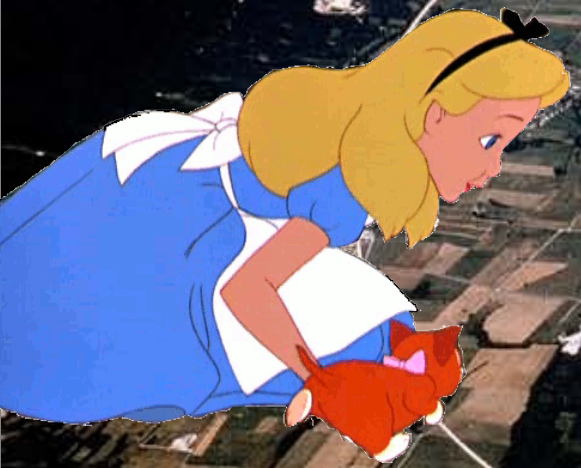
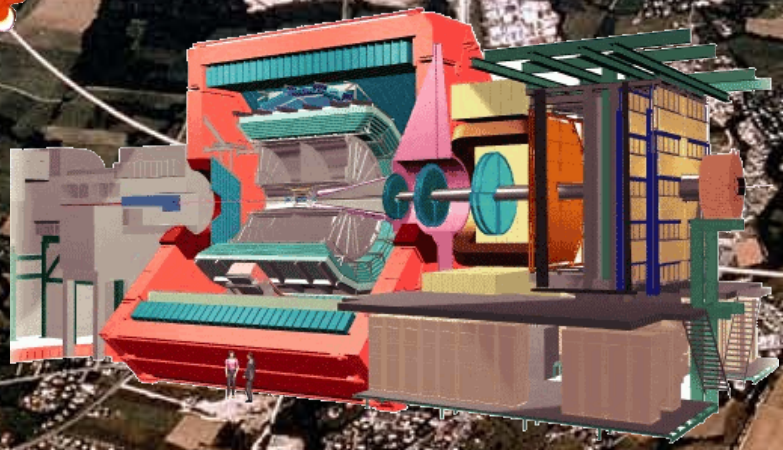
First results from ALICE

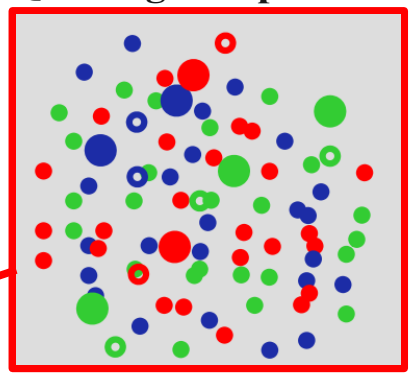
Christine Nattrass
University of Tennessee at Knoxville





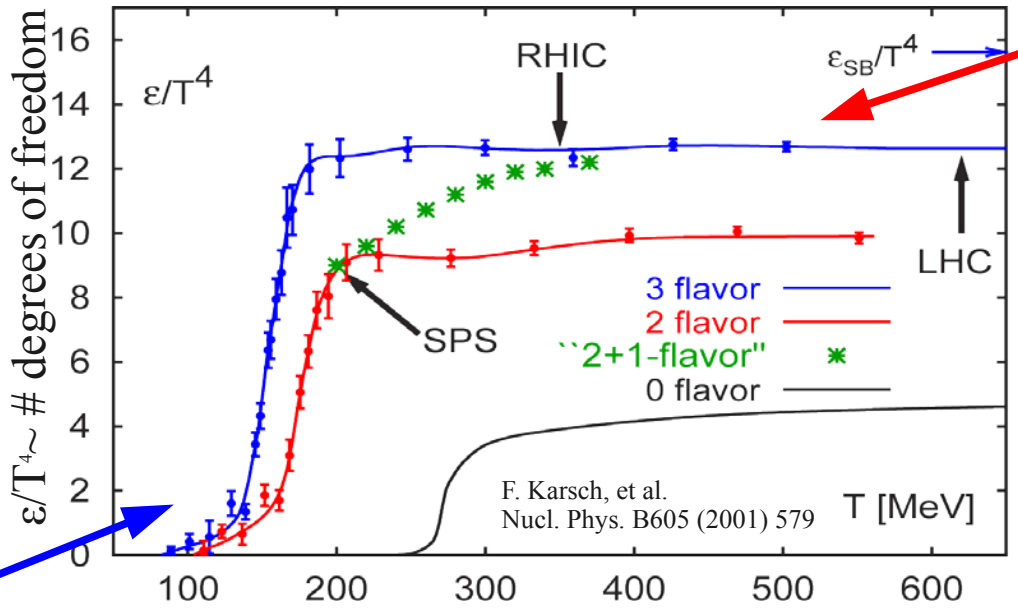
Exploring QCD at high temperatures

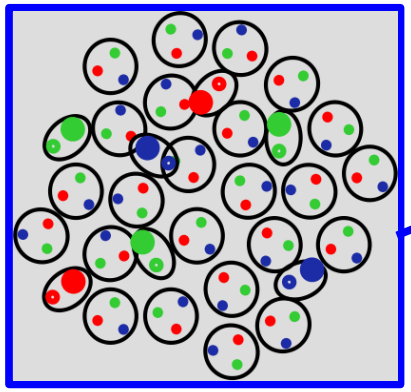
Quark-gluon plasma



Deconfined - more degrees of freedom

$T_c \sim 175 \pm 8$ MeV $\rightarrow \varepsilon_c \sim 0.3$ -1 GeV/fm^3



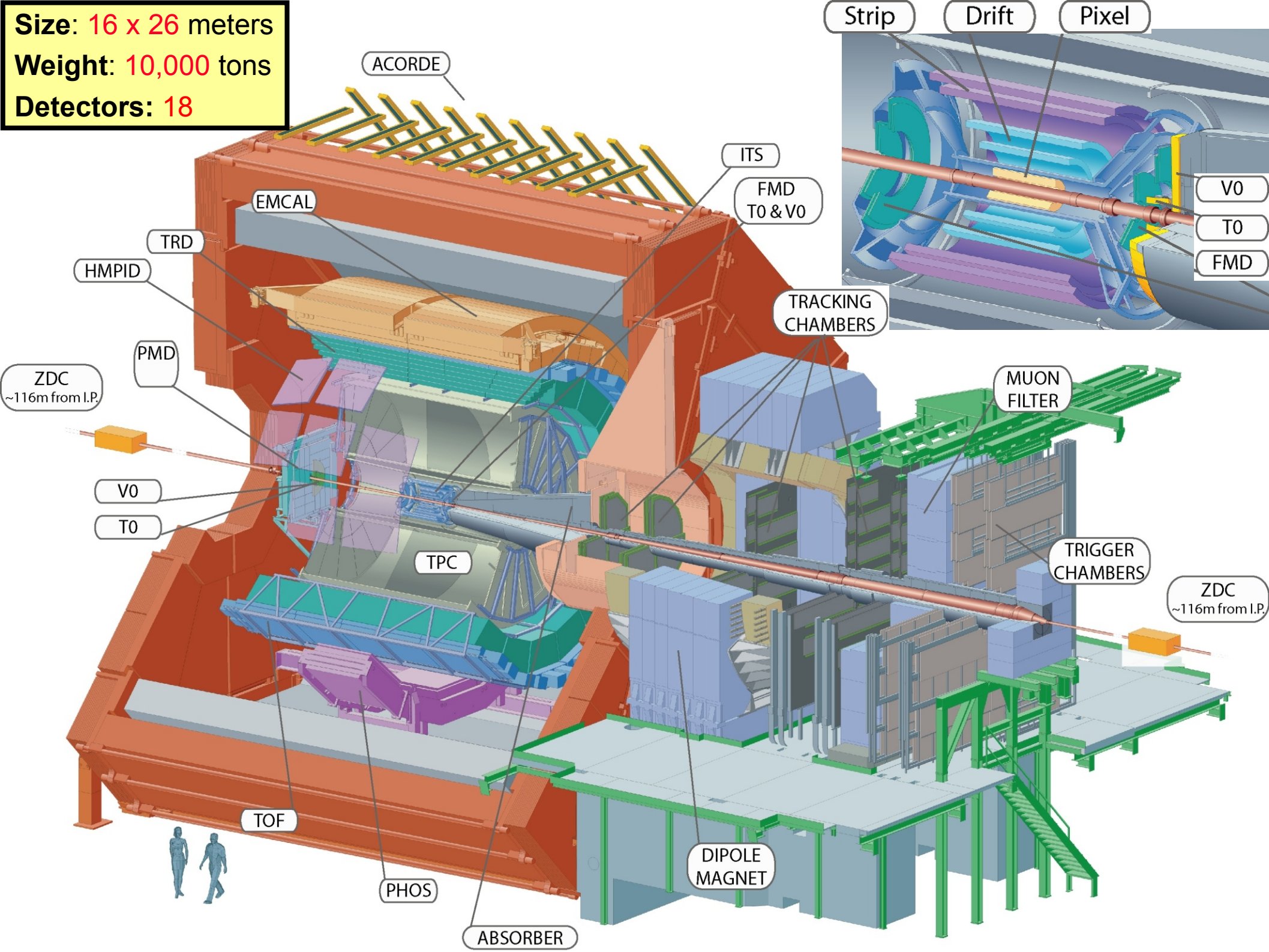


Confined - fewer degrees of freedom

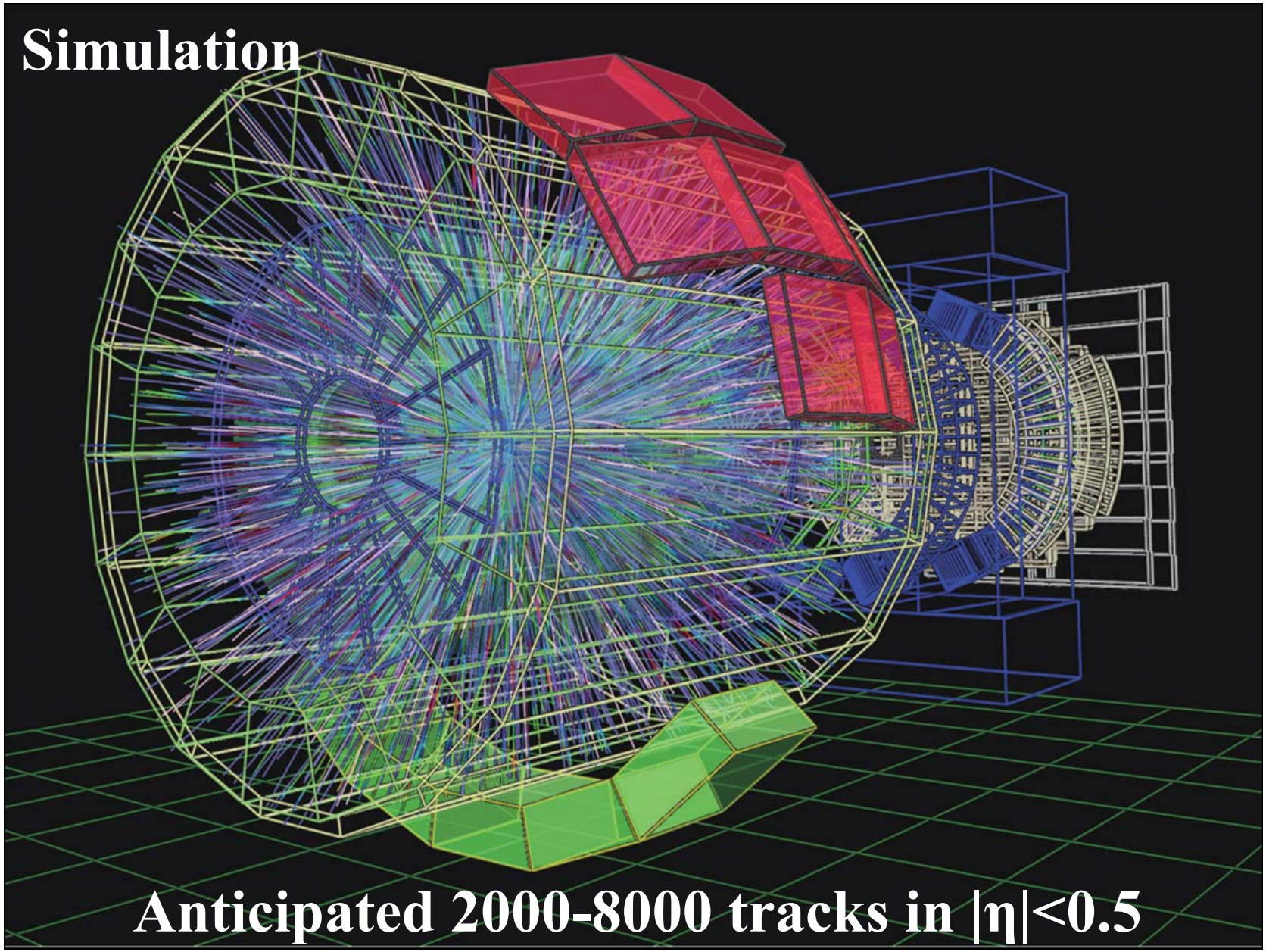
Simple expectations for heavy ion physics at the LHC

	SPS	RHIC	LHC	
$\sqrt{s_{NN}}$ (GeV)	17	200	5500	***28x***
$dN_{ch}/d\eta$	~700	~1200	~2000-8000	***2-7x***
T/T_c	1.1	1.9	3.0-4.2	***Hotter***
ε (GeV/fm^3)	3	5	15-60	***Denser***
τ_{QGP} (fm/c)	$\leq$2	2-4	>10	***Longer lived***

Size: 16 x 26 meters
Weight: 10,000 tons
Detectors: 18



Pb+Pb collisions



Results in p+p

Physics in p+p

- Collect reference data for heavy-ion program
  - Many signals in Pb+Pb measured relative to pp
  - Some require ~ 10^9 minimum-bias events
- Comprehensive study of minimum bias events at the LHC
  - Testing and improvement of models
  - Particle production (low p_T, particle identified data)

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Published results

- N_{ch} multiplicity & distributions
  - 900 GeV: EPJC: Vol. 65 (2010) 111
  - 900 GeV, 2.36 TeV: EPJC: Vol. 68 (2010) 89
  - 7 TeV: EPJC: Vol. 68 (2010) 345
- $\bar{p}/p$ ratio (900 GeV & 7 TeV) PRL: Vol. 105 (2010) 072002
- Momentum distributions(900 GeV) PL B: Vol. 693 (2010) 53
- Bose-Einstein correlations (900 GeV) PRD: Vol. 82 (2010) 052001

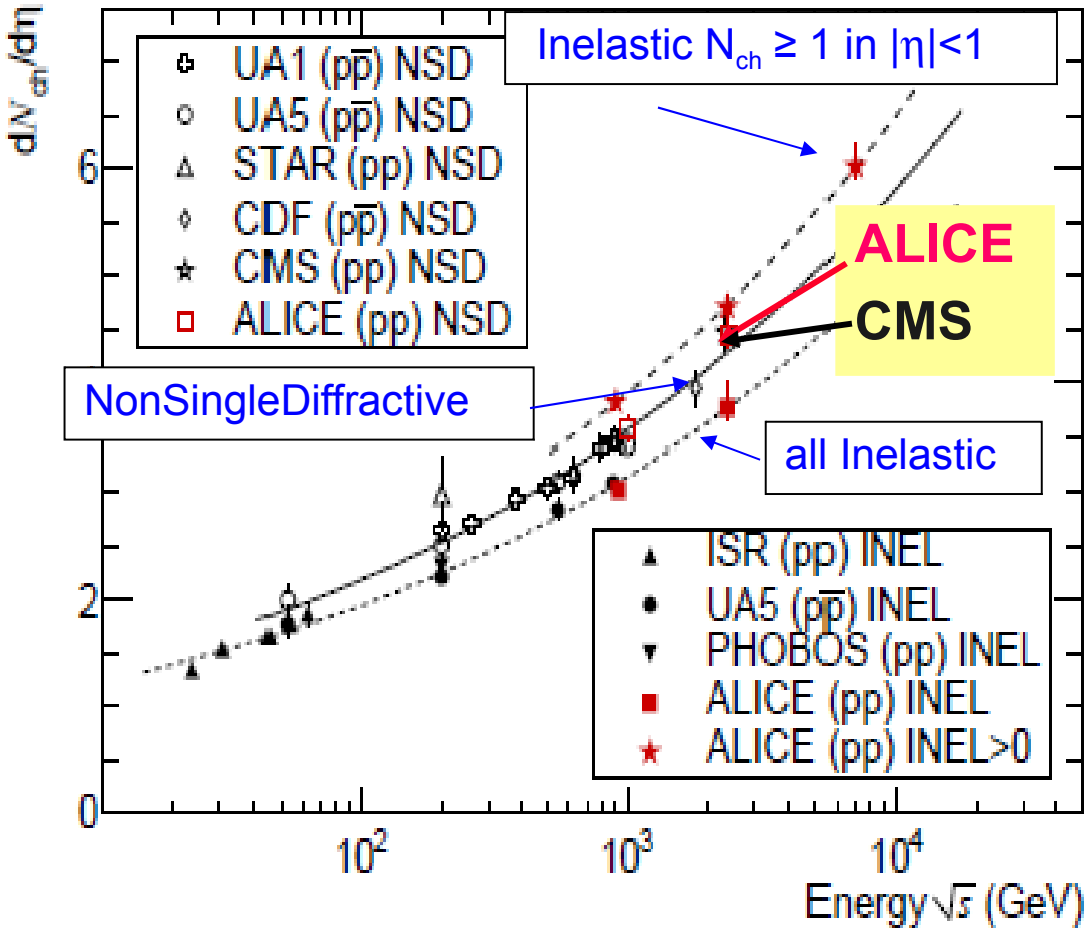
Results in p+p

- Prepared for submission
  - ⇨ Identified particles (π,K,p)
  - ⇨ Strangeness (K^0,Λ,Ξ,ϕ)

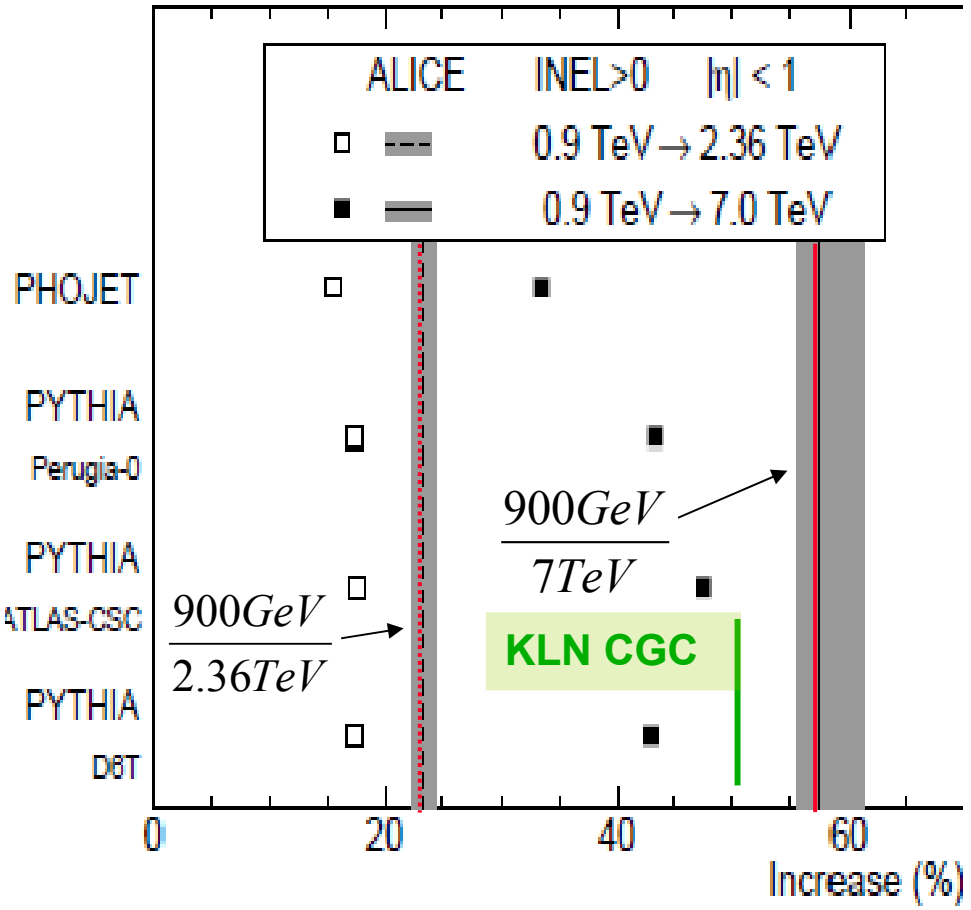
- Ongoing analyses
  - ⇨ 7 TeV pp spectra, HBT, identified particles, strangeness
    - ✪ High multiplicity
  - ⇨ π^0 and η transverse momentum spectra
  - ⇨ Heavy flavour: charm (D^0,D^+, D*), c,b –> μ, e^-
  - ⇨ J/ψ –> $\mu\mu$, e^+e^-
  - ⇨ pQCD: event topology, 2-particle correlations, jet fragmentation, …

