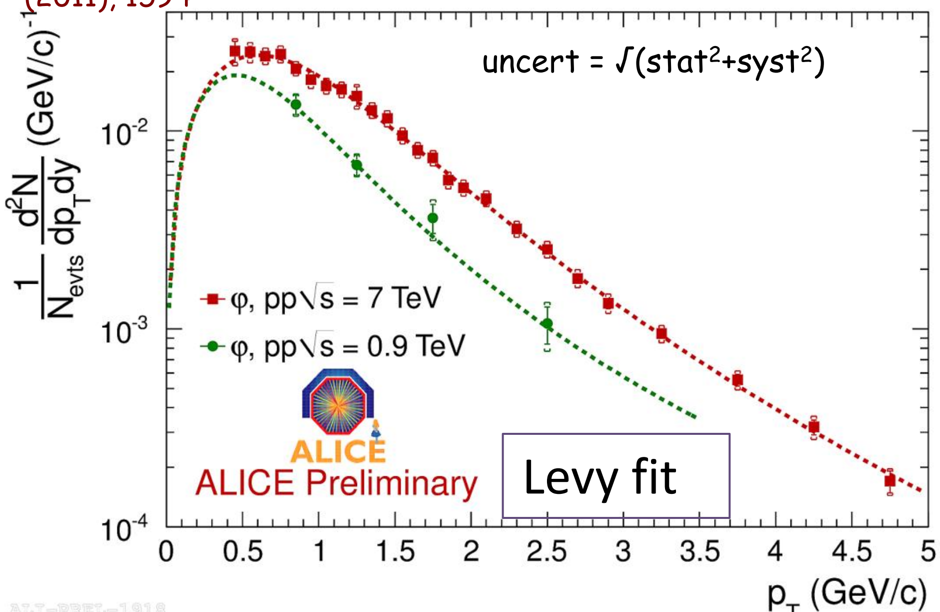


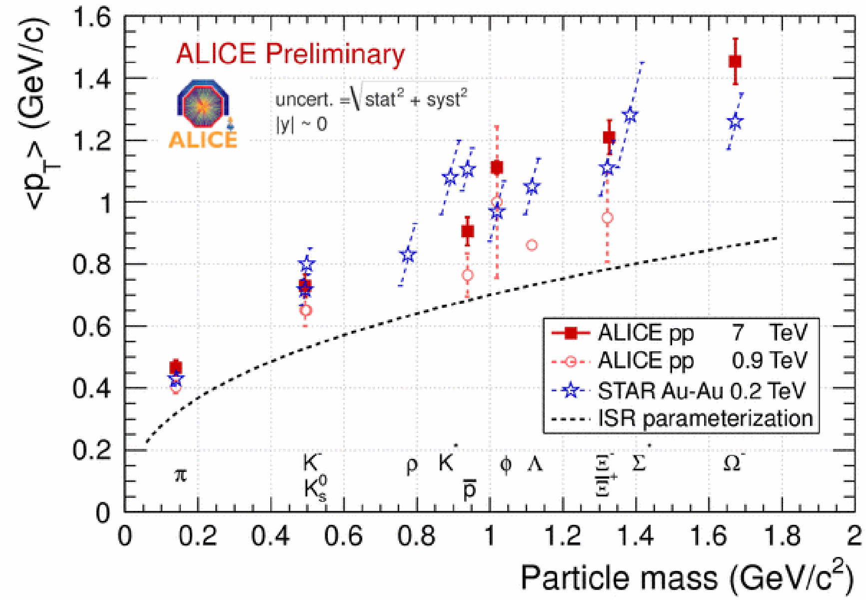




φ @ 0.9 and 7 TeV pp, yield and $\langle p_T \rangle$

φ @ 0.9 TeV : ALICE Collaboration, Eur. Phys. J. **C71** (2011), 1594





√s	dN/dy	T	n
0.9 TeV	0.021 ± 0.005	164 ± 91	4.2 ± 2.5
7 TeV	0.0334 ± 0.0008	286 ± 14	7.0 ± 0.6

A rise in the mean p_T with collision energy is observed!

dN_{φ}/dy increases proportionally to dN_{ch}/dy from 0.9 TeV to 7 TeV

- Charged multiplicity ALICE Collaboration, Eur. Phys. Journal **C 68** (2010), 345

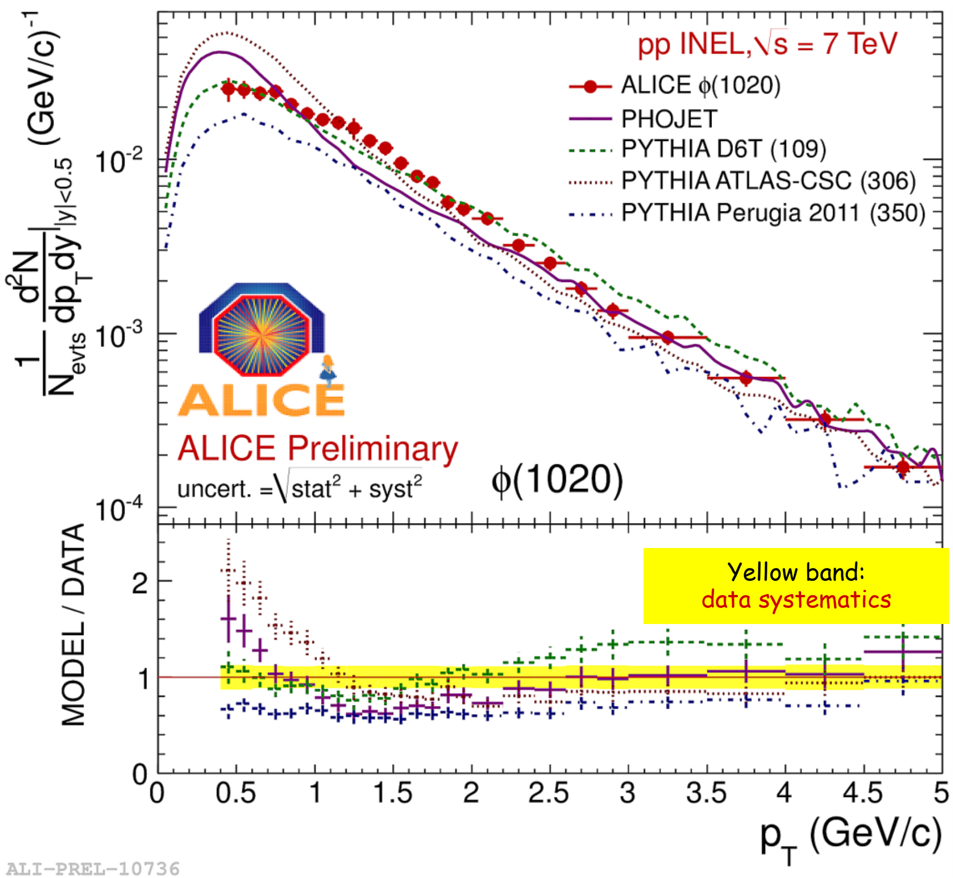
ISR ($(\sqrt{s})_{pp}$ = 62 GeV) parameterization doesn't describe pp data at LHC energies, while it describes RHIC pp data

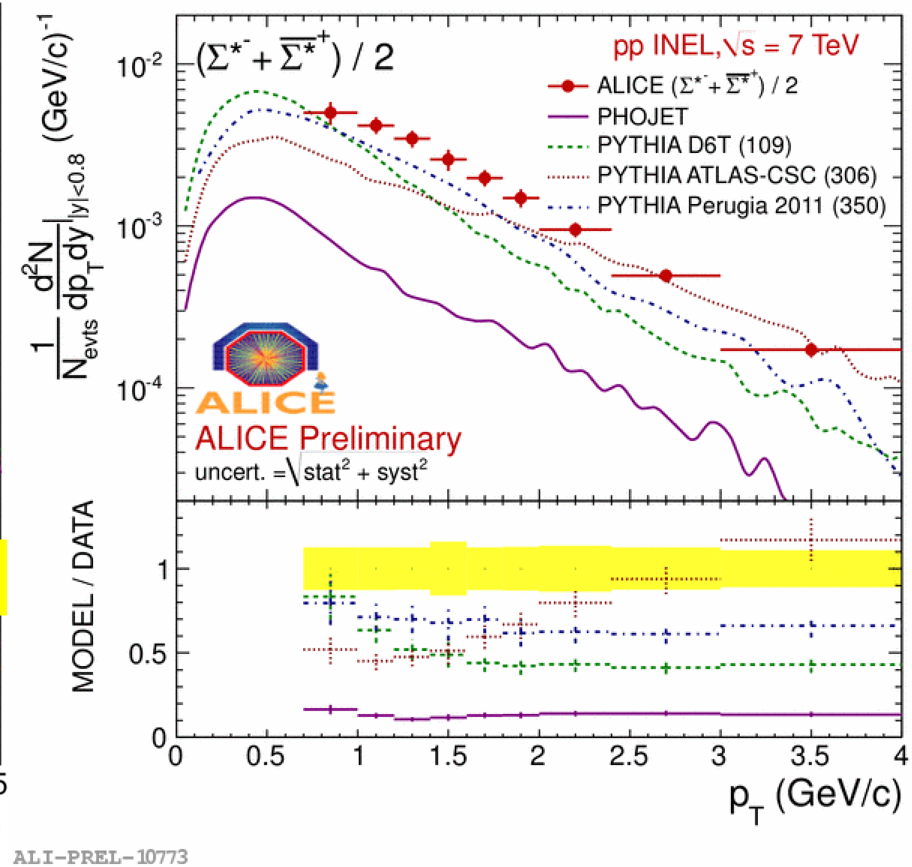
Comparison with MC @ 7 TeV

$p_T \leq 2$ GeV/c: good agreement with PYTHIA D6T

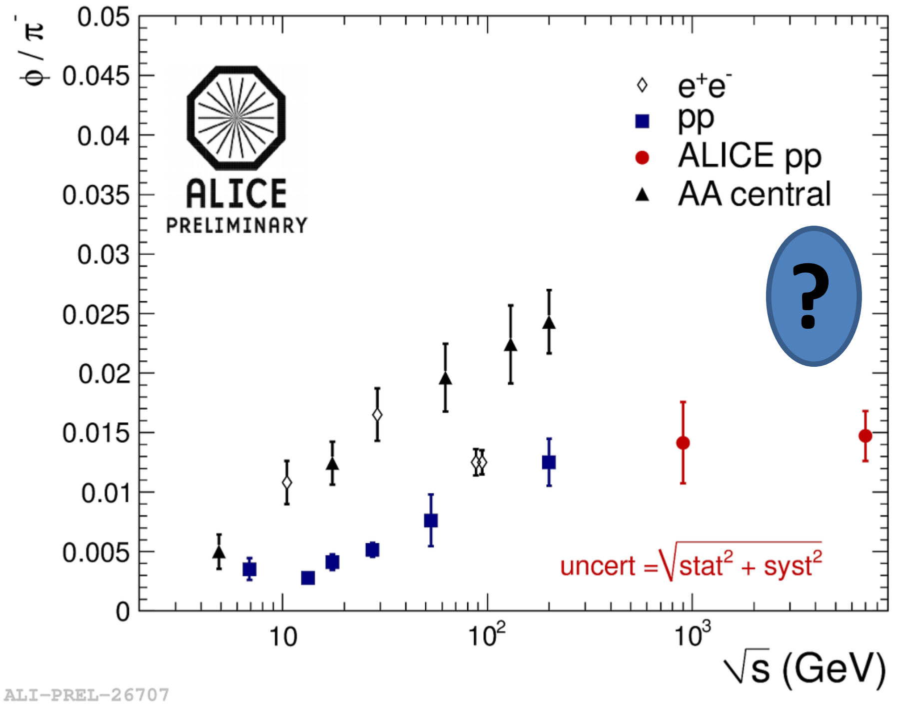
$p_T \geq 2$ GeV/c: good agreement with PHOJET

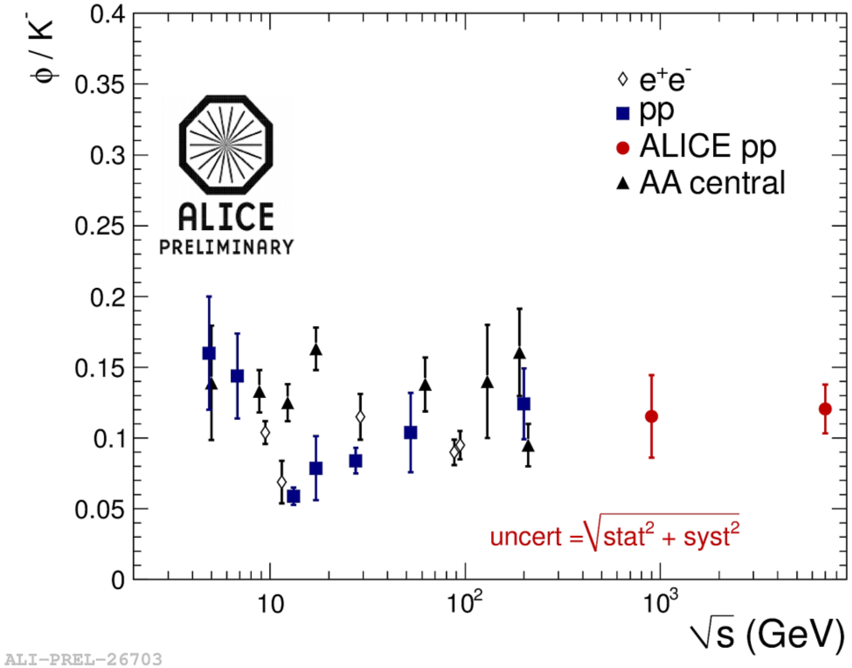
PYTHIA tunes describe better the $\varphi(1020)$ than $\Sigma(1385)$ resonance