$dN_{ch}/d\eta$ versus $\sqrt{s}$

$dN_{ch}/d\eta$ versus $\sqrt{s}$



Relative increase in $dN_{ch}/d\eta$



Results:

increase with energy significantly stronger in data than MC's

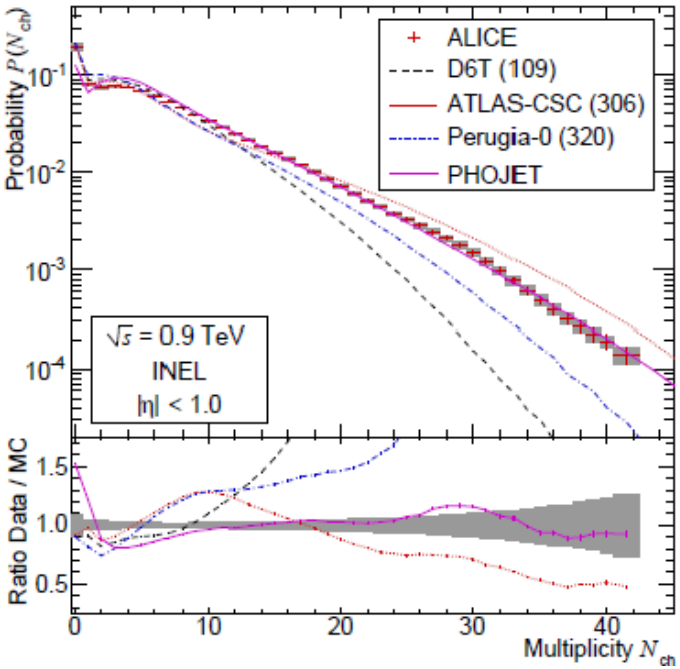
- ALICE & CMS agree to within 1 σ (< 3%)

Monte Carlo scoreboard

	variable/tune	D6T	Perugia0	CSC	PHOJET
900 GeV	$dN_{ch}/d\eta$	-20%	-17%	+3%	-2%
	N_{ch}				
	p_T				
	$<p_T>0$				
	$K^0_S, \Lambda, \bar{\Lambda}$				
	φ				
2.36 TeV	$dN_{ch}/d\eta$	-24%	-21%	-2%	-8%
	N_{ch}				
7 TeV	$dN_{ch}/d\eta$	-27%	-24%	-4%	-17%
	N_{ch}				

MC << Data | MC ≈ Data | MC >> Data

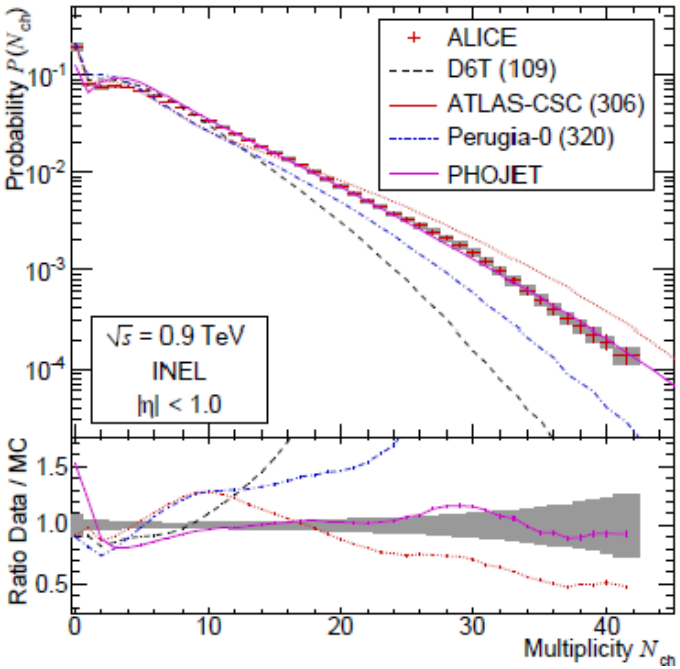
Multiplicity distributions

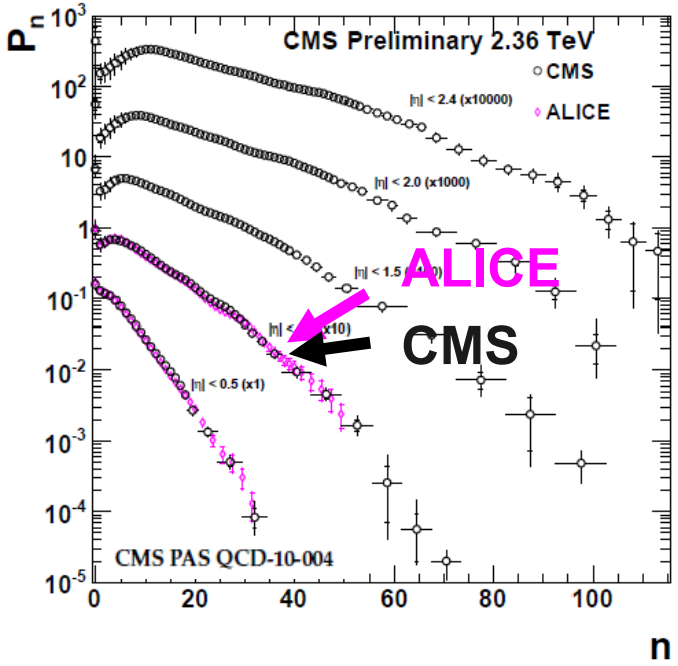


900 GeV

- Data from 900 GeV
- Substantial discrepancies between Monte Carlo and the data

Multiplicity distributions

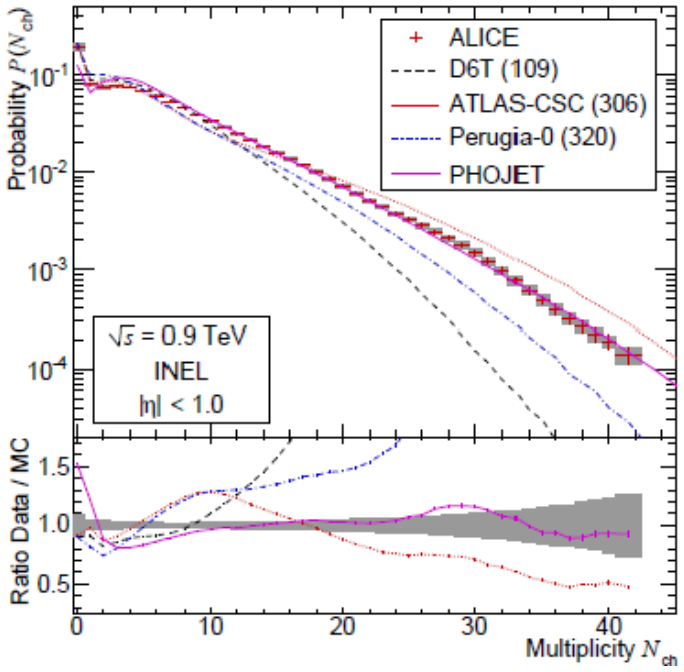


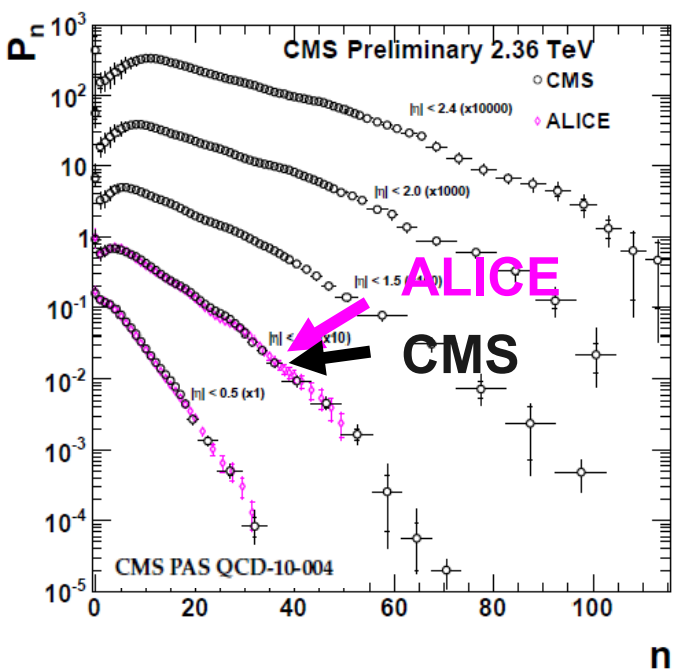


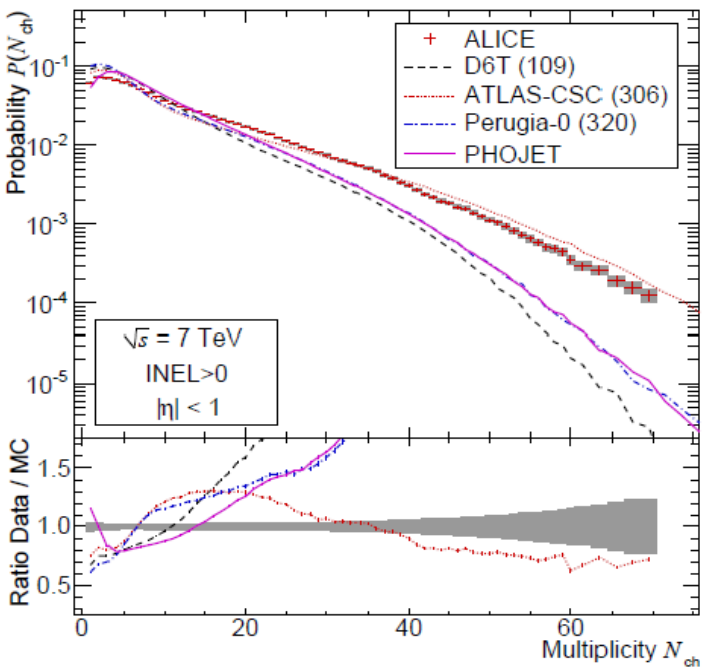
900 GeV **2.36 TeV**

- Data from 900 GeV, 2.36 TeV
- Substantial discrepancies between Monte Carlo and the data
- Agreement between ALICE & CMS

Multiplicity distributions







900 GeV **2.36 TeV** **7 TeV**

- Data from 900 GeV, 2.36 TeV, and 7 TeV
- Substantial discrepancies between Monte Carlo and the data
- Agreement between ALICE & CMS

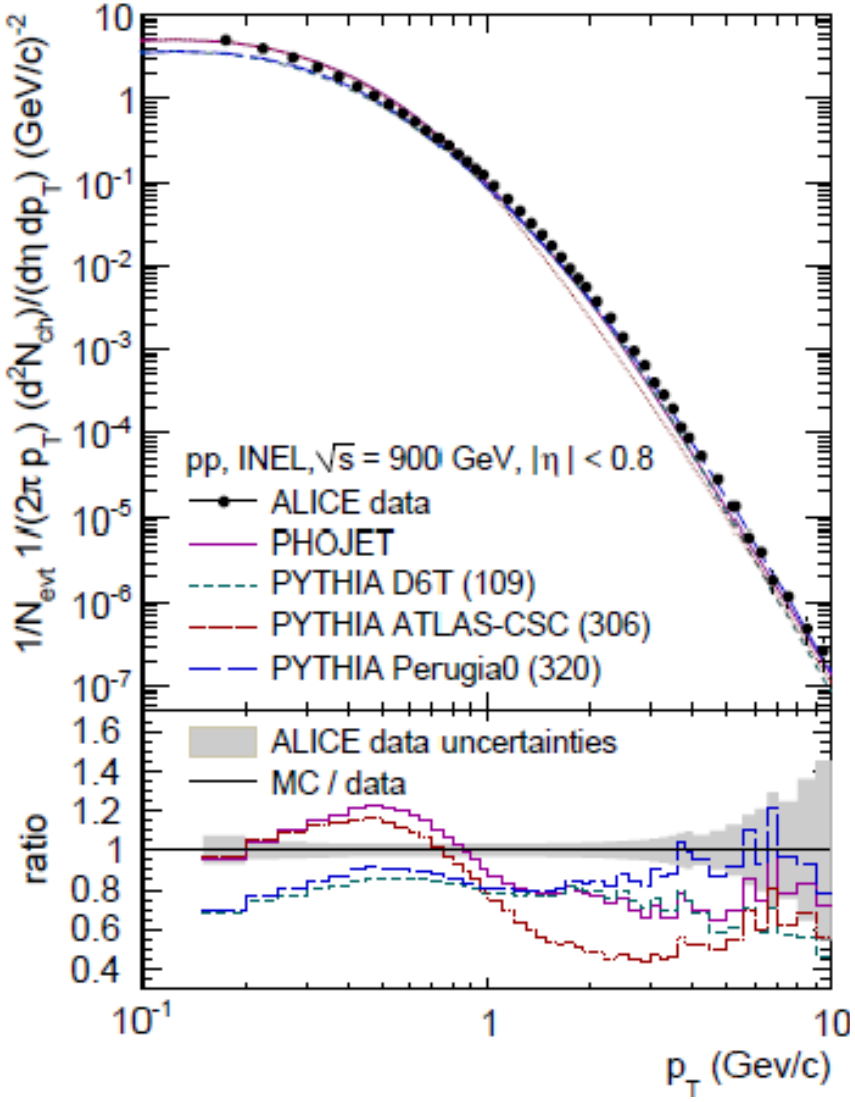
Monte Carlo scoreboard

	variable/tune	D6T	Perugia0	CSC	PHOJET
900 GeV	$dN_{ch}/d\eta$	-20%	-17%	+3%	-2%
	N_{ch}	$N_{ch}>10$	$N_{ch}>5$	$N_{ch}>15$	$N_{ch}>10$
	p_T				
	$\langle p_T \rangle$				
	$K^0_S, \Lambda, \bar{\Lambda}$				
	φ				
2.36 TeV	$dN_{ch}/d\eta$	-24%	-21%	-2%	-8%
	N_{ch}	$N_{ch}>10$	$N_{ch}>5$	$N_{ch}>20$	$N_{ch}>15$
7 TeV	$dN_{ch}/d\eta$	-27%	-24%	-4%	-17%
	N_{ch}			$N_{ch}>30$	

MC << Data | MC ≈ Data | MC >> Data

Momentum distributions at 900 GeV

p_T distribution



Momentum distributions at 900 GeV

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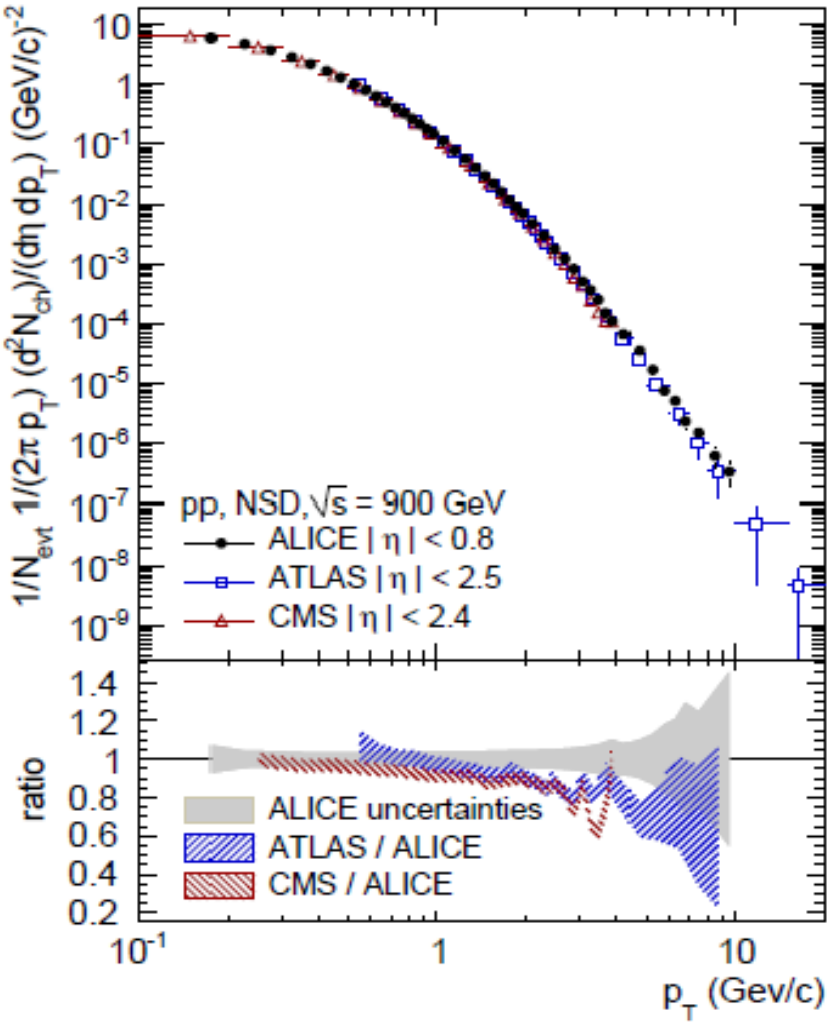
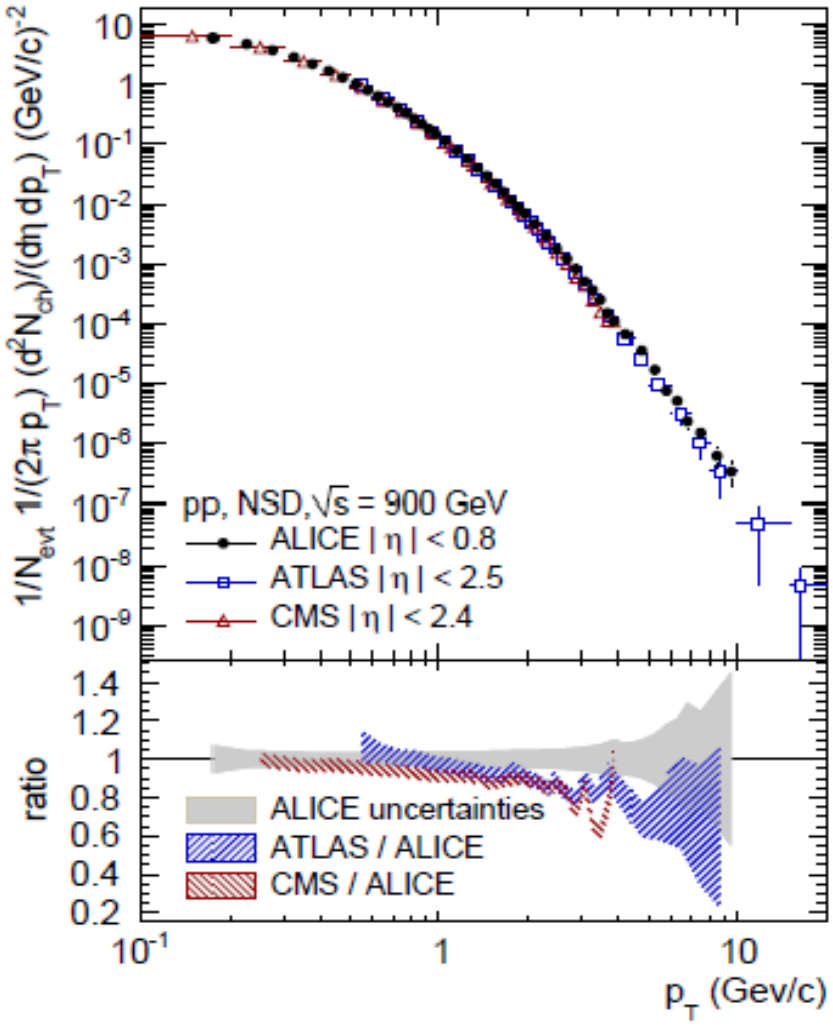
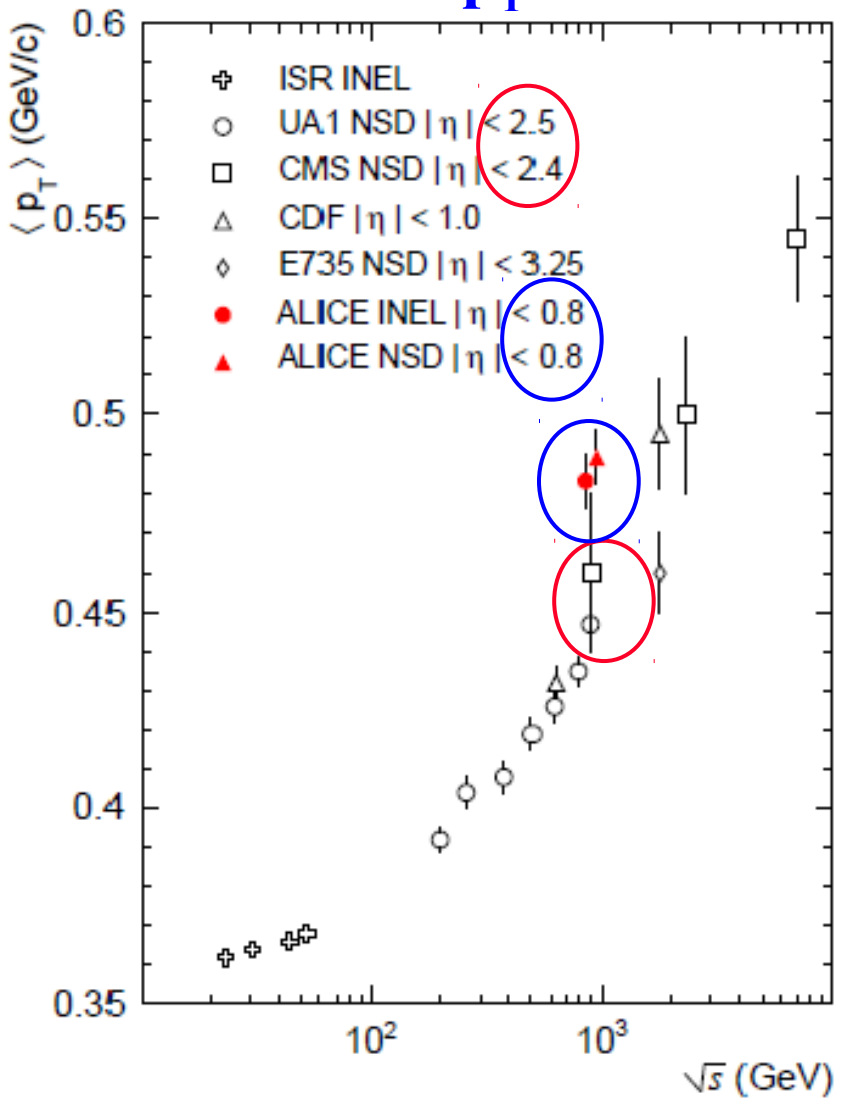