φ/π and φ/K ratio





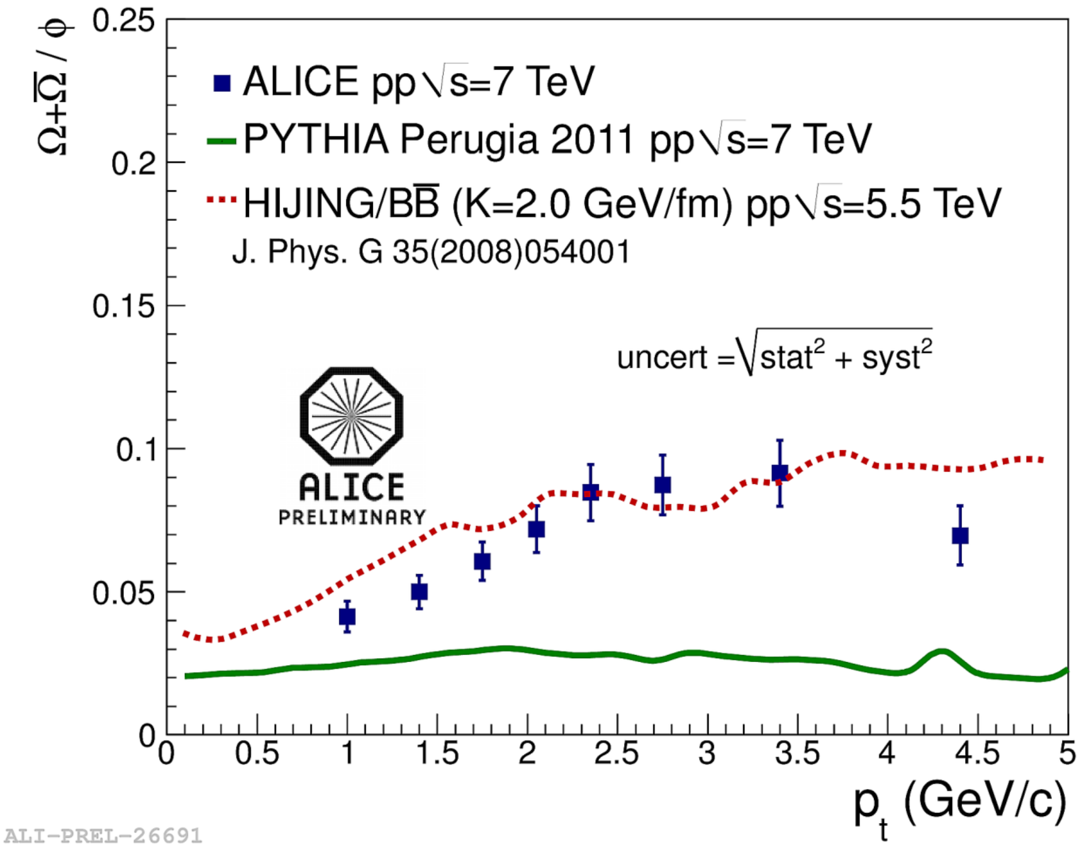
- The φ/π ratio increases with energy both in heavy-ion and in pp collisions. Will the value at LHC energy confirm this trend?
- At 200 GeV in pp collisions we observe a saturation.

- The φ/K ratio doesn't increase with energy.
- Same in all system sizes.

Ω+anti-Ω/φ ratio at 7 TeV

HIJING (K=2 GeV/fm) rescale factor

$$\frac{\left[\frac{\left(\Omega+\overline{\Omega}\right)}{\varphi}\right]_{7TeV}}{\left[\frac{\left(\Omega+\overline{\Omega}\right)}{\varphi}\right]_{5.5TeV}} \approx 1.1$$



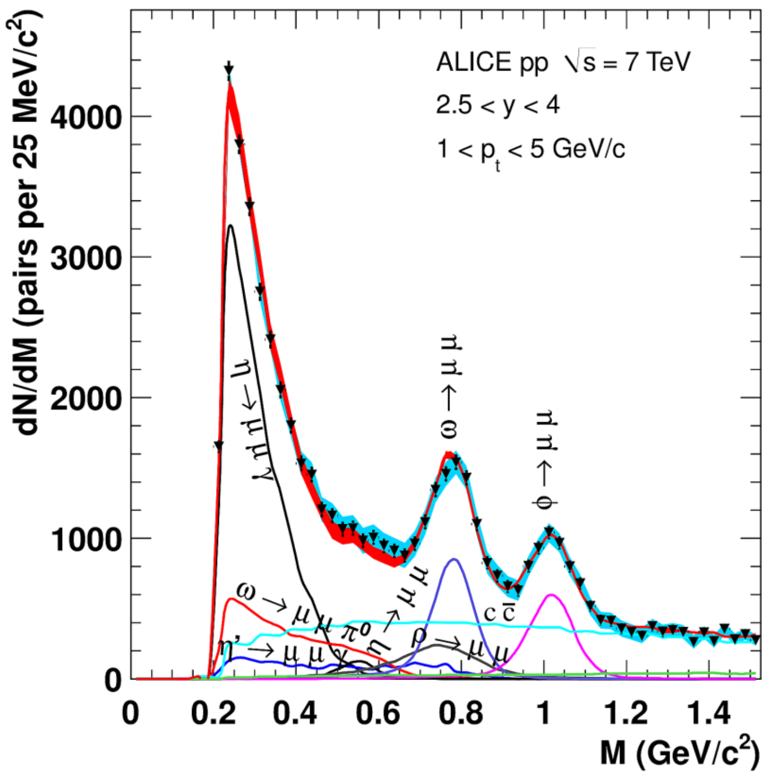
Pythia Perugia 2011 is a factor 1.5-5 below data. It underpredicts multistrange baryon yield.

Predictions of HIJING/BB with a Strong Color Field modeled by an increased string tension are in agreement with the data.