Momentum distributions at 900 GeV

p_T distribution



$\langle p_T \rangle$



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	p_T		$p_T>4$ GeV/c	$p_T>1$ GeV/c	$p_T>1$ GeV/c
	$\langle p_T \rangle$				
	K^0_S, Λ, $\bar{\Lambda}$				
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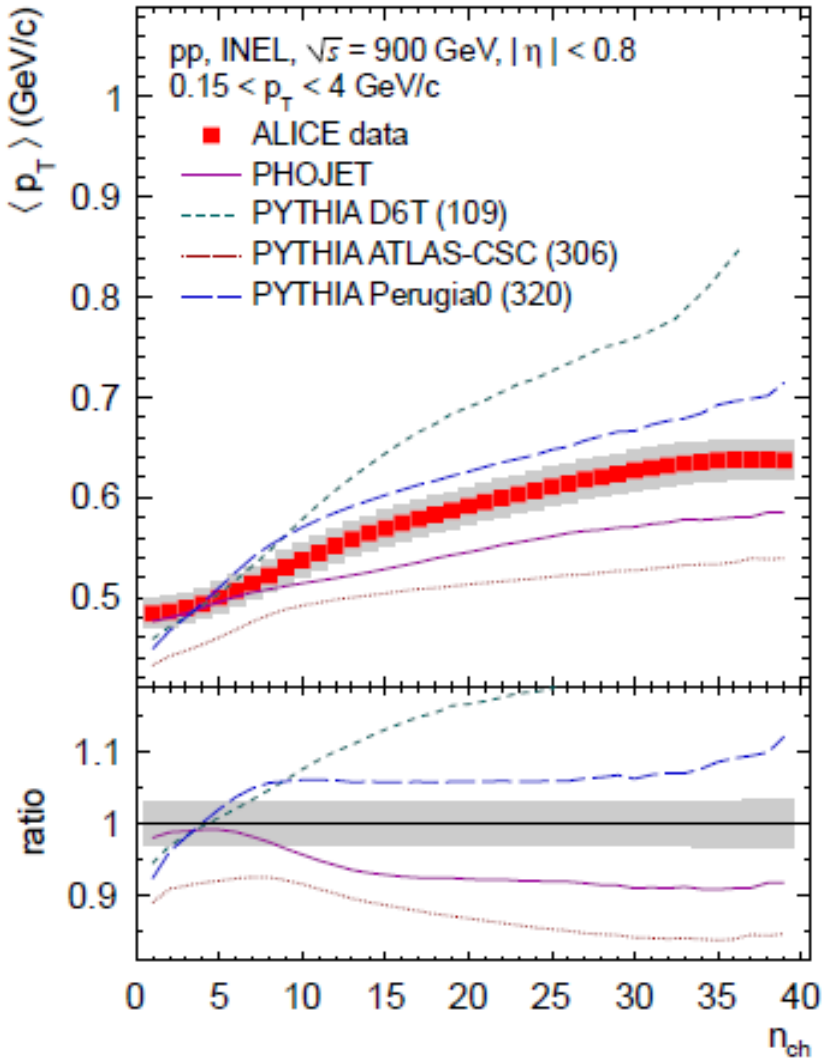
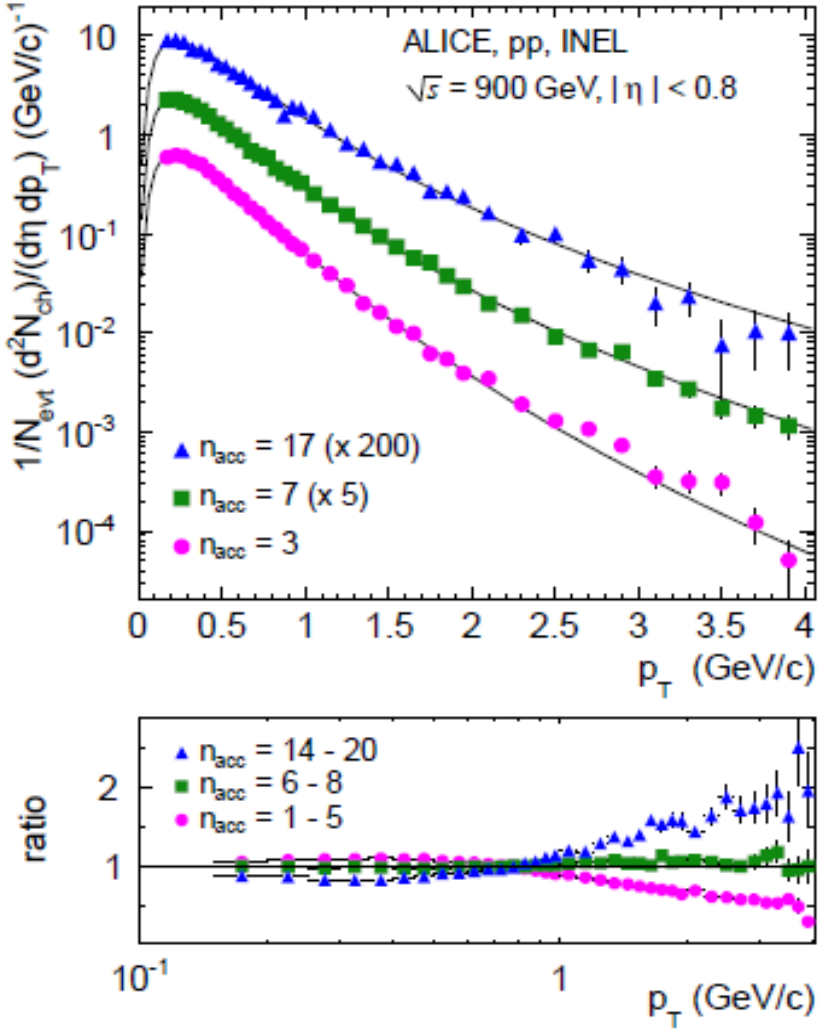
	N_{ch}			$N_{ch}>30$	

MC << Data | MC ≈ Data | MC >> Data

$\langle p_T \rangle$ versus multiplicity





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	$\langle p_T \rangle$				$p_T>1$ GeV/c
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	N_{ch}			$N_{ch}>30$	

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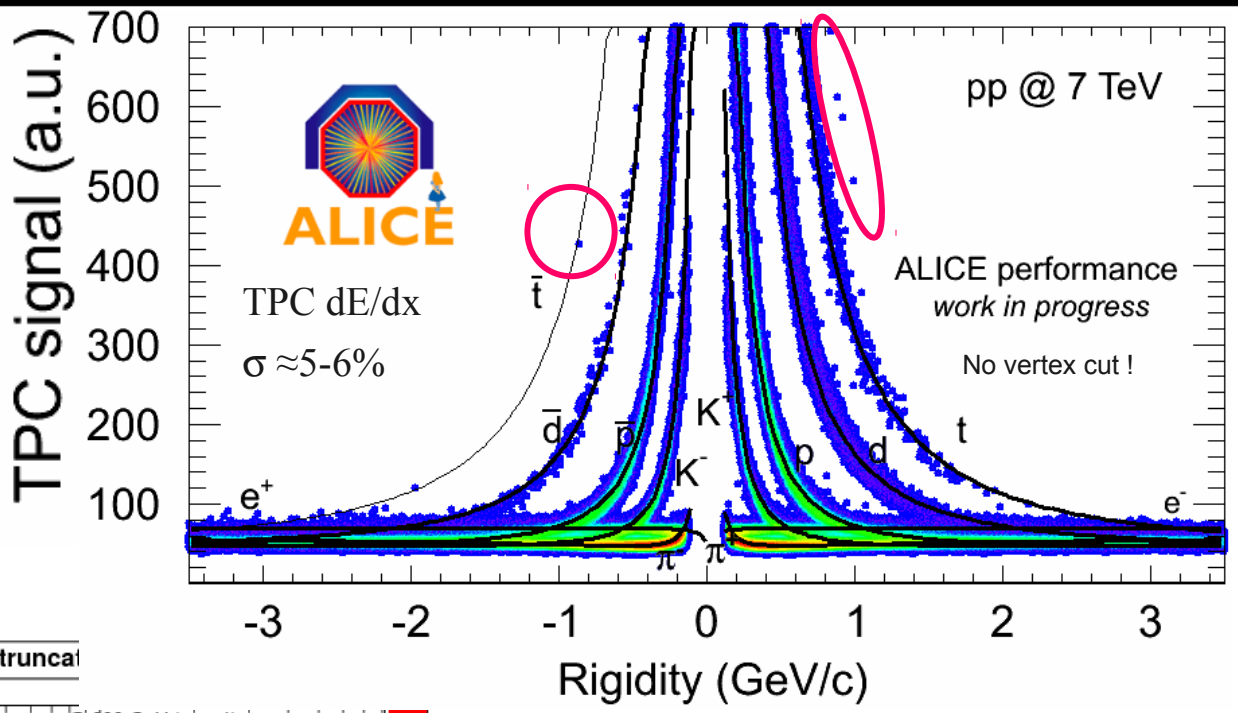
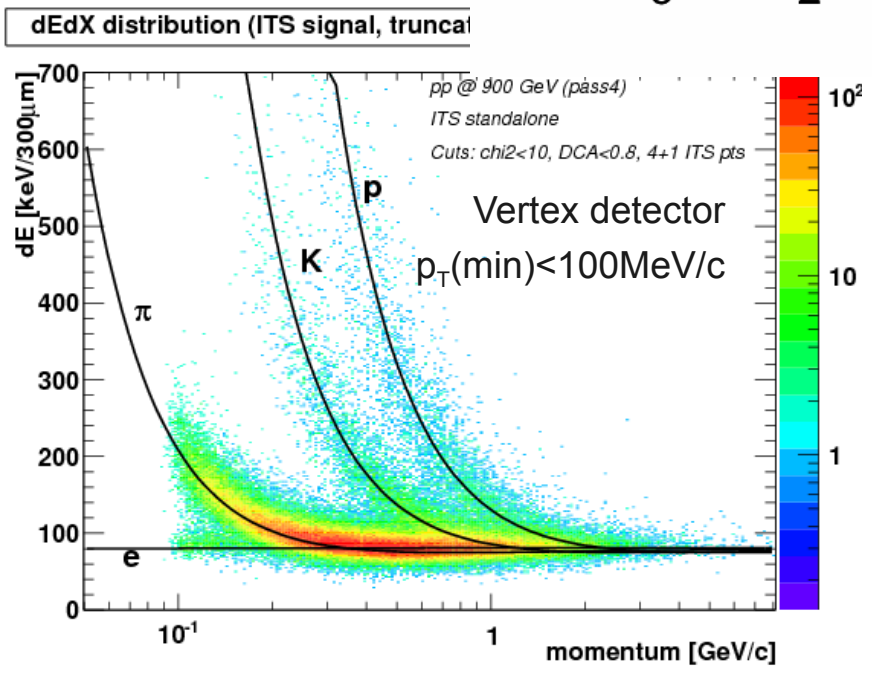
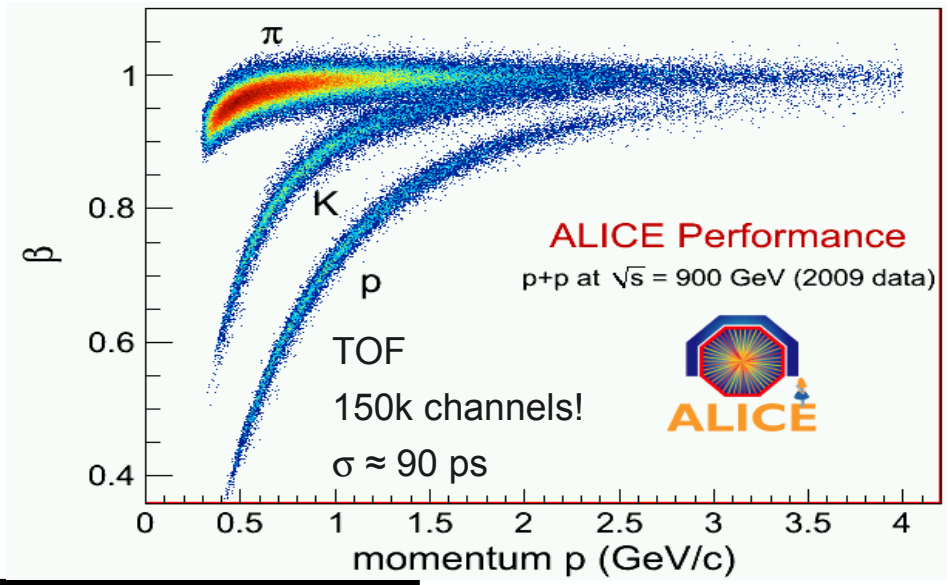
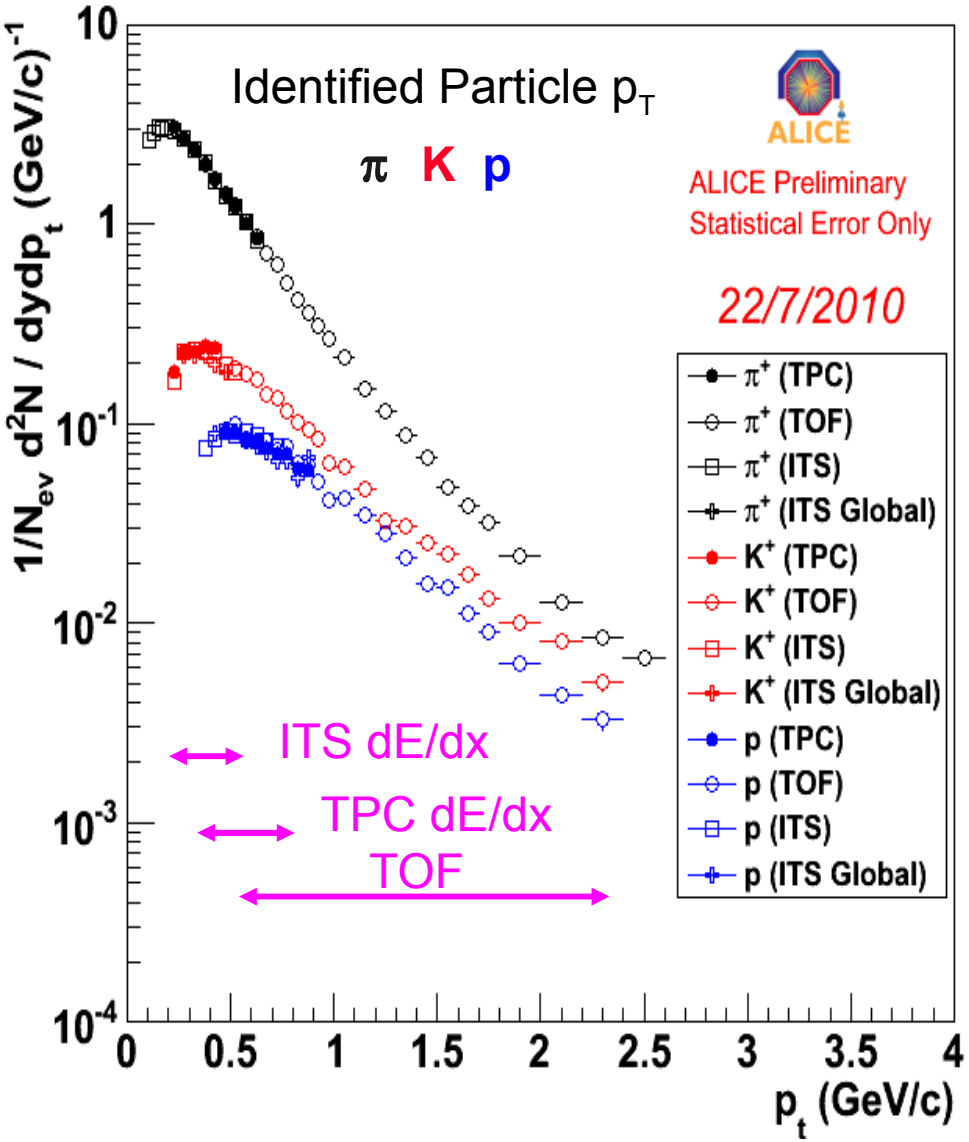
Particle identification







Identified particle spectra



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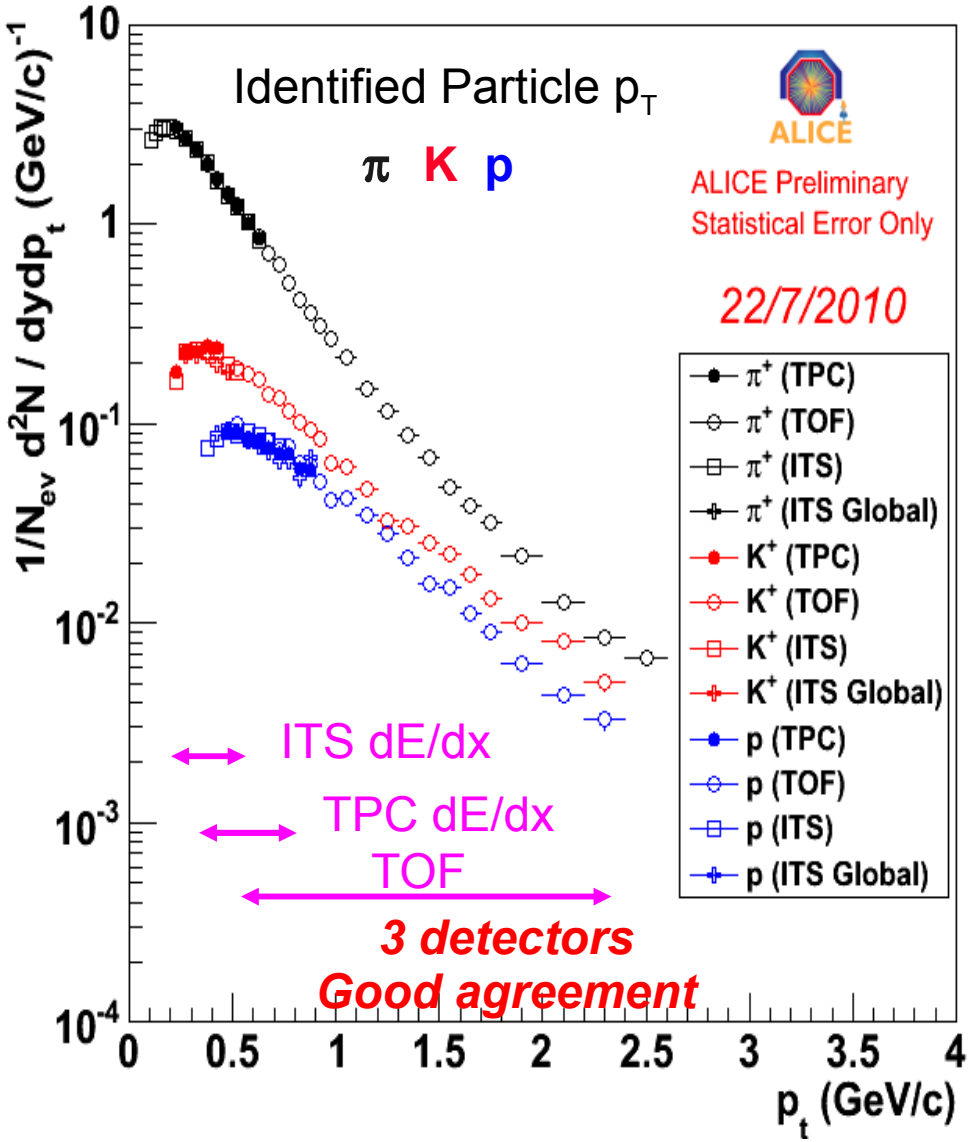

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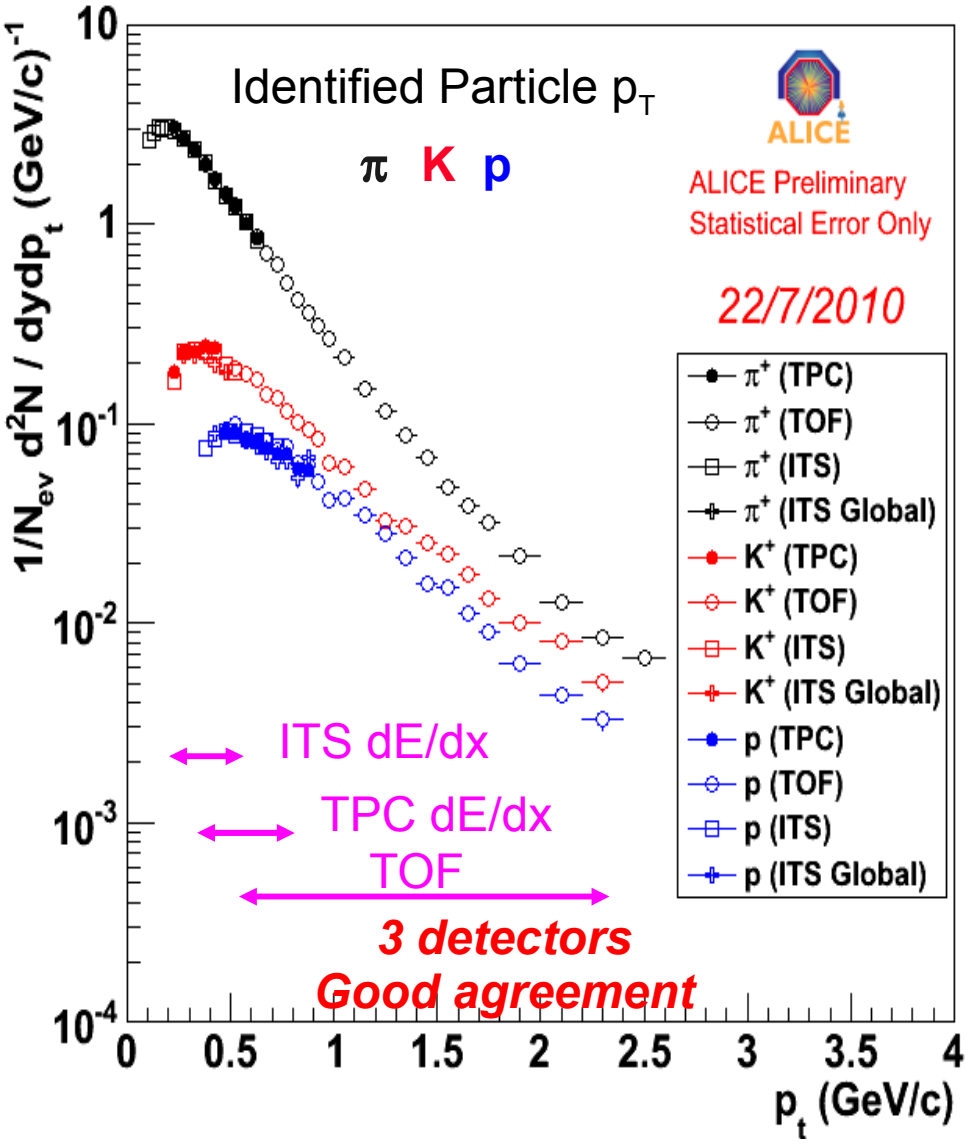

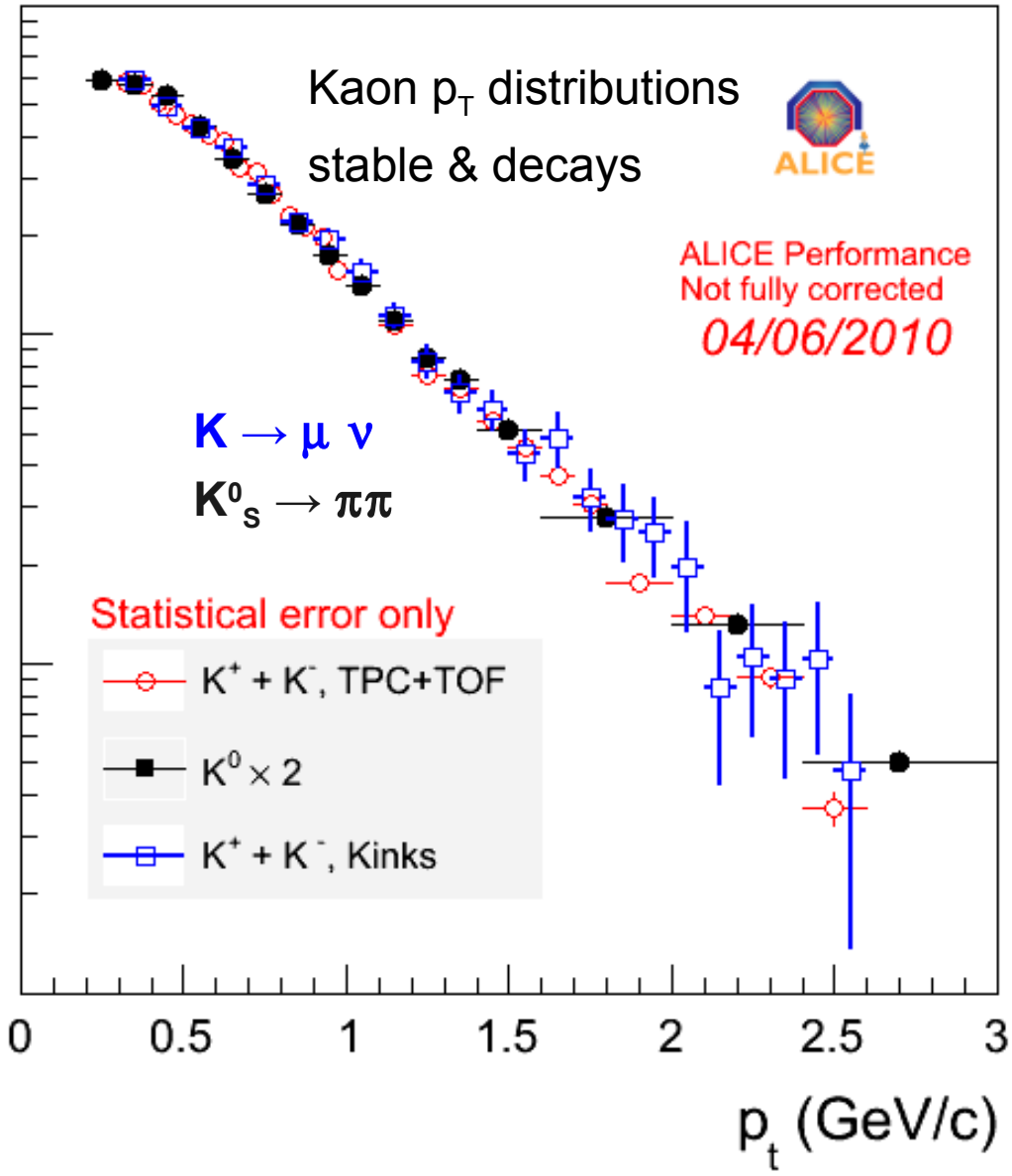

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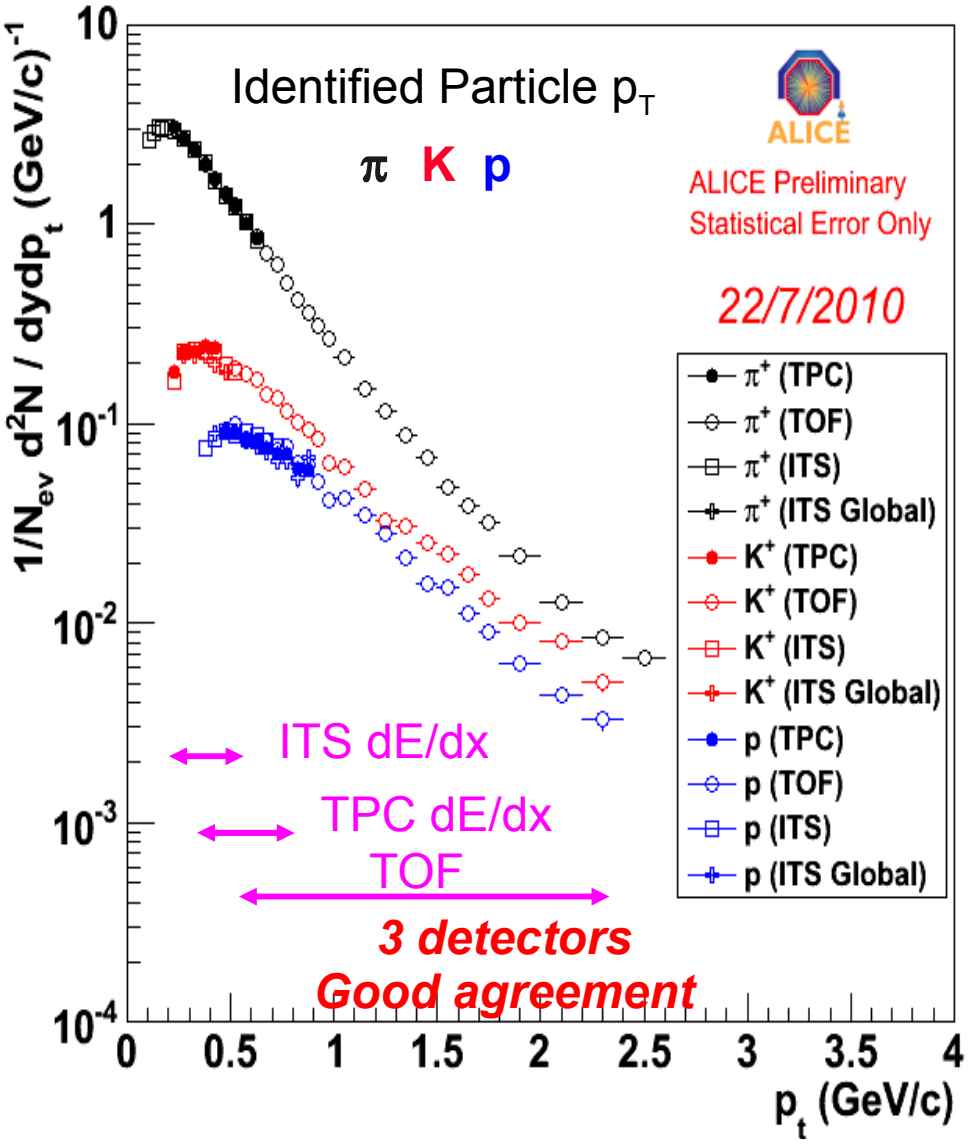
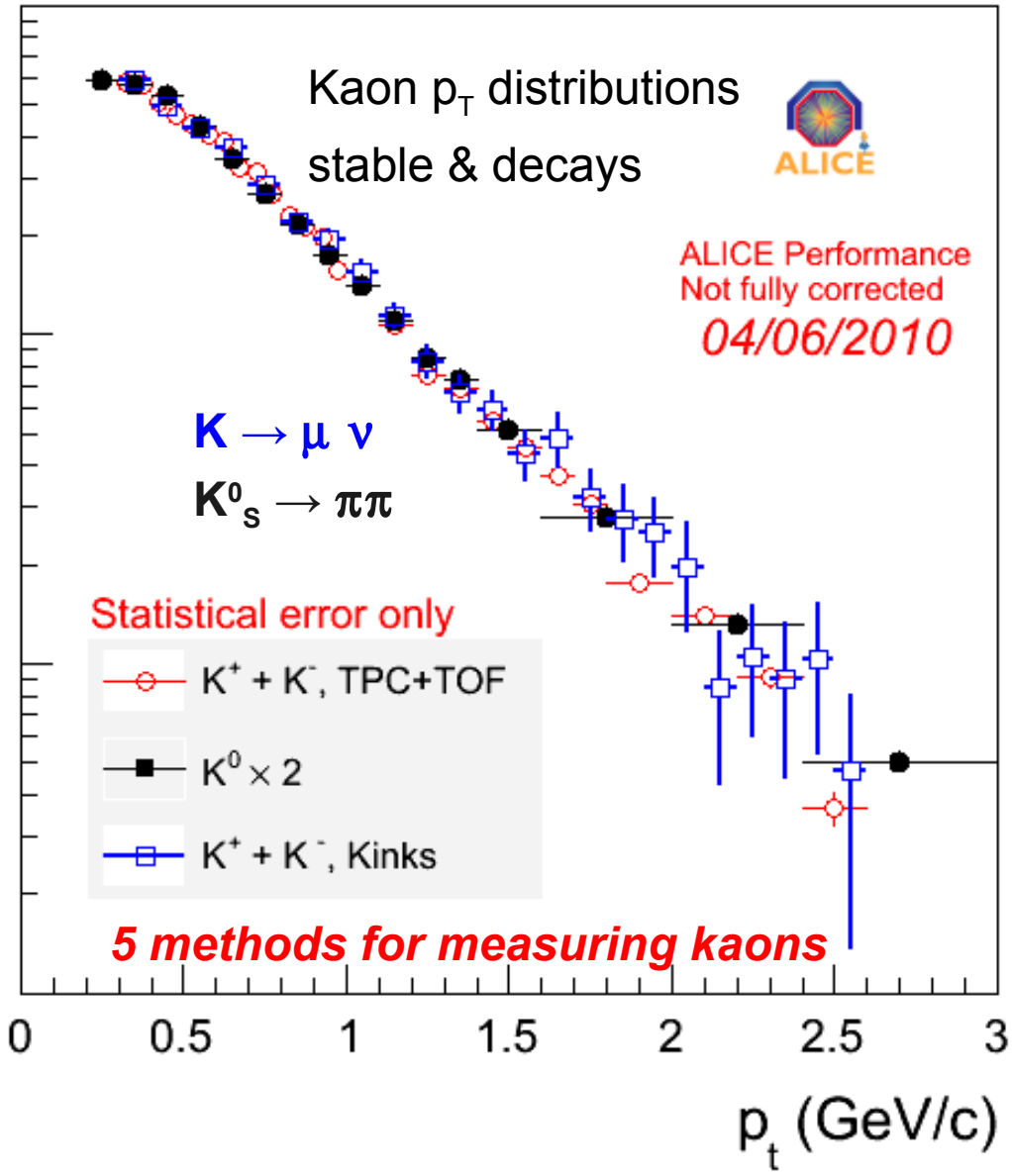
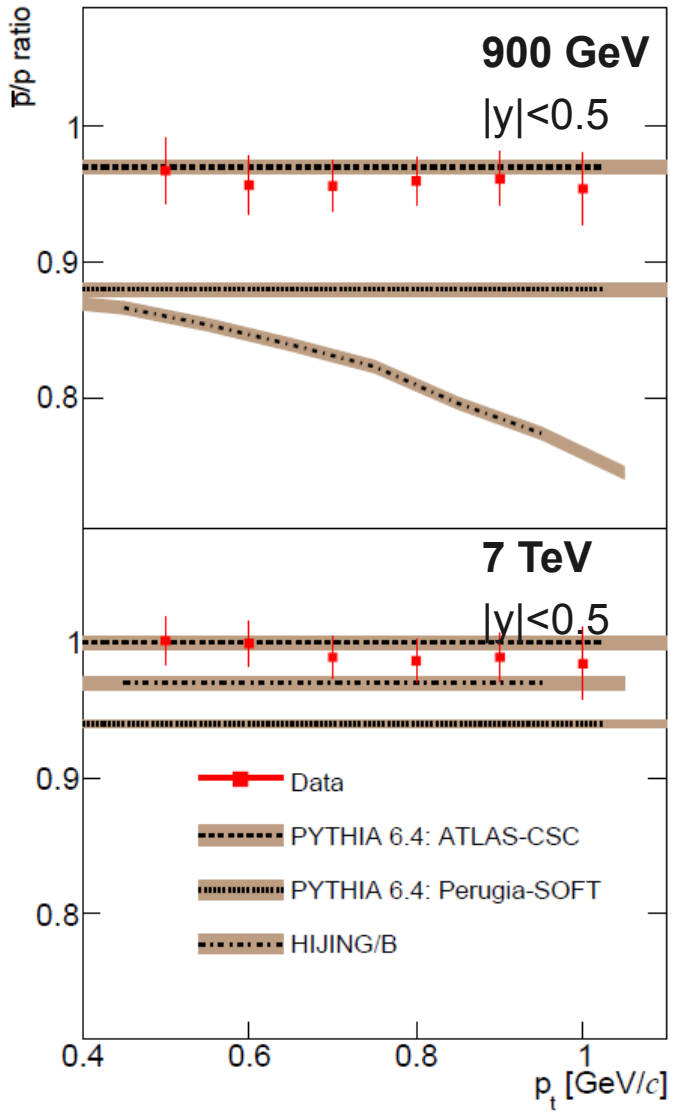
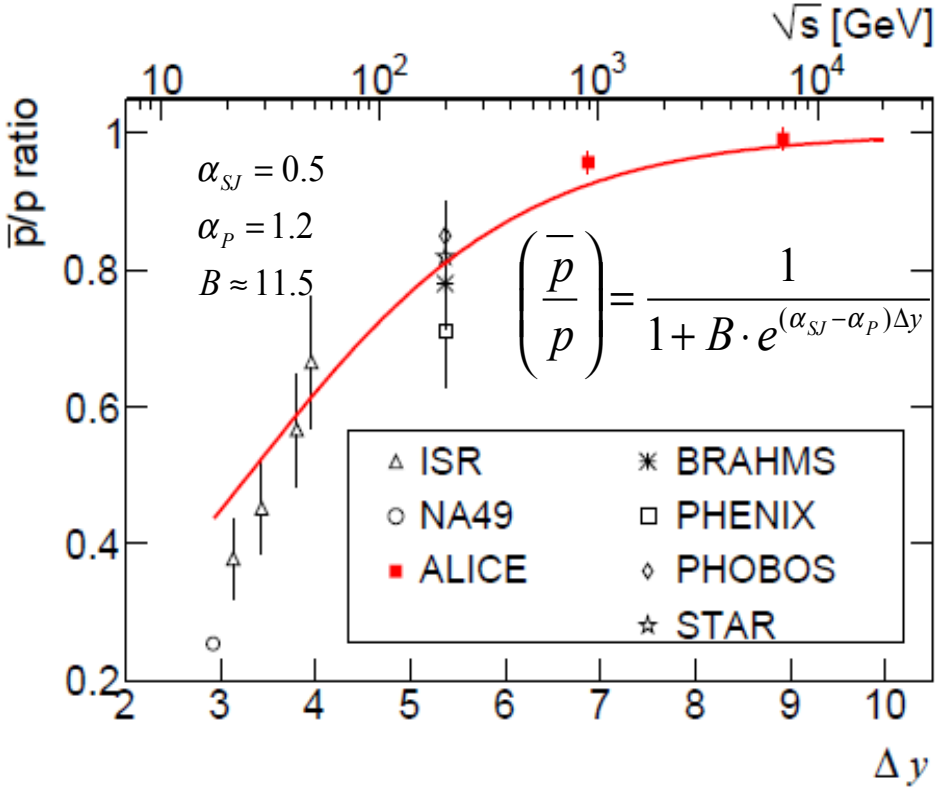