Low-mass dimuon results

Low mass dimuon spectrum in pp collisions at 7 TeV

ALICE coll. Phys. Lett. B 710 (2012) 557



Blue band: syst. uncertainty from bck. subtraction
Red band: Sum of all simulated contributions

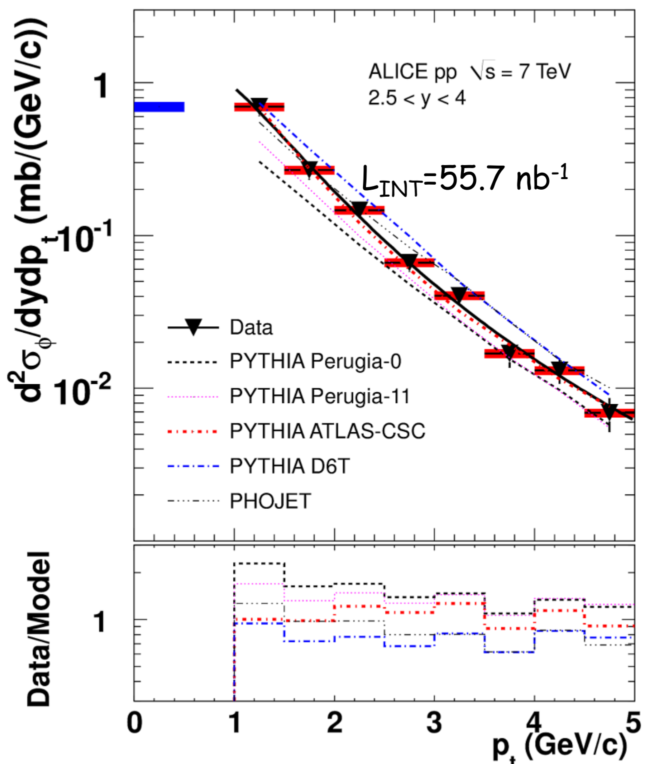
Processes contributing to the dimuon mass spectrum are the light meson ($\eta,\rho,\omega,\eta',\varphi$) decays into muons and the correlated semi-leptonic open charm and beauty decay

Fit of the dimuon mass spectrum after background subtraction:

- free parameters of the fit are the normalization of η, ω, φ and open charm
- other processes normalized with ratios between cross sections or branching ratios

φ and ω cross section @ 7 TeV

ALICE coll. Phys. Lett. B 710 (2012) 557



Fitted with:

$$\frac{p_T}{\left[1+(p_T/p_0)^2\right]^n}$$

φ values

p_0= 1.16±0.023GeV/c

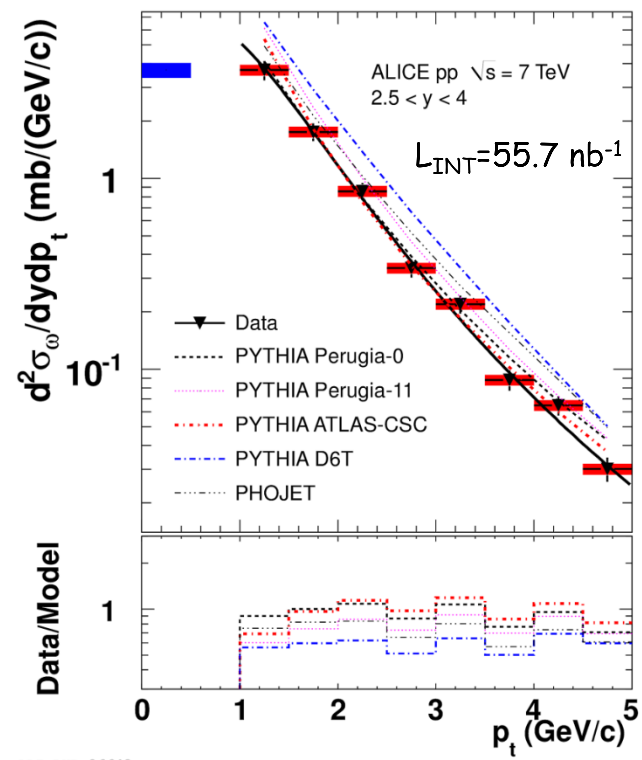
n=2.7±0.2

ω values

p_0= 1.44±0.09 GeV/c

n=3.2±0.1

ALICE coll. Phys. Lett. B 710 (2012) 557



σ_φ = 0.940 ±0.084(stat.) ±0.076(syst.) mb
in 2.5<y<4.0 and 1<p_t<5 Gev/c

σ_ω = 5.28 ±0.54(stat.) ±0.49(syst.) mb
in 2.5<y<4.0 and 1<p_t<5 Gev/c

σ_φ is reproduced by PHOJET and ATLAS-CSC and D6T PYTHIA tunes, underestimated by Perugia-0 and 2011 tunes

σ_ω overestimated by all models except PYTHIA-Perugia0

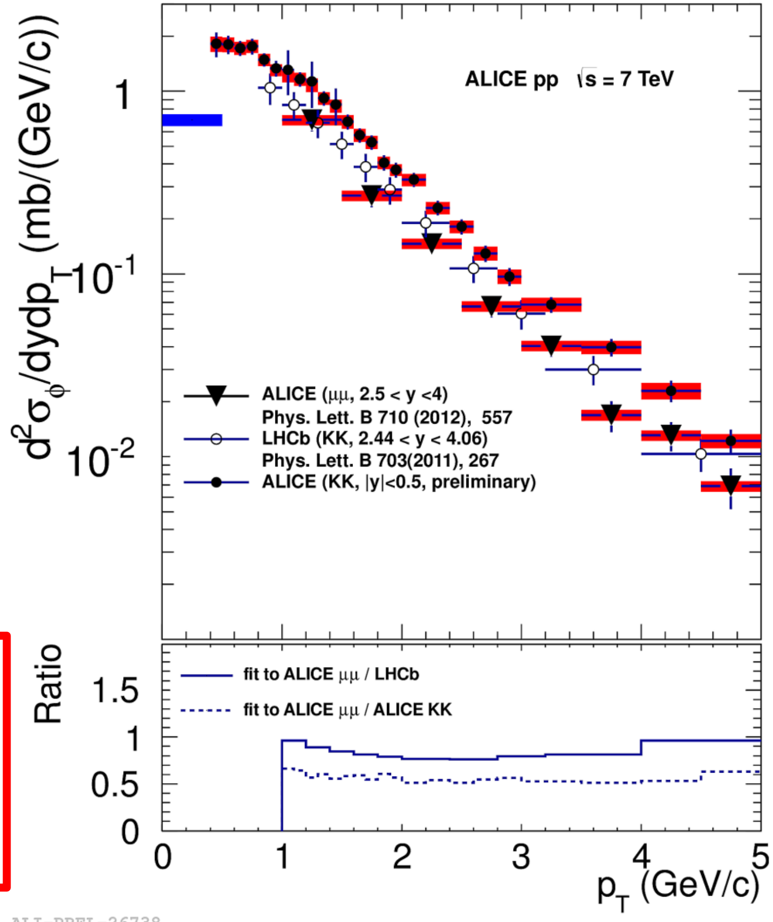
$\varphi \to KK$ and $\varphi \to \mu\mu$ @ 7 TeV

ALICE results, $\varphi \to \mu\mu$ Phys. Lett. B710 (2012)557.