$\bar{p}/p$ ratio

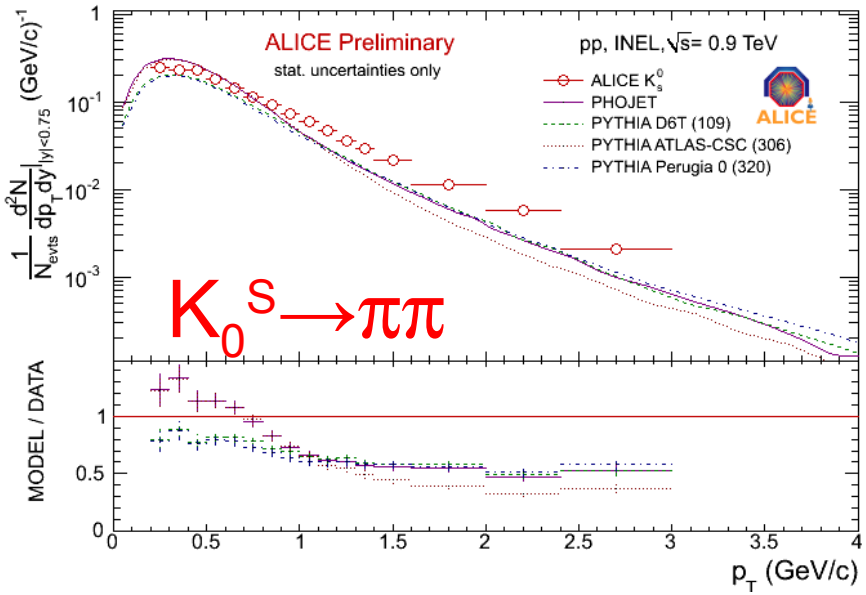




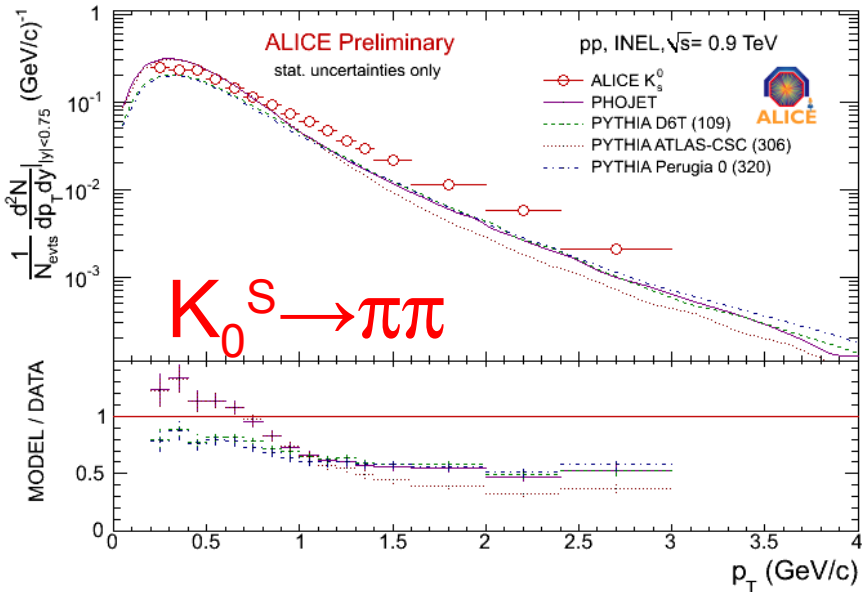
0.9 TeV: $\bar{p}/p$ = **0.957**±0.006(stat) ±0.014(syst)

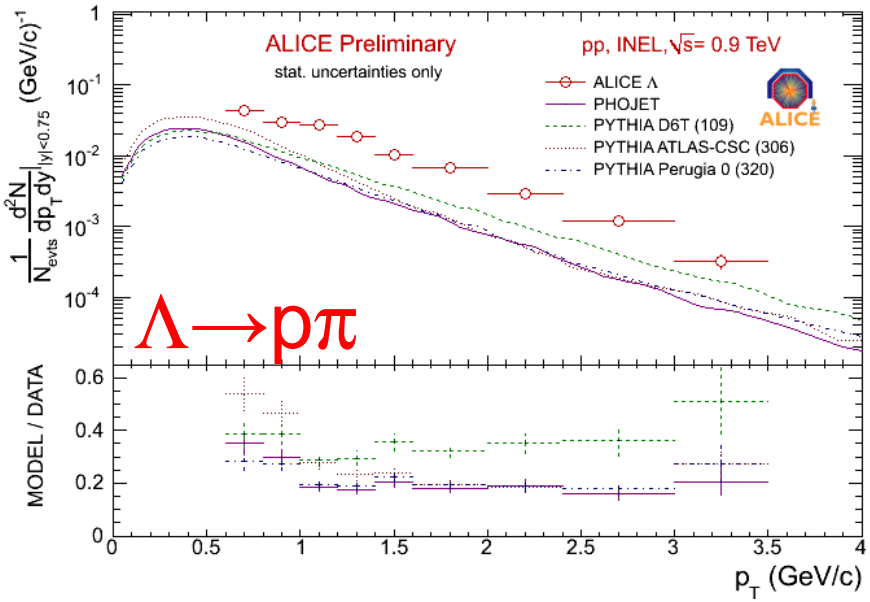
7 TeV: $\bar{p}/p$ = **0.990**±0.006(stat) ±0.014(syst)

Strange particles at 900 GeV



Strange particles at 900 GeV





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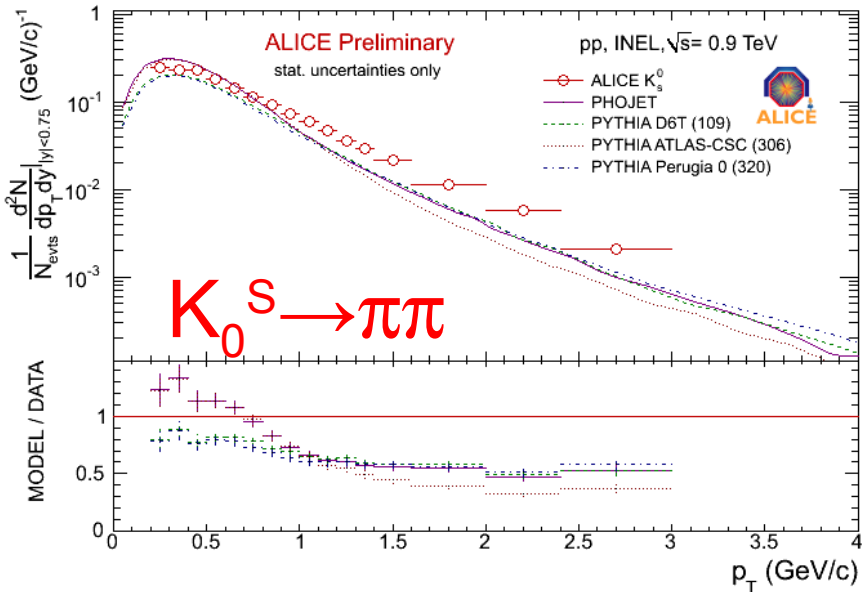

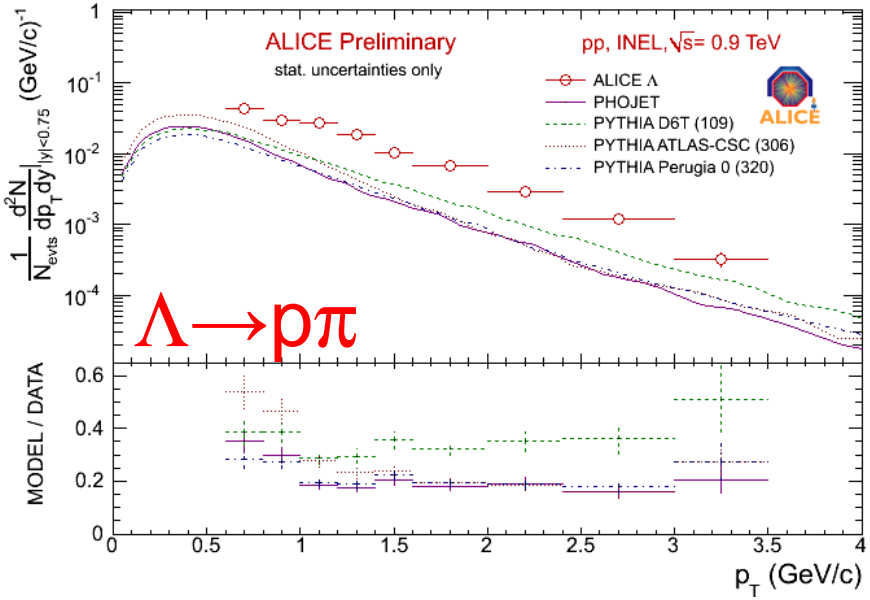

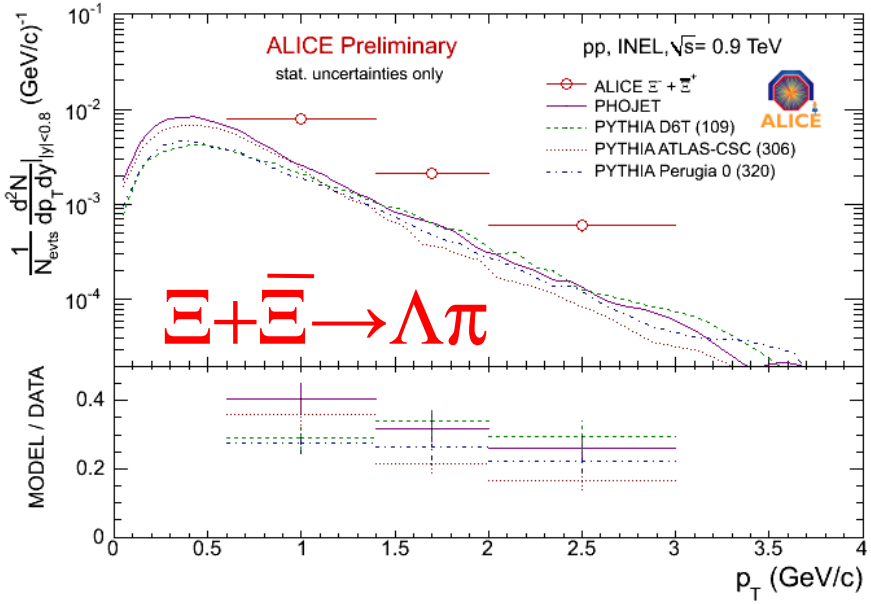

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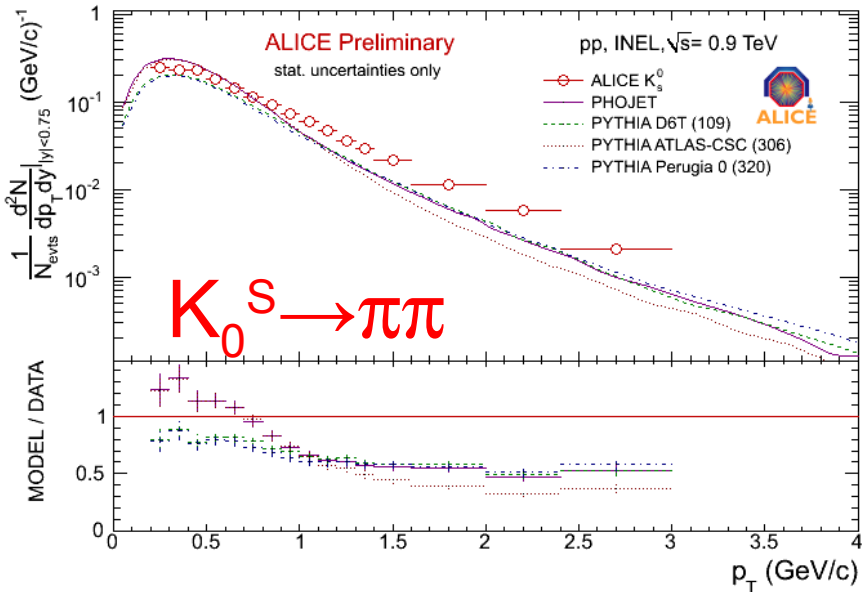

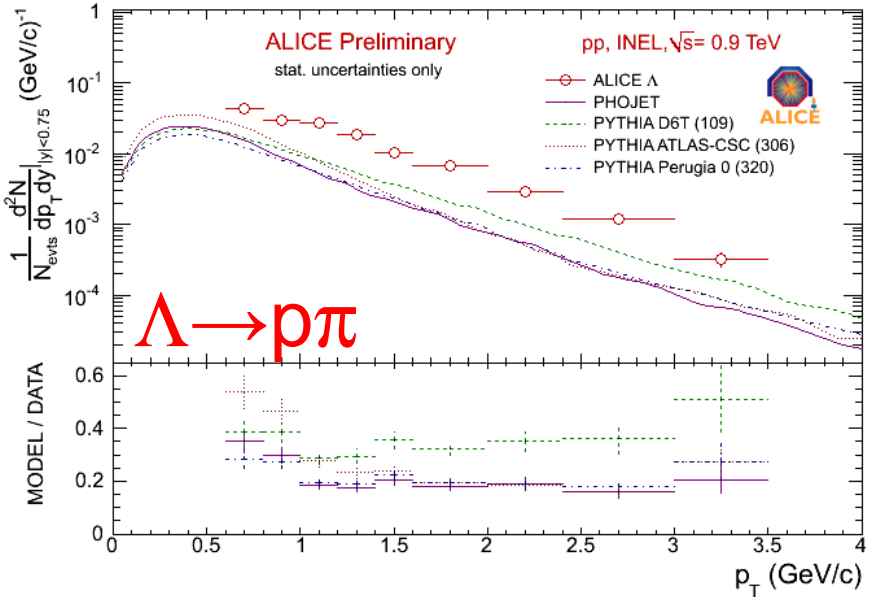

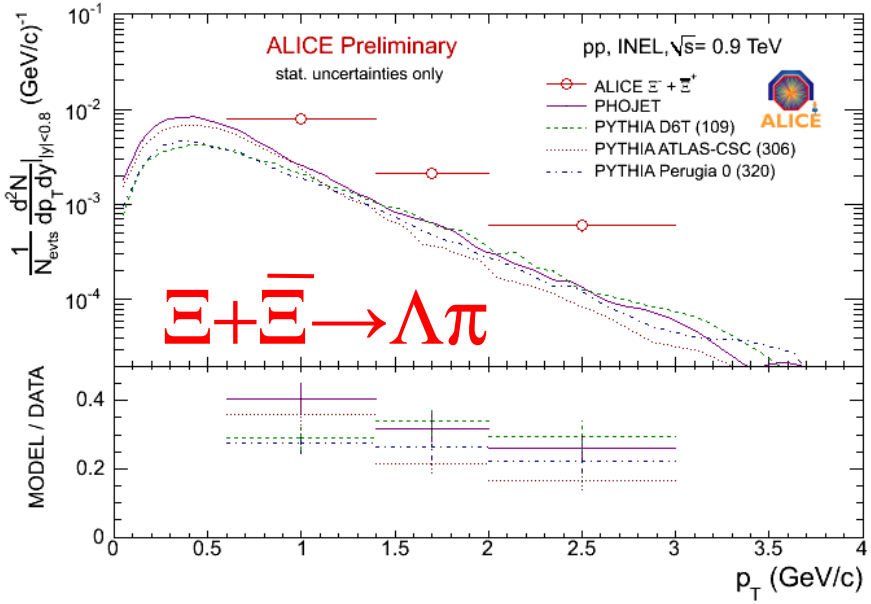

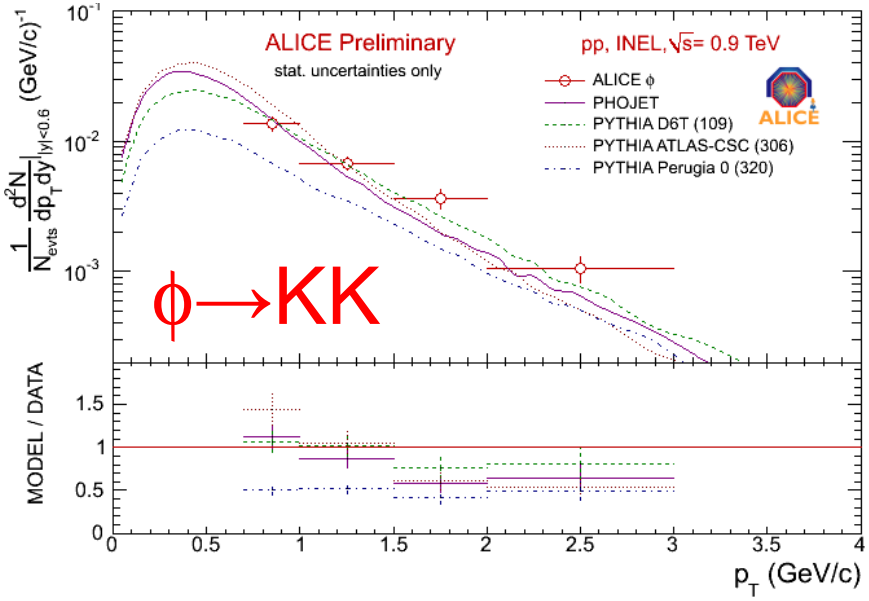

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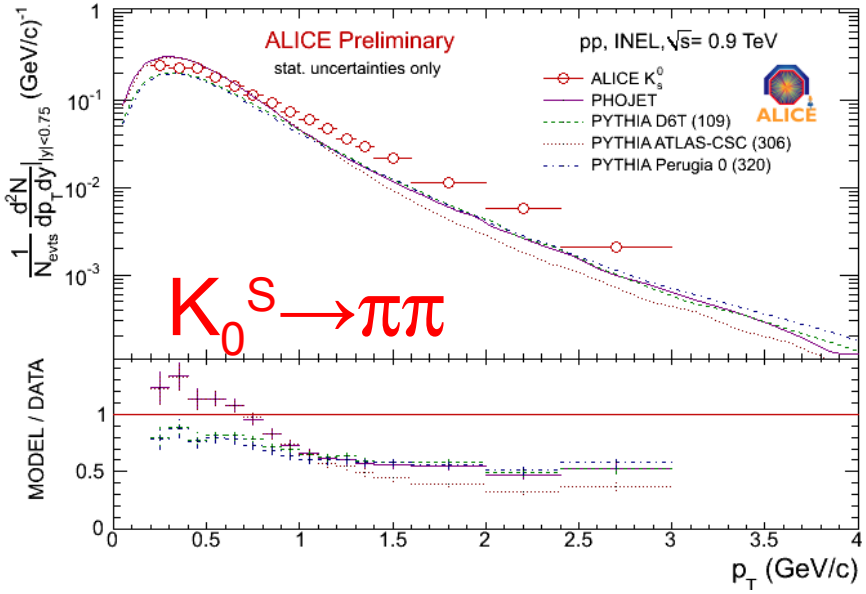

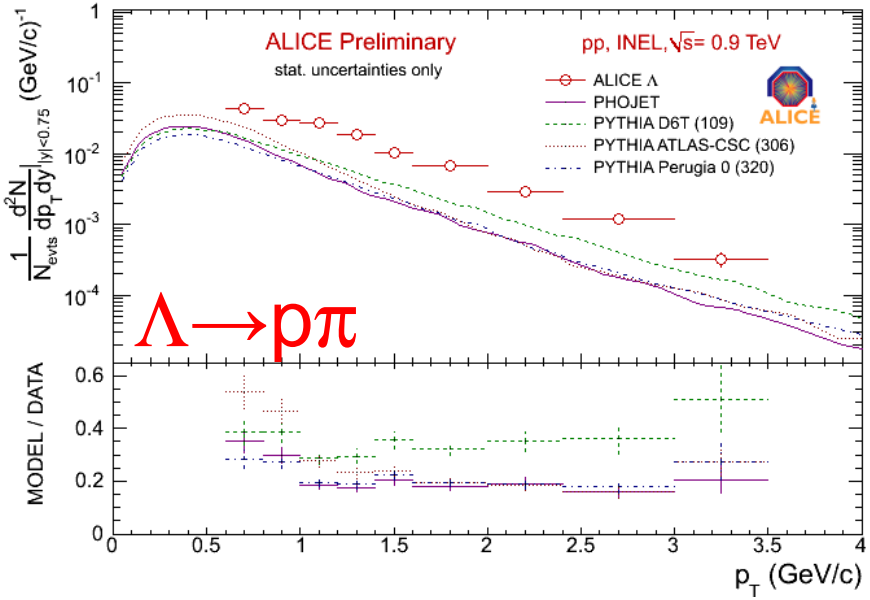

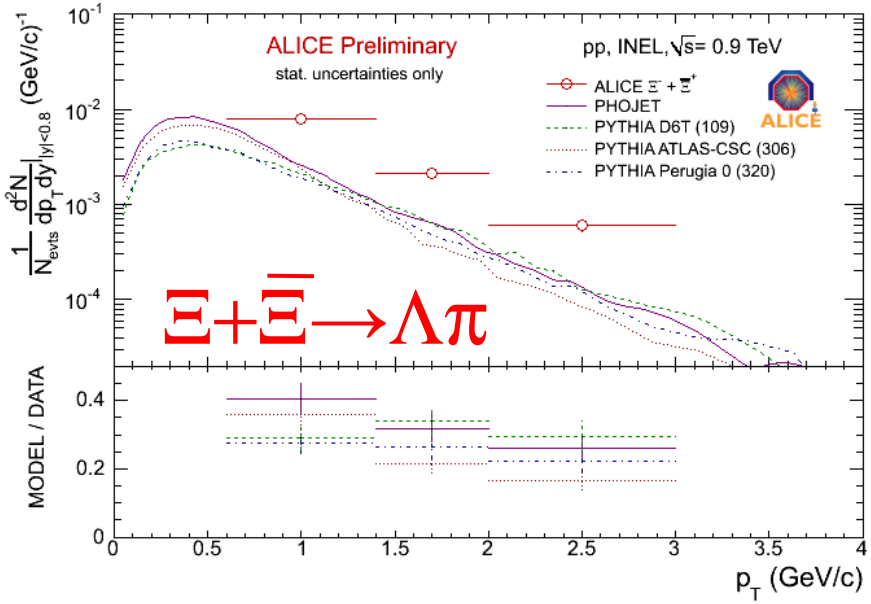

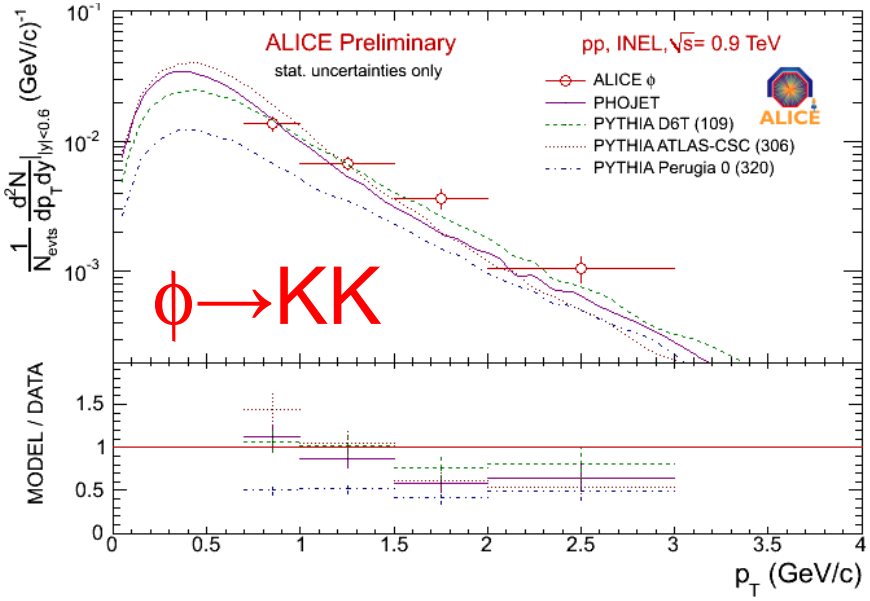

- PYTHIA and PHOJET consistently below data

Monte Carlo scoreboard

	variable/tune	D6T	Perugia0	CSC	PHOJET
900 GeV	$dN_{ch}/d\eta$	-20%	-17%	+3%	-2%
	N_{ch}	$N_{ch}>10$	$N_{ch}>5$	$N_{ch}>15$	$N_{ch}>10$
	p_T		$p_T>4$ GeV/c	$p_T>1$ GeV/c	$p_T>1$ GeV/c
	$<p_T>$				$p_T>1$ GeV/c
	$K^0_S, \Lambda, \bar{\Lambda}$				
	φ				
2.36 TeV	$dN_{ch}/d\eta$	-24%	-21%	-2%	-8%
	N_{ch}	$N_{ch}>10$	$N_{ch}>5$	$N_{ch}>20$	$N_{ch}>15$
7 TeV	$dN_{ch}/d\eta$	-27%	-24%	-4%	-17%
	N_{ch}			$N_{ch}>30$	

MC <<<< Data | MC << Data | MC ≈ Data | MC >> Data

Monte Carlo scoreboard

	variable/tune	D6T	Perugia0	CSC	PHOJET
900 GeV	$dN_{ch}/d\eta$	-20%	-17%	+3%	-2%
	N_{ch}	$N_{ch}>10$	$N_{ch}>5$	$N_{ch}>15$	$N_{ch}>10$
	p_T		$p_T>4$ GeV/c	$p_T>1$ GeV/c	$p_T>1$ GeV/c
	$<p_T>$				$p_T>1$ GeV/c
	$K^0_S, \Lambda, \bar{\Lambda}$				
	φ				
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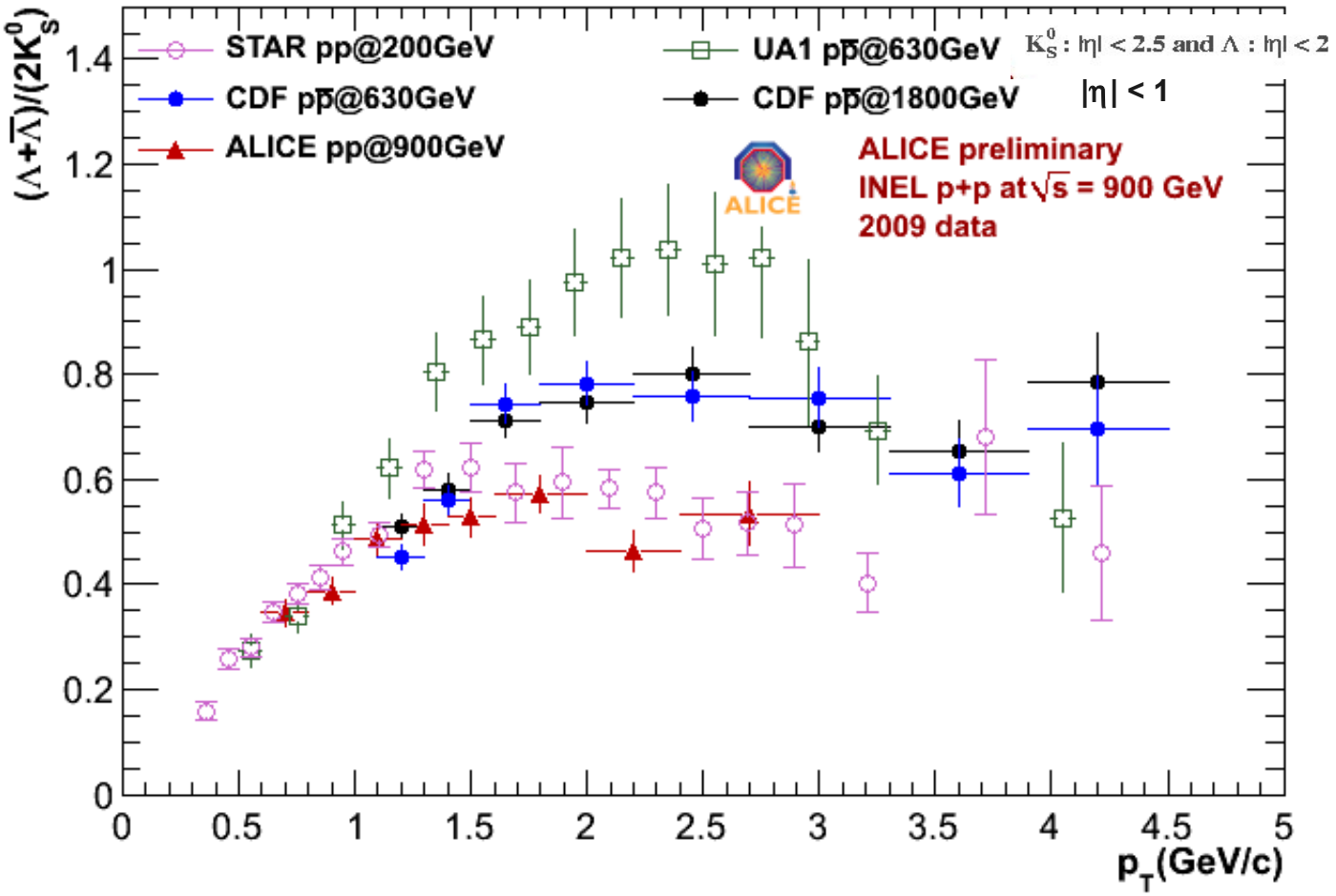
	N_{ch}			$N_{ch}>30$	

MC <<<< Data | MC << Data | MC ≈ Data | MC >> Data

Conclusion:
- None of the tested MC's (adjusted at lower energy) does really well
- Tuning one or two results is doable, getting everything right will require more effort

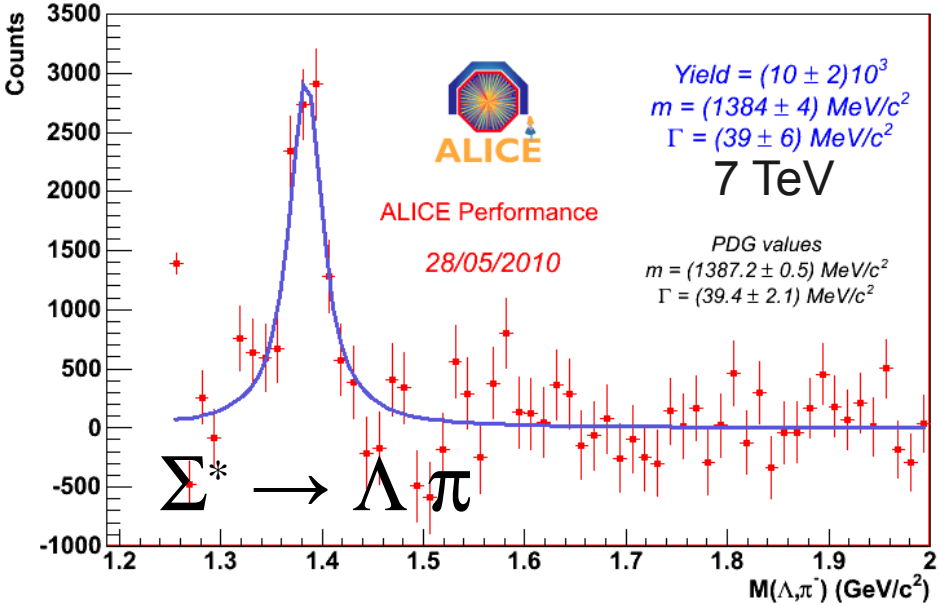
(and may, with some luck, actually teach us something on soft QCD rather than only turning knobs).

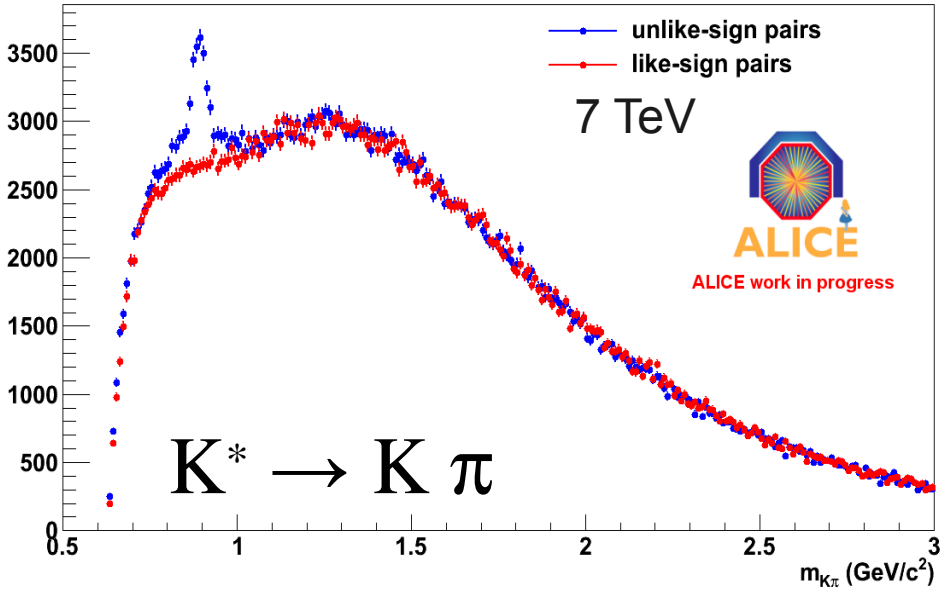
Λ/K_0^S ratio at 900 GeV

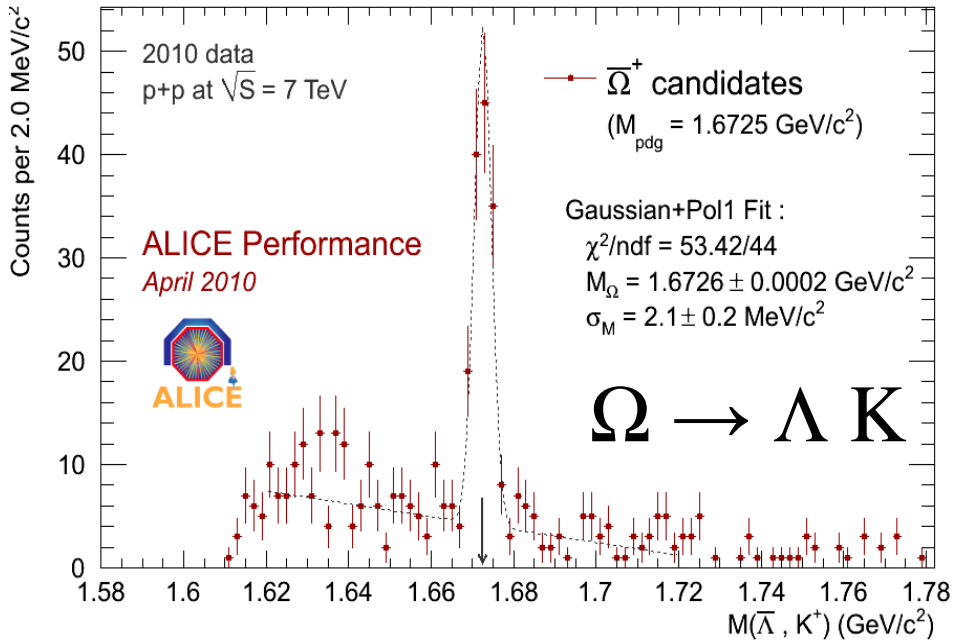


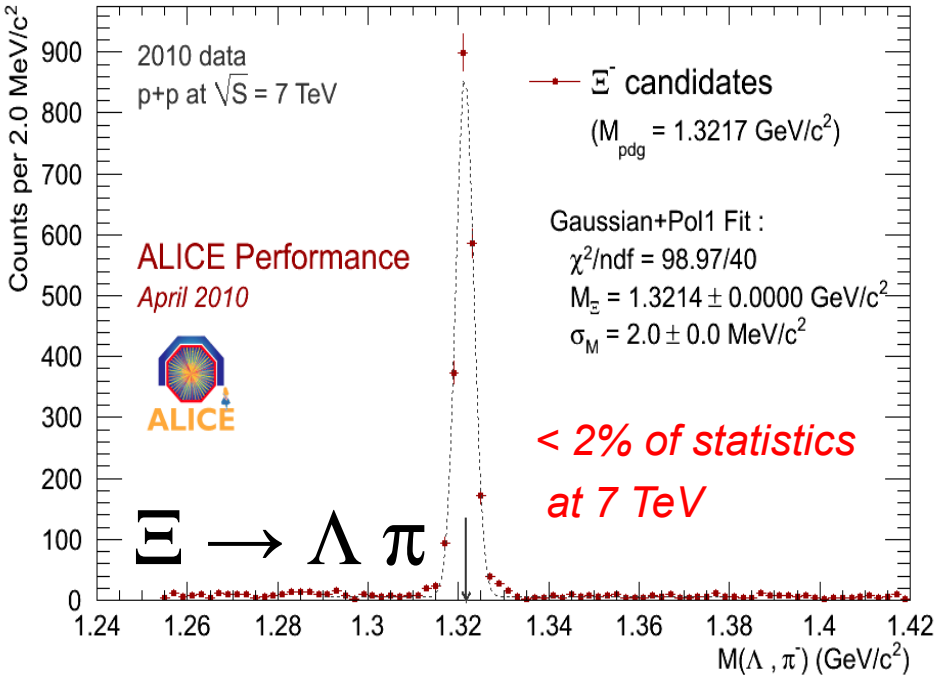
- Very good agreement between STAR (200 GeV) and ALICE (900 GeV)
- Very different from CDF (630/1800) and UA1 (630) for $p_T > 1.5$ GeV
- - UA1(630) and CDF(630) don't agree either …
  - Different triggers, acceptance, feed-down correction?

More to come...


Counts
ALICE
ALICE Performance
28/05/2010
Yield = (10 ± 2)10³
m = (1384 ± 4) MeV/c²
Γ = (39 ± 6) MeV/c²
7 TeV
PDG values
m = (1387.2 ± 0.5) MeV/c²
Γ = (39.4 ± 2.1) MeV/c²
Σ* → Λ π
M(Λ,π⁻) (GeV/c²)


unlike-sign pairs
like-sign pairs
7 TeV
ALICE
ALICE work in progress
K* → K π
m_Kπ (GeV/c²)


Counts per 2.0 MeV/c²
2010 data
p+p at √S = 7 TeV
Ω̄⁺ candidates
(M_pdg = 1.6725 GeV/c²)
Gaussian+Pol1 Fit :
χ²/ndf = 53.42/44
M_Ω = 1.6726 ± 0.0002 GeV/c²
σ_M = 2.1 ± 0.2 MeV/c²
ALICE Performance
April 2010
ALICE
Ω → Λ K
M(Λ̄ , K⁺) (GeV/c²)


Counts per 2.0 MeV/c²
2010 data
p+p at √S = 7 TeV
Ξ⁻ candidates
(M_pdg = 1.3217 GeV/c²)
Gaussian+Pol1 Fit :
χ²/ndf = 98.97/40
M_Ξ = 1.3214 ± 0.0000 GeV/c²
σ_M = 2.0 ± 0.0 MeV/c²
ALICE Performance
April 2010
ALICE
< 2% of statistics
at 7 TeV
Ξ → Λ π
M(Λ , π⁻) (GeV/c²)

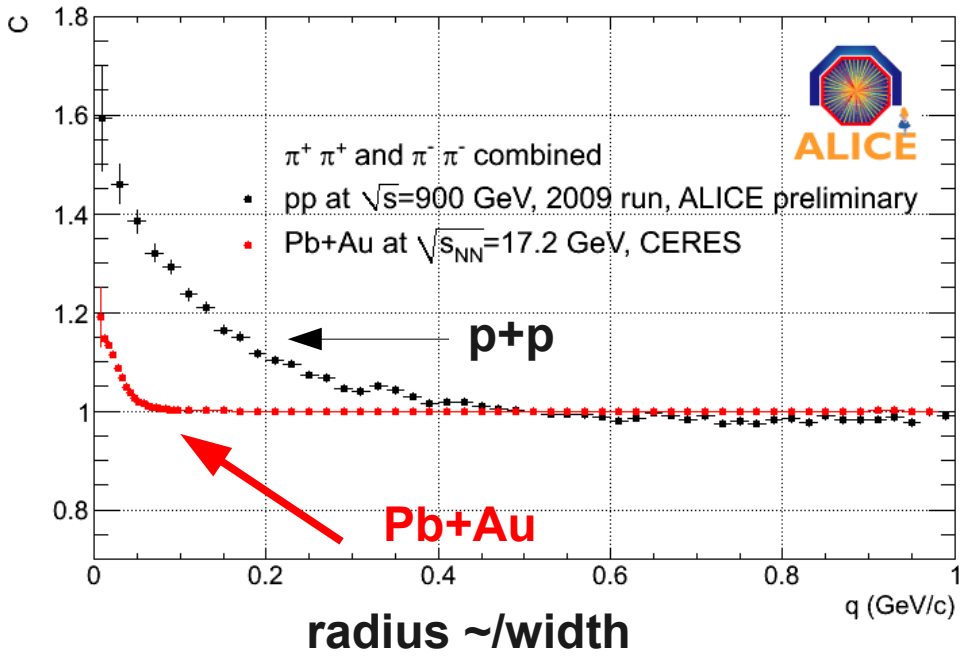
Bose-Einstein correlations

QM enhancement of identical Bosons at small momentum difference:

- Enhancement of e.g. like-sign pions at low momentum difference $q_{inv}=|p_1-p_2|$

➡ Measure the space-time evolution of the dense matter formed in heavy-ion collisions.