Slope $\varphi \to KK$ consistent with slope $\varphi \to \mu\mu$ (2.5<y<4.0, 1<p_t<5 GeV/c)

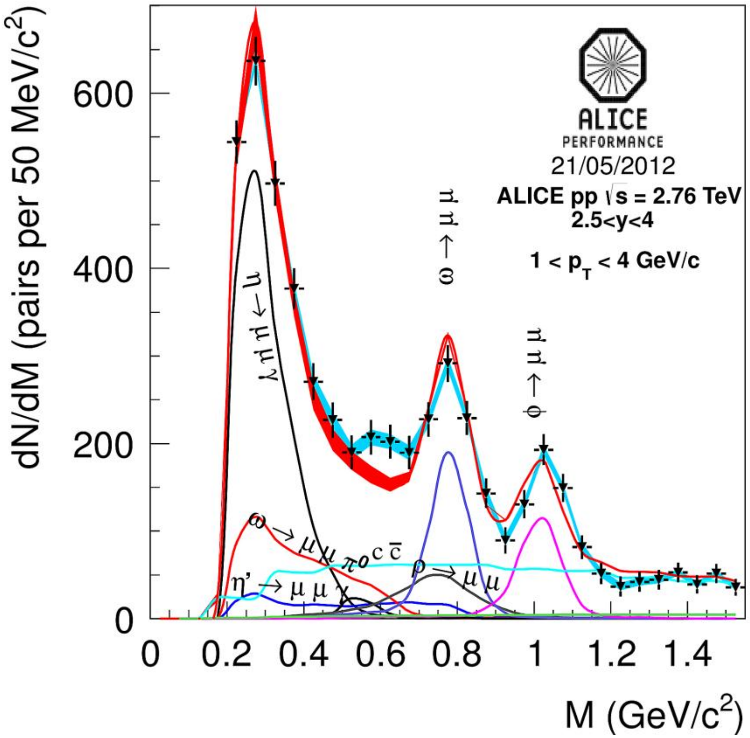
Difference between forward and mid-central rapidity yield as expected from D6T PYTHIA tune

σ_φ = 0.940 ±0.084(stat.) ±0.076(syst.) mb in 2.5<y<4.0 and 1<p_t<5 Gev/c
σ(LHCb) in ALICE range = 1.07±0.15(stat.+syst.) mb

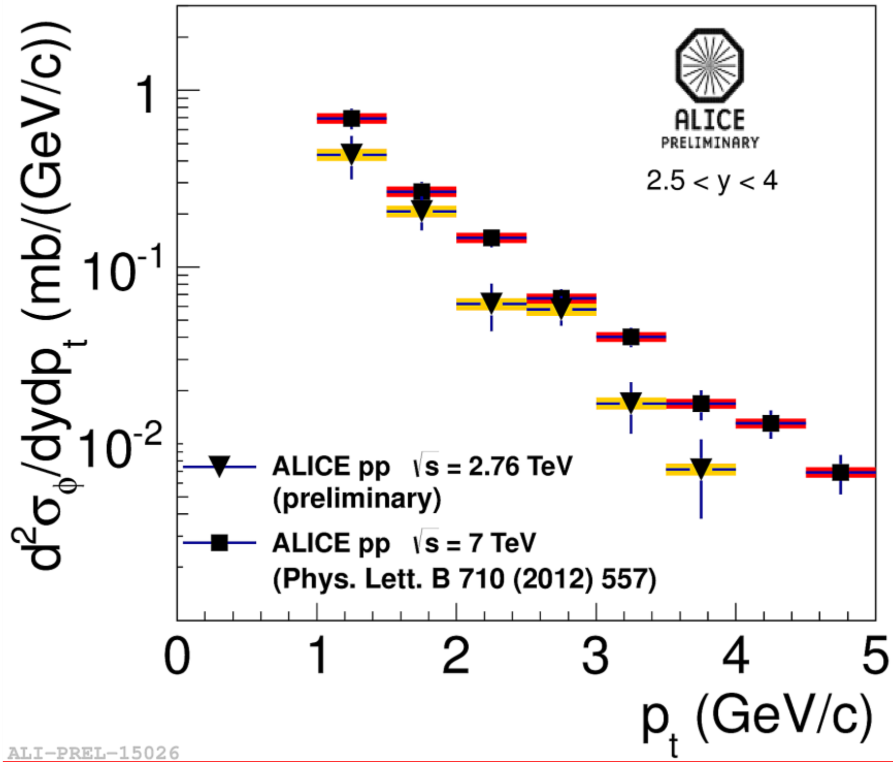


LHCb results, $\varphi \to KK$ (2.44<y<4.06, 0.8<p_T<5 GeV/c) Phys. Lett. B703(2011)267.

Comparison φ@ 2.76 and 7 TeV



Blue band: syst. uncertainty from bck. subtraction
Red band: Sum of all simulated contributions



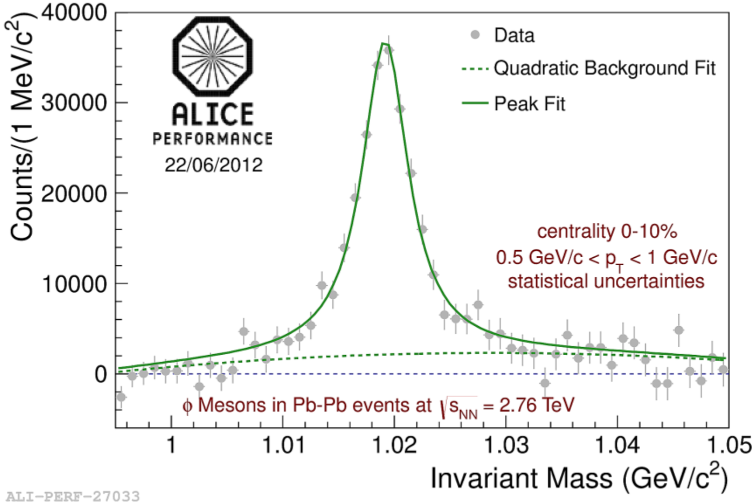
σ_φ =0.587 ±0.070(stat.) ± 0.045 (mb)
in 2.5<y<4.0 and 1<p_t<4 Gev/c and L_{INT}=17.6 nb^{-1}