➡ Interpretation for "small systems" (p+p, $e^+ + e^-$) is less obvious...



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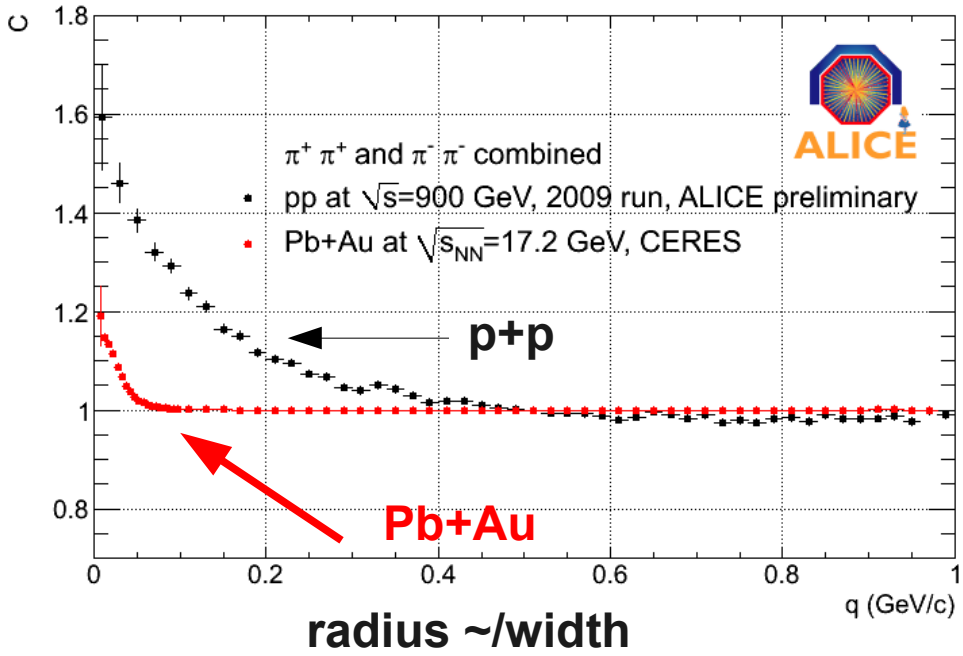
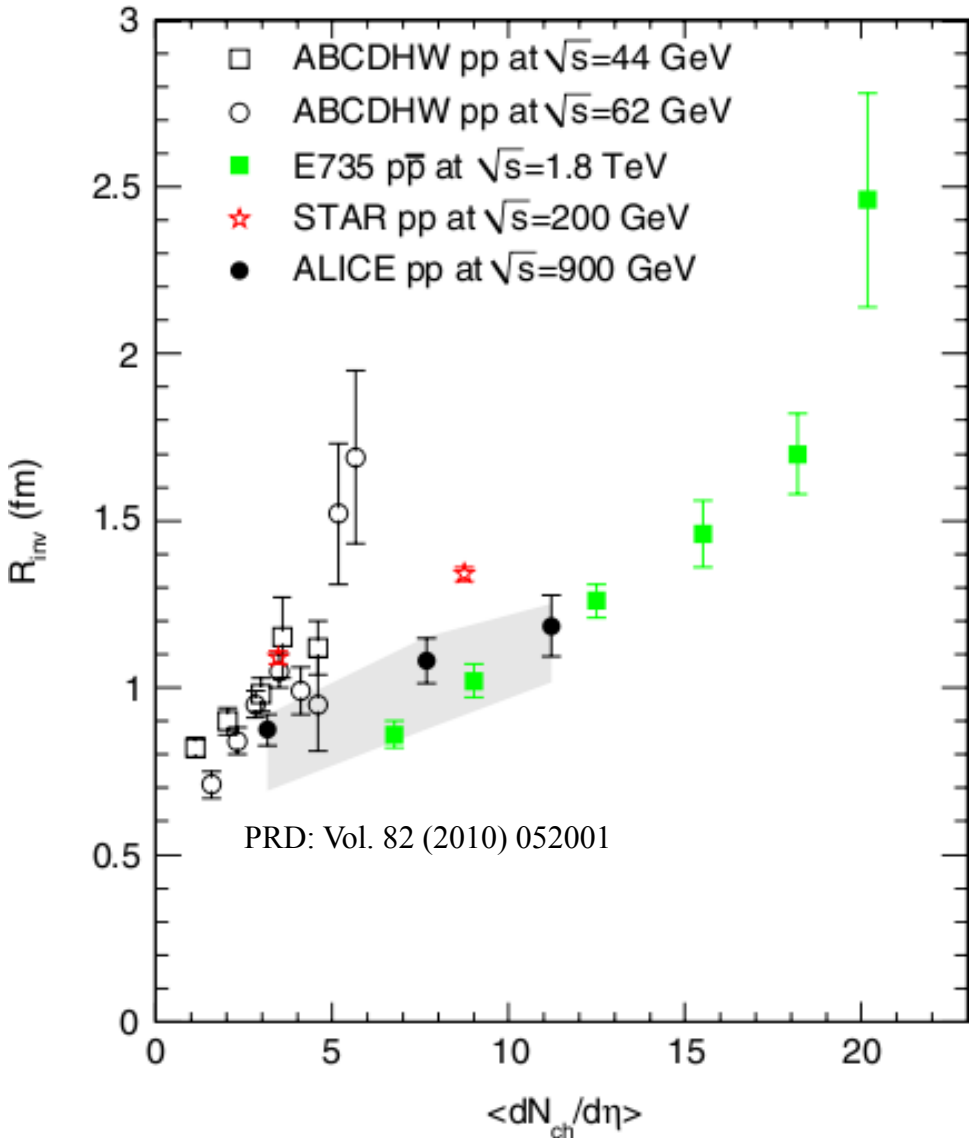
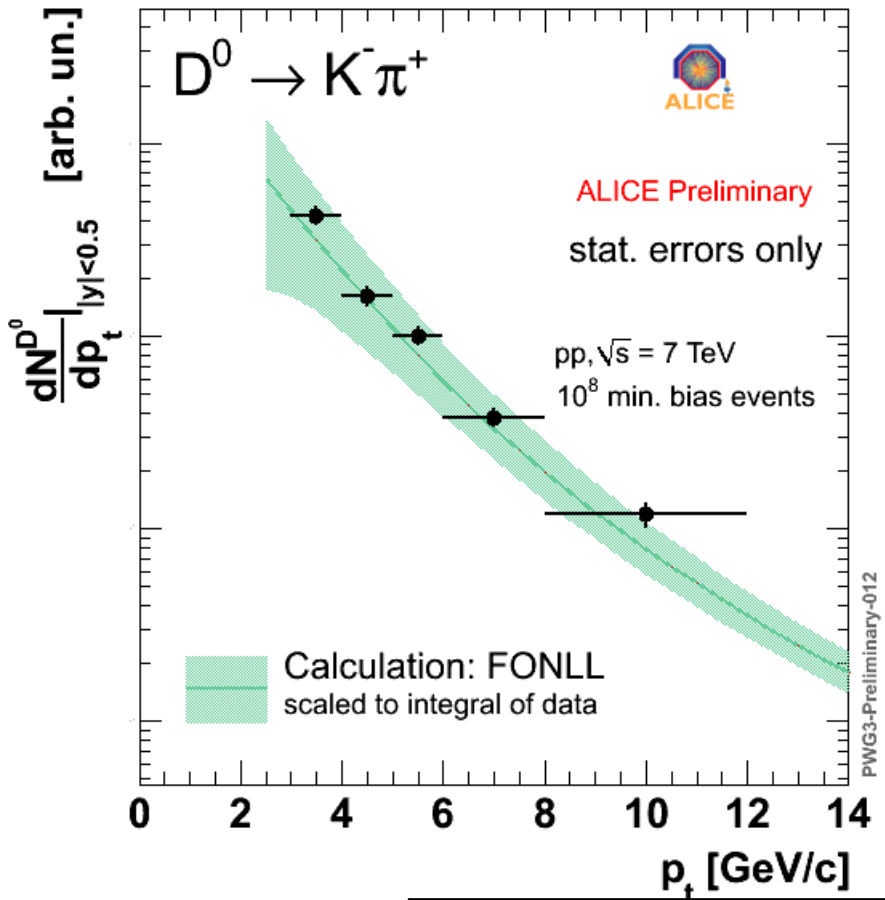


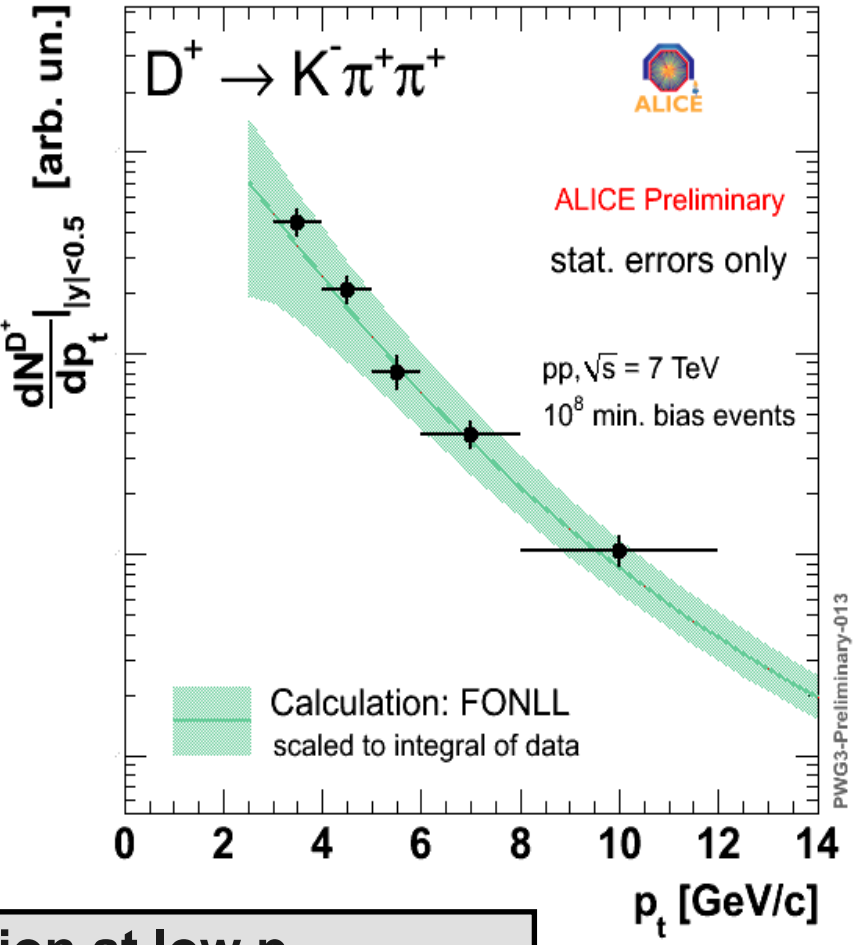
radius ~/width



Source radius vs N_{ch}

D^0 and D^+ dN/dp_t



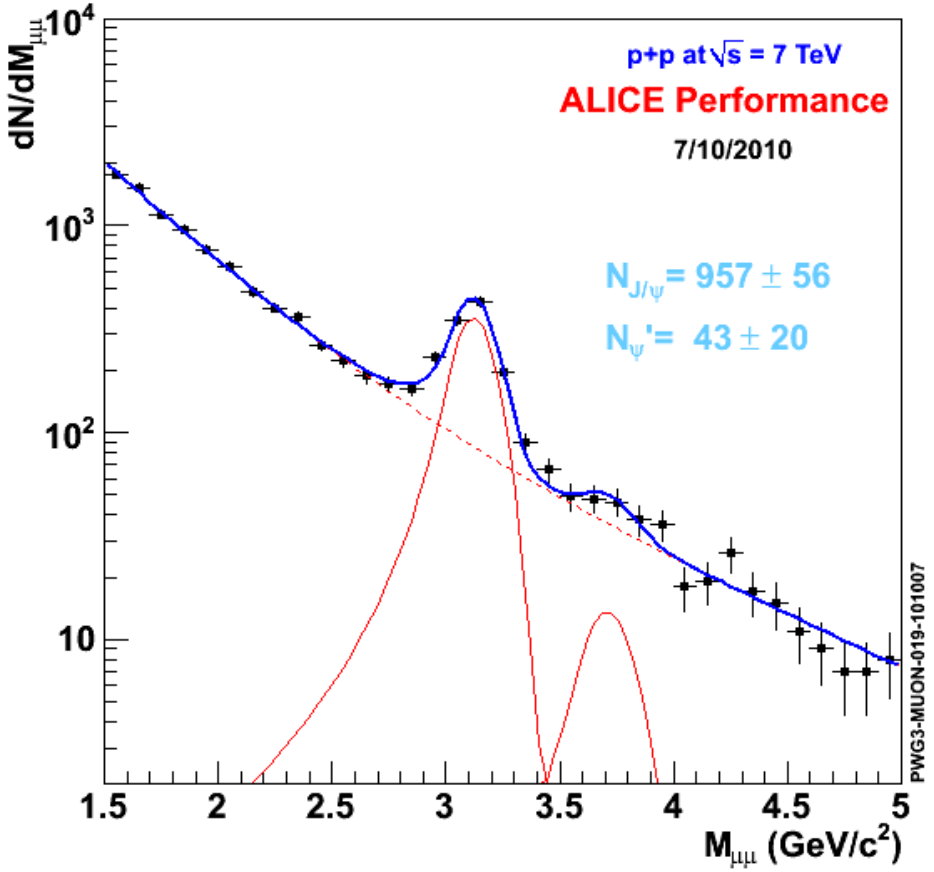


- Most of the cross section at low p_T
- Shape at low p_T very uncertain
- 10^9 MB events => measure below 1 GeV

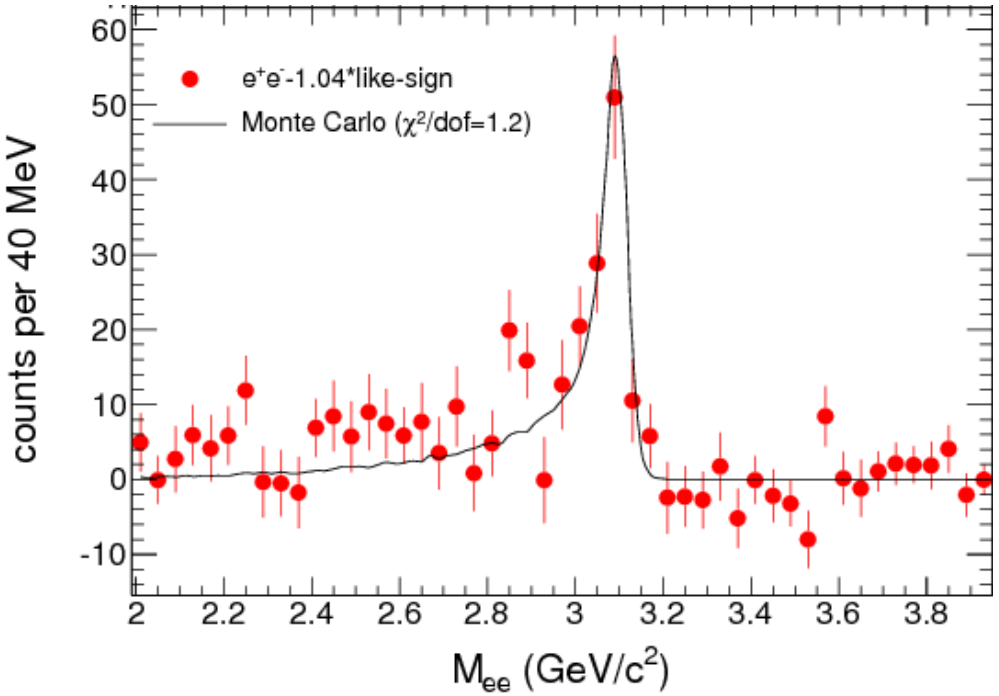
  (PID important at low p_T !)