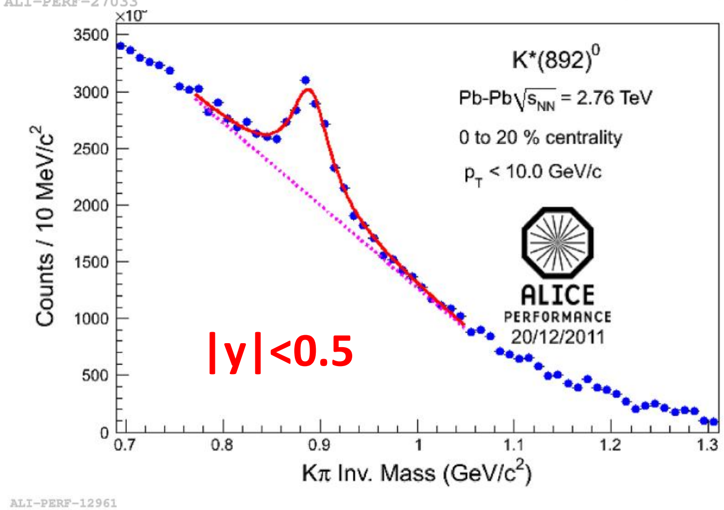
PHOJET and PYTHIA with ATLAS-CSC and D6T tunes reproduce σ_φ

Pb- Pb results

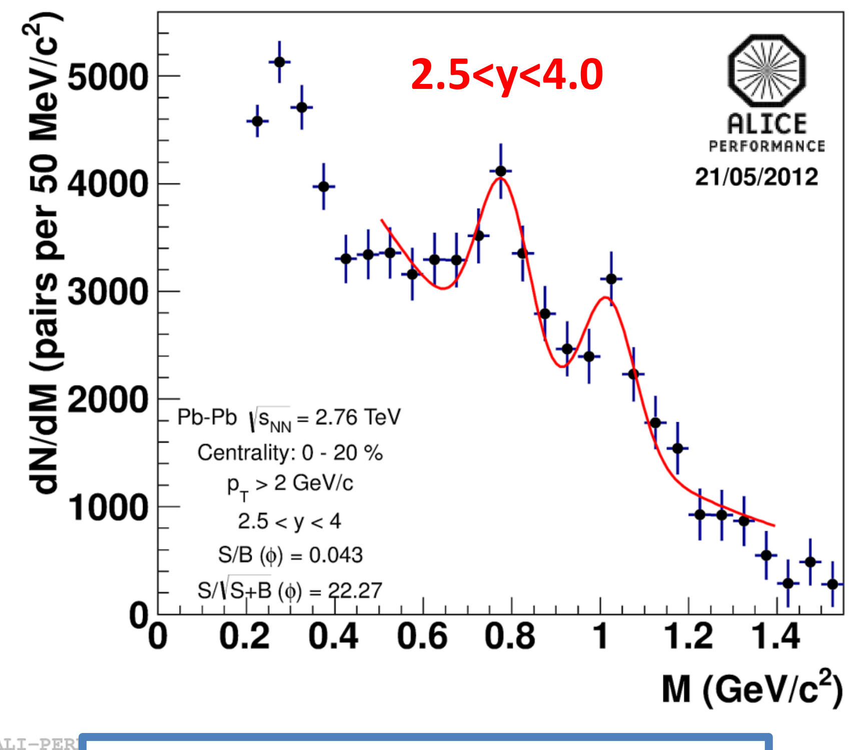
Invariant mass signals Pb-Pb @2.76 TeV

Hadronic channel



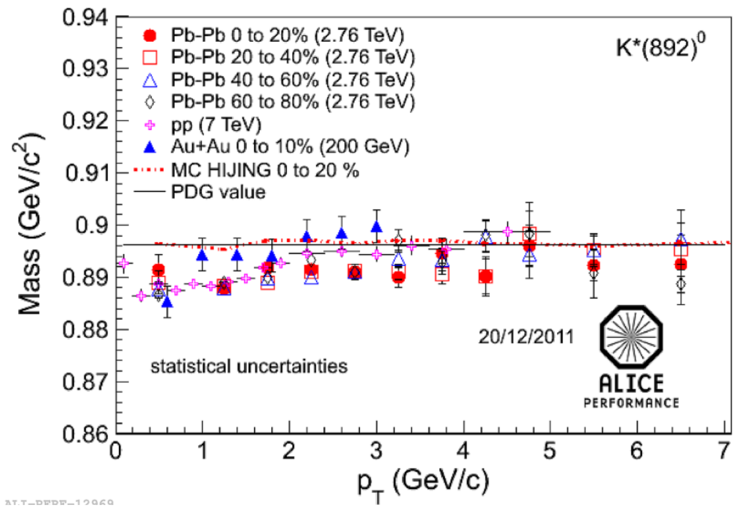


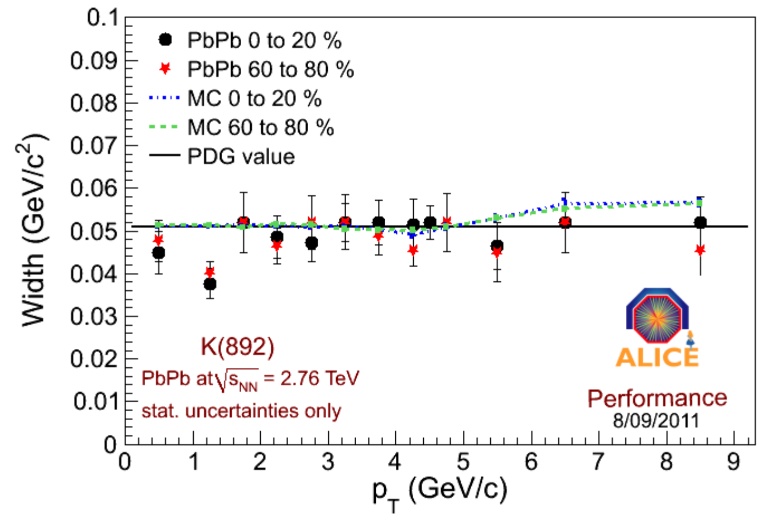
Dimuon channel

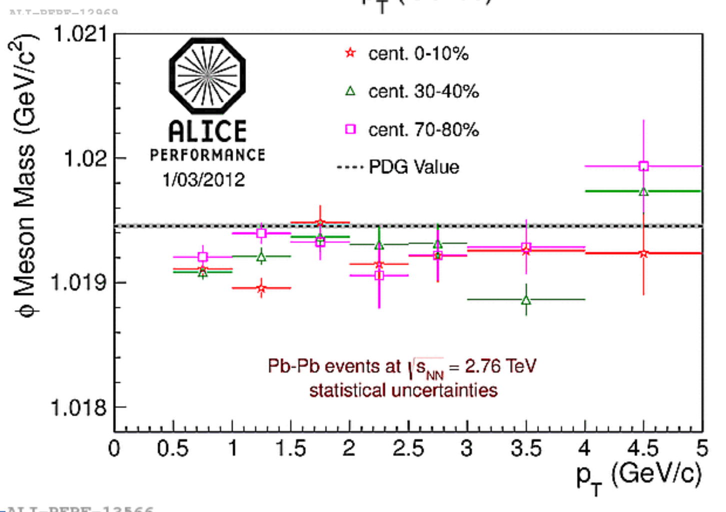


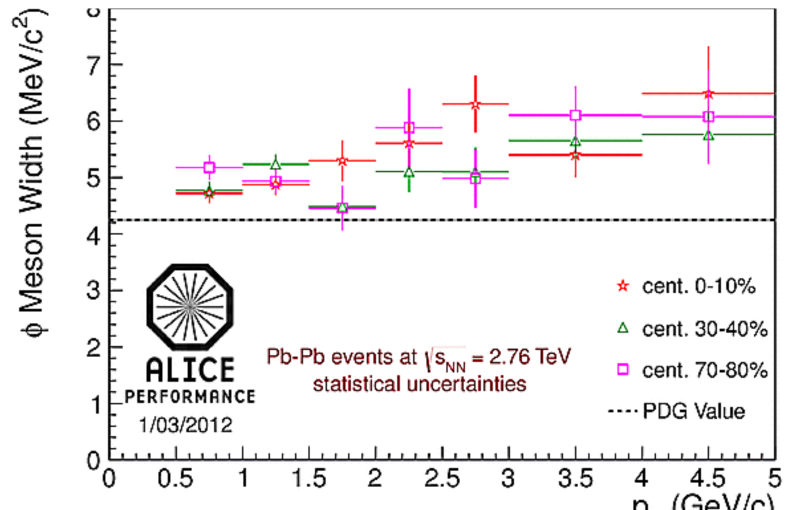
Combinatorial background estimated by event-mixing

K* and φ mass and width



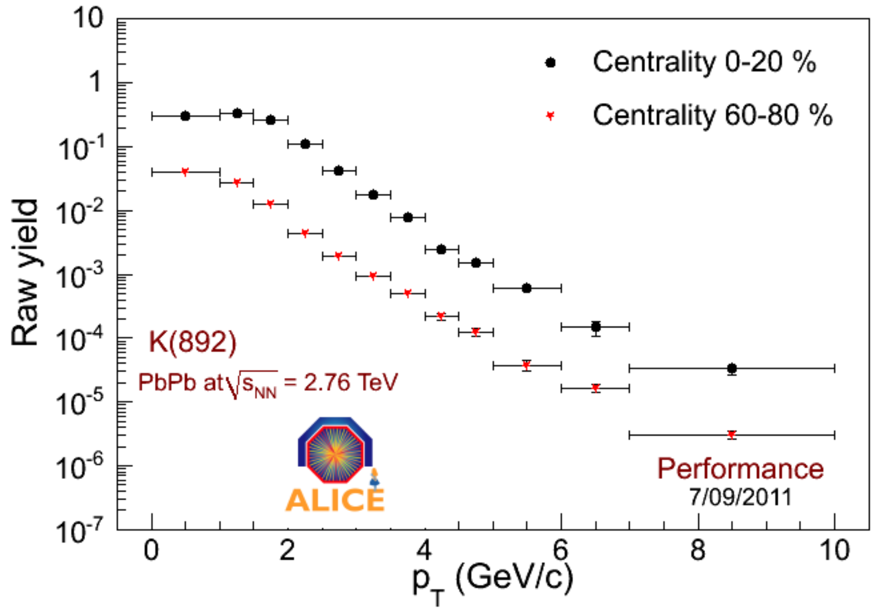




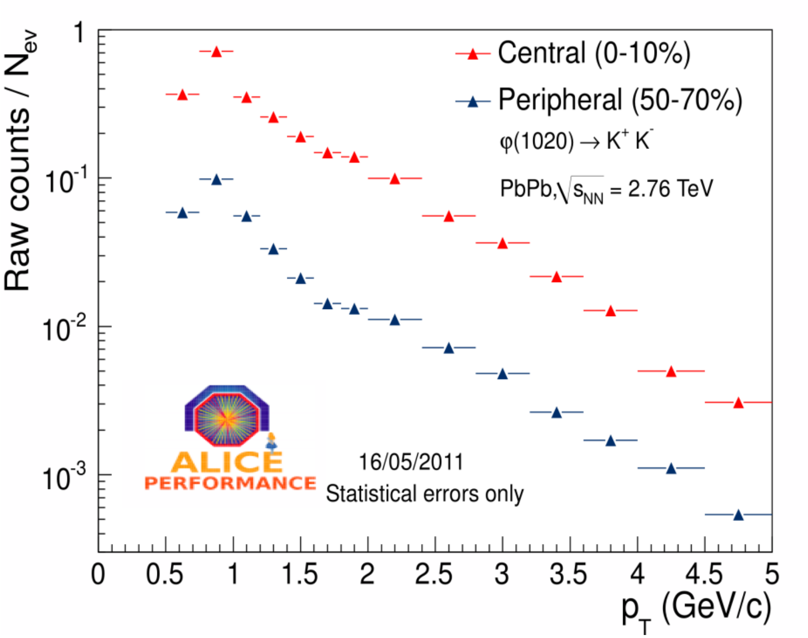


K* →No width broadening. Mass shift: the same in pp and Pb-Pb collisions→No medium effect.
φ →No mass shift or width broadening in Pb-Pb collisions

K*(892) and φ(1020) raw spectra in Pb-Pb



Corrected spectra will come soon.



Summary pp results

- Yield and transverse momentum spectrum of ($\varphi(1020)$, $\Sigma^*(1385)^{\pm}$) at mid-rapidity and $\omega(782)$ and $\varphi(1020)$ at forward rapidity have been measured in 7 TeV pp collisions and 2.76 and 7 TeV pp collisions, respectively, by their hadronic and leptonic decay channel.

- In pp collisions φ/K is indipendent of energy, φ/π saturates at the energy above 200 GeV.

- Forward-($\mu\mu$ channel) and mid-rapidity (KK channel) φ spectra in 7 TeV pp collisions are in agreement considering the different rapidity range.

- None of PHOJET and PYTHIA tunes give a full satisfactory description of the spectra at mid-rapidity. In particular they underestimate strange baryon resonances yield.

- PHOJET and ATLAS-CSC and D6T PYTHIA tunes reproduce σ_{φ} ($2.5<y<4.0$, $1<p_t<5$ Gev/c) in pp collisions at 2.76 and 7 TeV. σ_{ω} at 7 TeV is equal to Perugia-0 PYTHIA value.

- The Ω+anti-Ω/φ ratio at $|y|<0.5$, not reproduced by Pythia Perugia 2011, is in good agreement with a prediction of HIJING/BB model with a SCF modeled with a string tension of 2 GeV/fm.