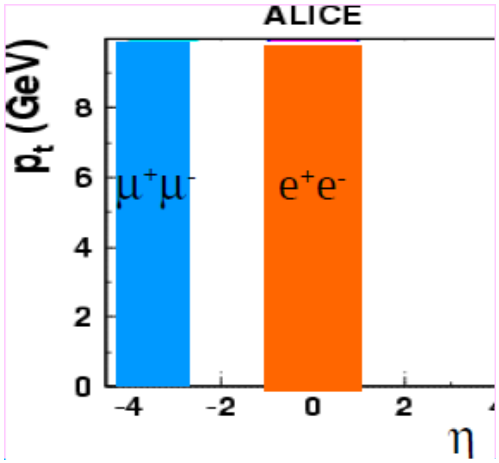
J/ψ production at 7 TeV

J/ψ → μ⁺μ⁻, y = 2.5–4.0



J/ψ → e⁺e⁻ |y| < 1



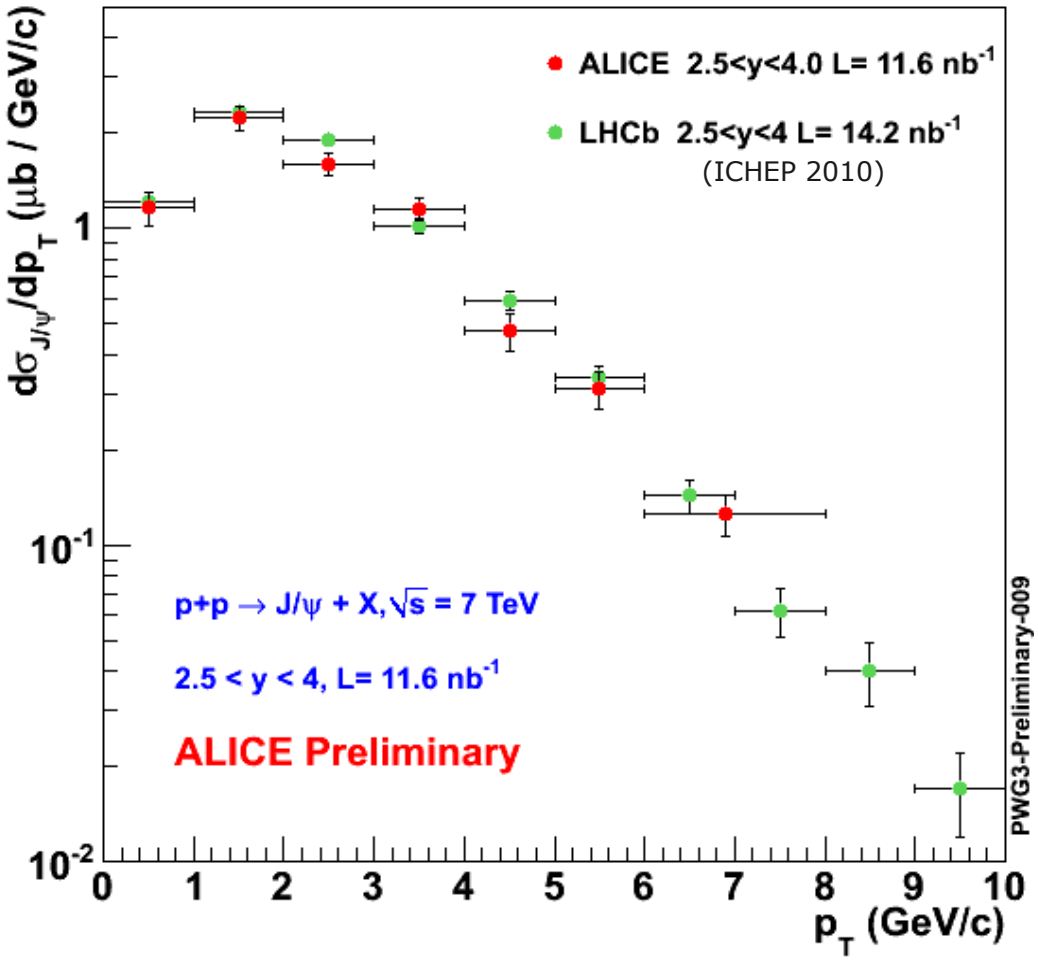


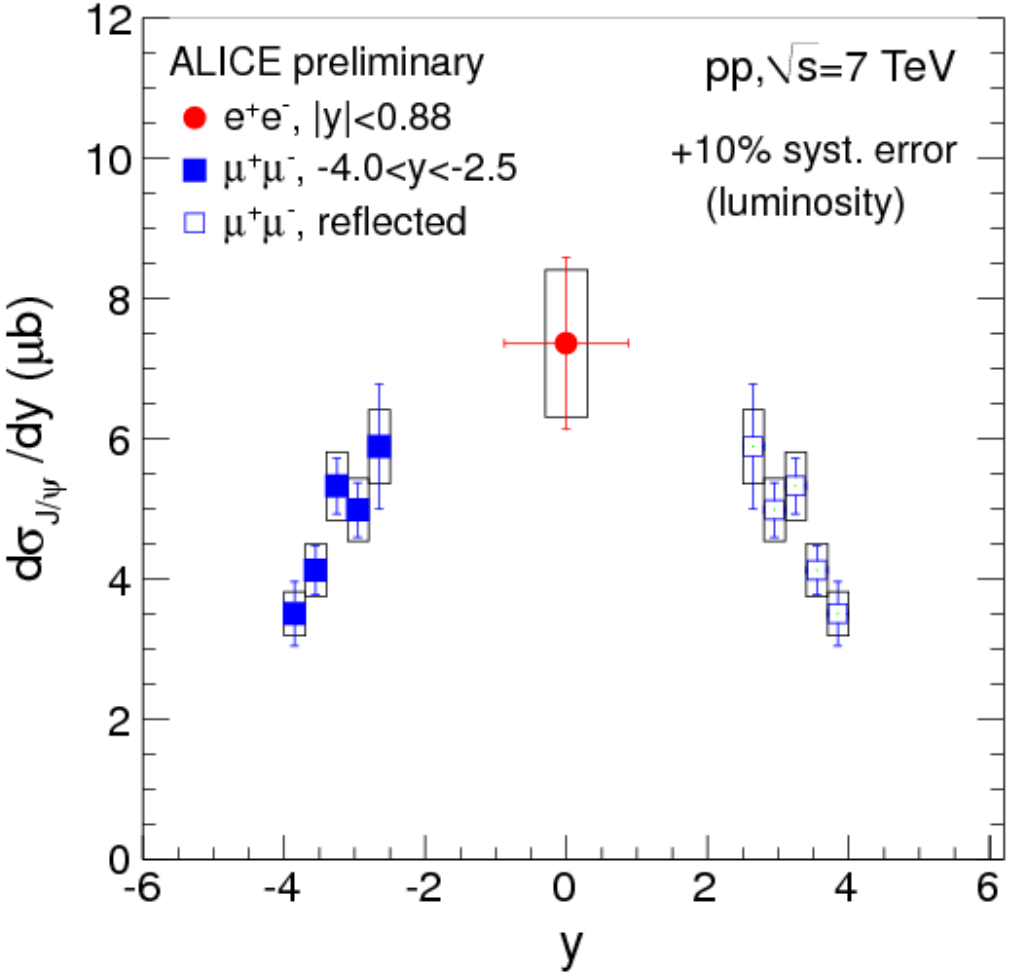
Measurement of J/ψ over wide pseudorapidity range

- **Rapidity spectra**
- **Transverse-momentum spectra**

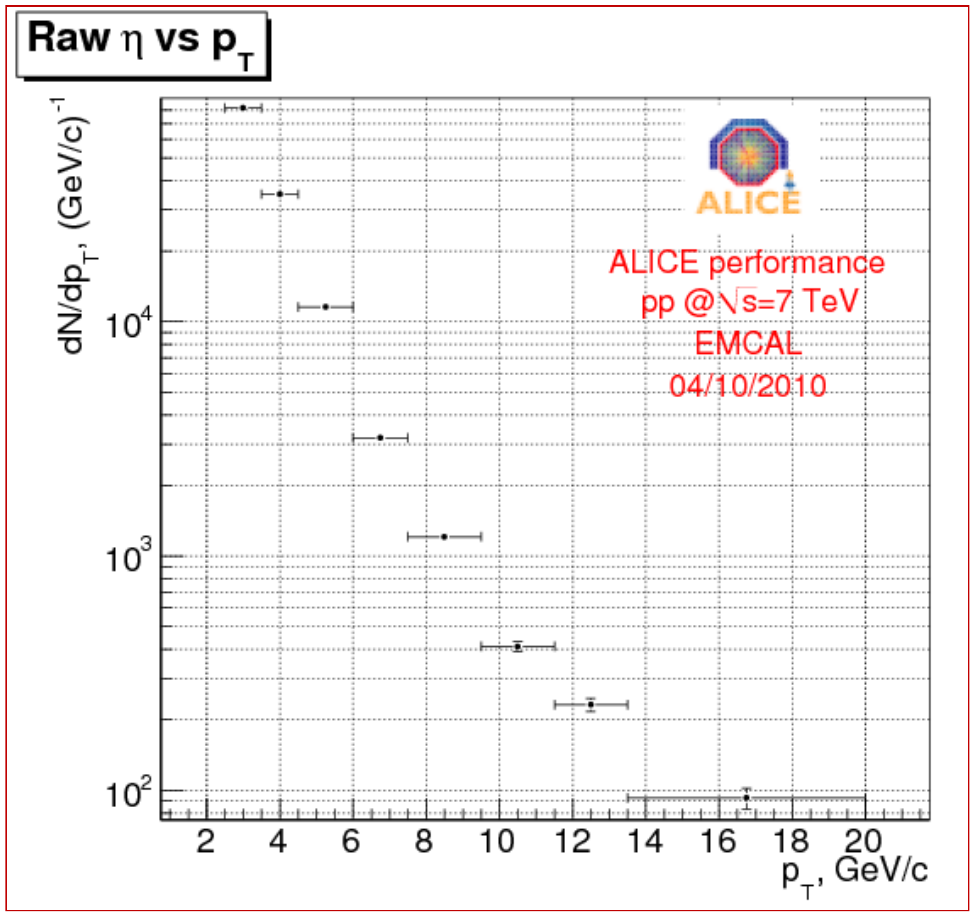
J/ψ production at 7 TeV

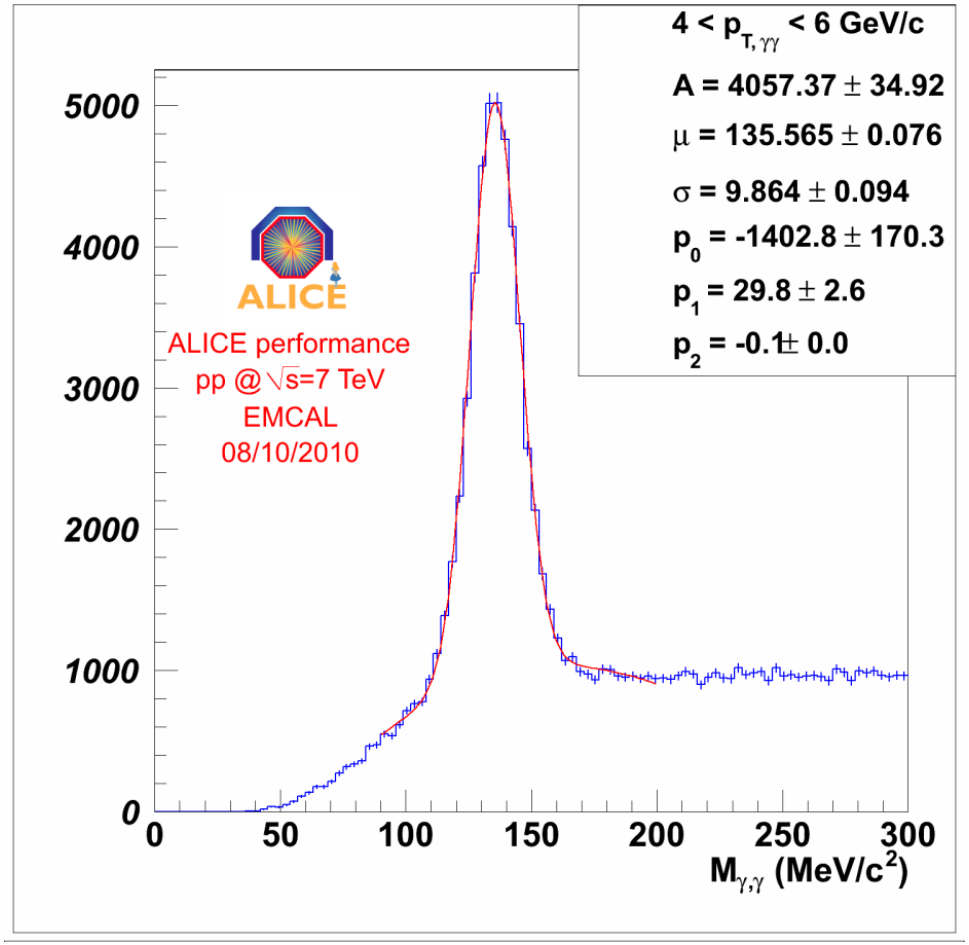
very good agreement with LHCb pt spectra and cross section
cross-section measurement in central–forward regions match





Electromagnetic calorimeter





- EMCal: -0.7 <η< 0.7, 80°<φ< 120° in 2010
  → 80°<φ< 180° in January 2011 – Ahead of schedule!
- DCAL: -0.7 <η< 0.7, 260°<φ< 320° in 2013
- Access to di-jets, γ-jet, improve p_T reach of $e^{\pm}$

Conclusions

- Results from p+p collisions
  - Multiplicity, spectra
  - $\bar{p}/p$ ratio
  - Identified particles
    - π.K,p
    - K^0_S,Λ
    - Ξ,Ω,Σ*,K*
    - $D^{\pm}D^0$ J/ψ
  - Bose-Einstein correlations
- Improve our understanding of p+p collisions
  - Monte Carlos need improvement
- Eagerly awaiting Pb+Pb

Backup slides

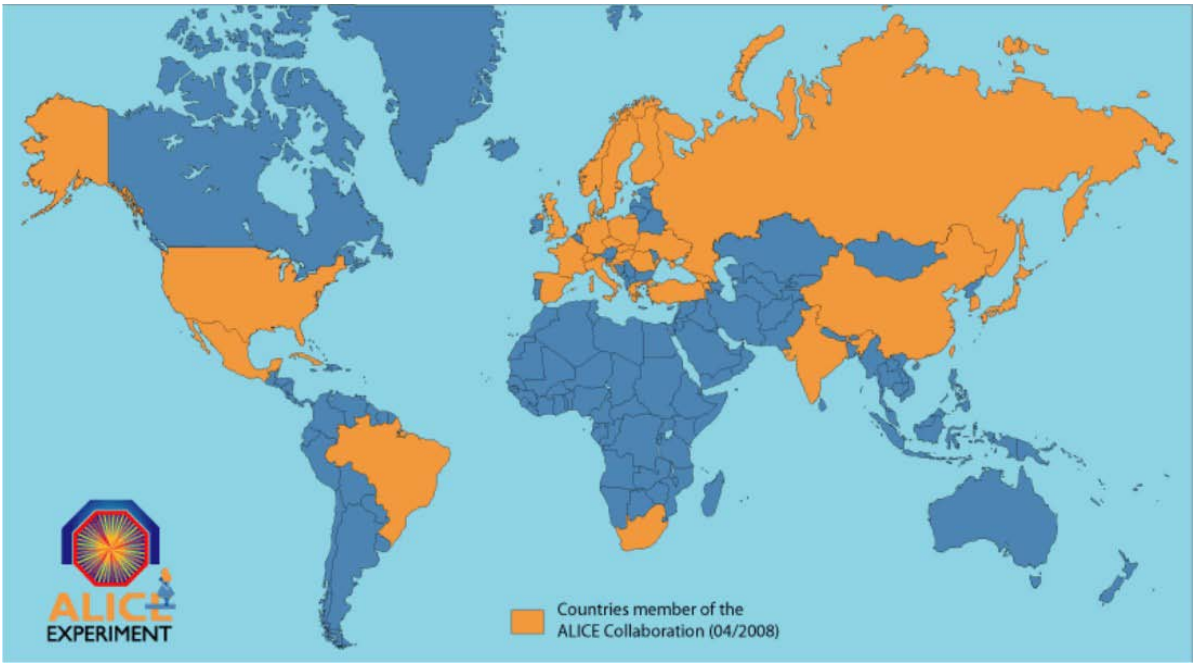
The ALICE Collaboration

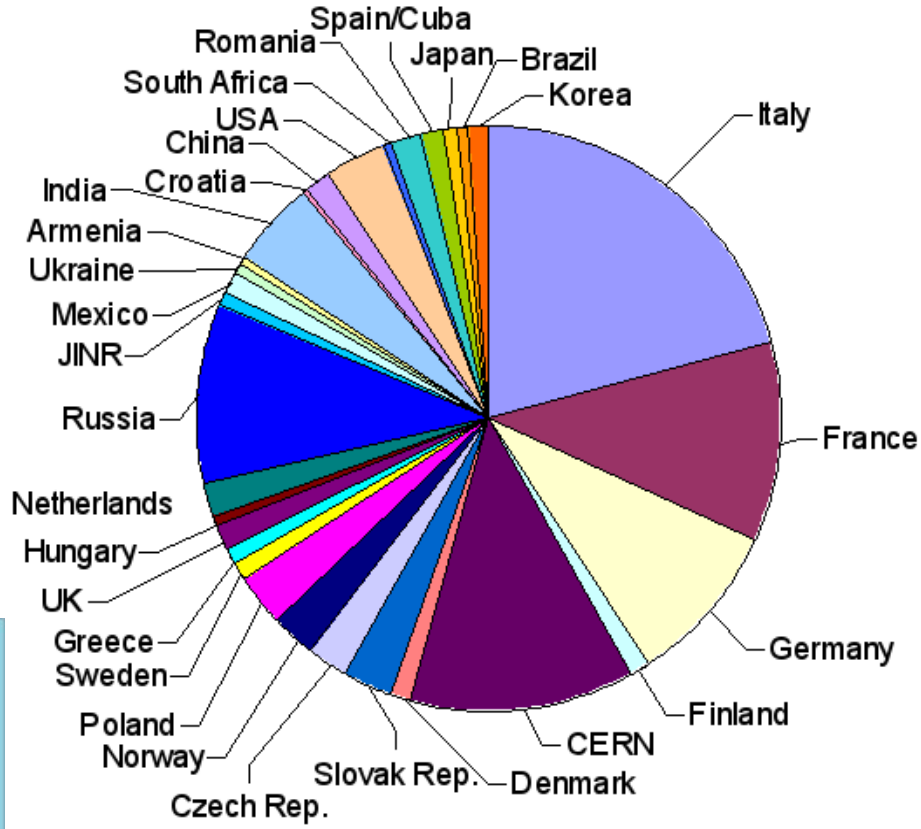
~1000 Members
63% from CERN member states

~30 Countries

~100 Institutes

~150 MCHF capital cost (+magnet)



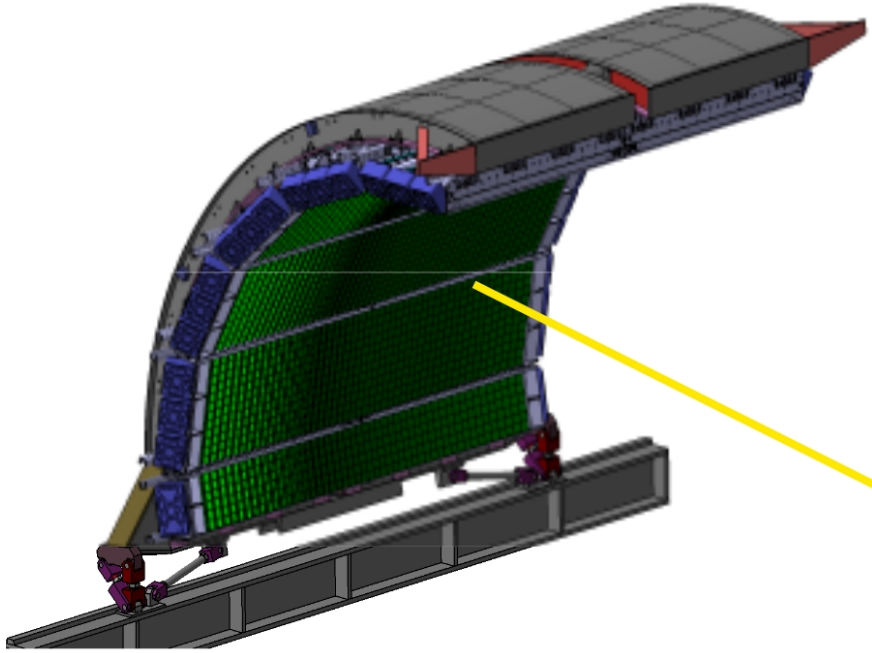


US ALICE

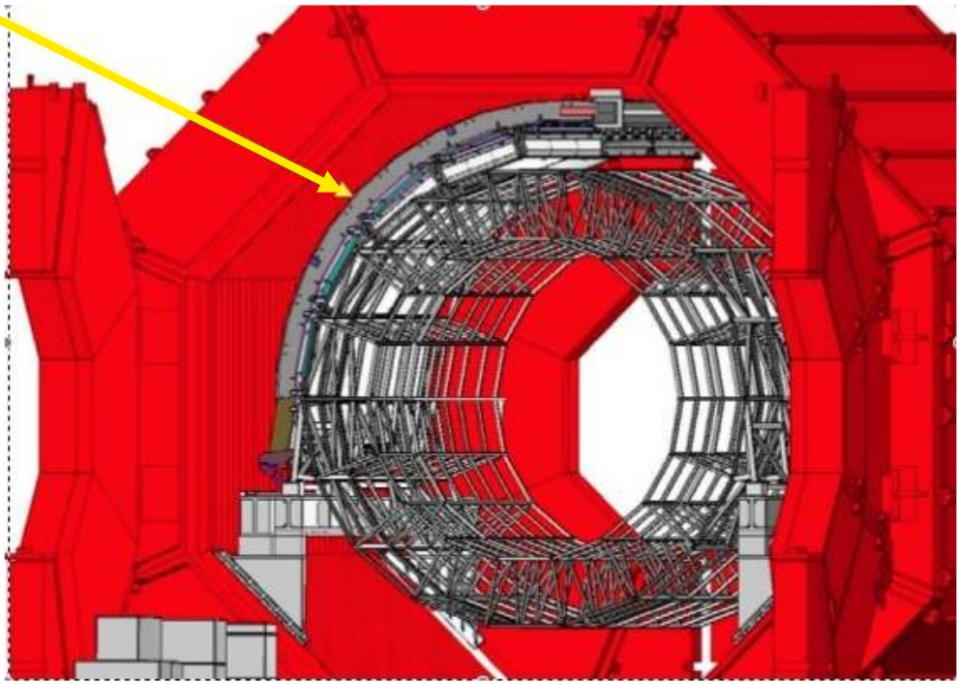
11 Institutions53 members (inc. 12 grad. Students)

Cal. St. U. –San Luis Obispo, Creighton University,University of Houston, Lawrence Berkeley Nat. Lab,Lawrence Livermore Nat. Lab, Oak Ridge Nat. Lab,Ohio State University, Purdue University, University of Tennessee, Wayne State University,Yale University

EMCal



Current coverage:
$\Delta\eta=1.4, \Delta\varphi=39^{o}$ ($R\approx0.3$ max)
Full calorimeter installation scheduled for 2012



- Lead-scintillator sampling calorimeter
- 13 k towers
- Each tower $\Delta\eta X\Delta\varphi= 0.014$ X 0.014
- Shashlik geometry
- Avalanche phototodiodes
- $\Delta\eta=1.4, \Delta\varphi=107^{o}$
- $\sigma(E)/E=0.12/\sqrt{E} + 0.02$

ALICE detectors and acceptance

Central barrel-0.9 < η < 0.9

- Δφ = 2π tracking, PID (TPC/ITS/TRD/ToF)
- single arm RICH (HMPID)
- single arm e.m. cal (PHOS)
- jet calorimeter (EMCal)

Forward muon arm-2.4 < η < -4

- absorber, 3 T-m dipole magnet
  5 tracking + 2 trigger planes

Multiplicity detectors-3.4 < η < 5

- including photon counting in PMD

Trigger & timing detectors

- 6 Zero Degree Calorimeters
- T0:ring of quartz window PMT's
- V0:ring of scintillator Paddles