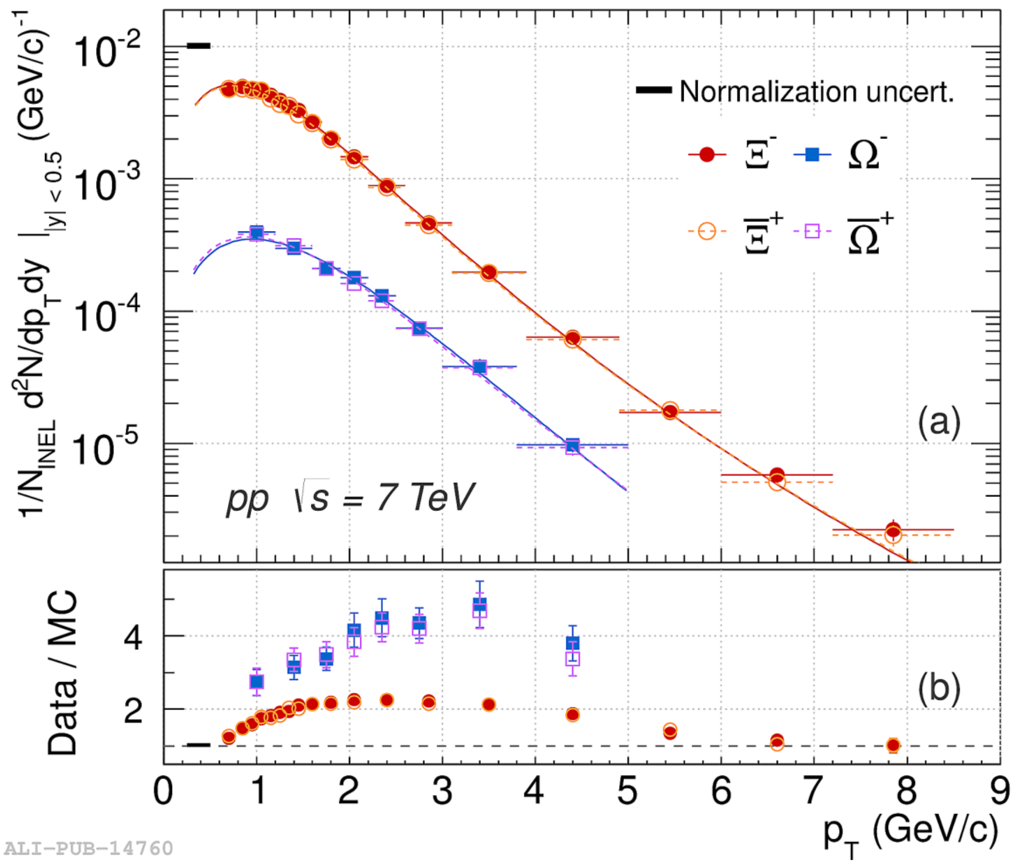
Summary PbPb results

- The widths of K*(892) and φ(1020) are in agreement with the PDG value including the detector effects. Masses of K* are lower in low p_t region for all collision systems. (→ no medium effect).

- Yield of resonances will be soon available.


THANKS

Backup slides


Normalization uncert.
Ξ^-
Ω^-
$\overline{\Xi}^+$
$\overline{\Omega}^+$
(a)
pp $\sqrt{s}$ = 7 TeV
(b)
Data / MC
p_T (GeV/c)
ALI-PUB-14760

Processes contributing to the mass spectrum

2-body and Dalitz decays of the light resonances + open charm / beauty

$$\eta \to \mu^+\mu^- \qquad \eta \to \mu^+\mu^-\gamma$$
$$\rho \to \mu^+\mu^- \qquad \omega \to \mu^+\mu^-\pi^0$$
$$\omega \to \mu^+\mu^- \qquad \eta' \to \mu^+\mu^-\gamma$$
$$\phi \to \mu^+\mu^-$$

Resonances are simulated with an hadronic cocktail generator.

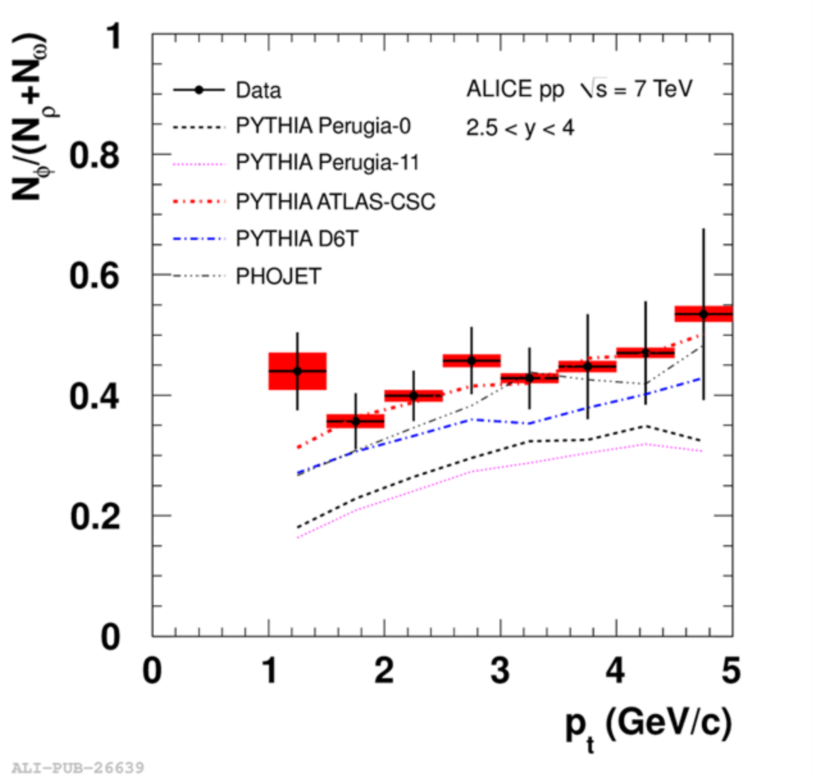
Open charm/beauty simulated via a parametrization of PYTHIA.

The p_t distribution of ρ, ω and φ is described by a power-law function (HERA-B parametrization). The parameter p_0 and n were tuned iteratively to the results of the analysis.
p_t distribution of η from measured distribution via two photon decay channel (ALICE coll.).

Free parameters of the fit:

- $\eta \to \mu\mu\gamma$ normalization
- $\omega \to \mu\mu$ normalization
- $\phi \to \mu\mu$ normalization
- open charm normalization

- $\sigma(\rho)/\sigma(\omega)$ ratio fixed to 1
- Charm/Beauty normalization fixed to LHCb measurement
- $\eta \to \mu\mu$ / $\eta \to \mu\mu\gamma$ and $\omega \to \mu\mu\pi^0$ / $\omega \to \mu\mu$ fixed to the BR ratios



$N_\phi/(N_\rho+N_\omega)$
Data
PYTHIA Perugia-0
PYTHIA Perugia-11
PYTHIA ATLAS-CSC
PYTHIA D6T
PHOJET
ALICE pp $\sqrt{s}$ = 7 TeV
2.5 < y < 4
p_t (GeV/c)
0 0.2 0.4 0.6 0.8 1
0 1 2 3 4 5
ALI-PUB-26639