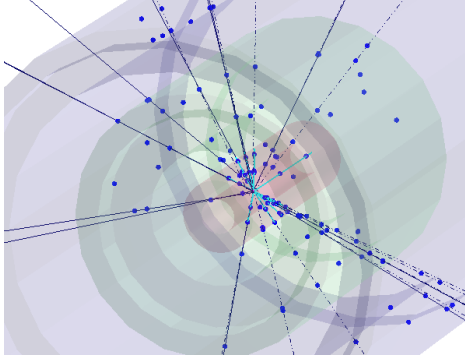


Overview of Minimum-Bias Activities in ALICE and Recent Results

Jan Fiete Grosse-Oetringhaus, CERN
for the ALICE collaboration

LPCC LHC MB & UE Workshop
September 2010

Content

- Recent MB results
  - dN_{ch}/dp_T, $\langle p_T \rangle$ vs. N_{ch}
  - Two-Pion Bose-Einstein Correlations
  - Proton-to-antiproton ratio
  - Identified particle spectra
  - Strangeness
  - Event shapes
- Covered in separate talks
  - Common plots for $dN_{ch}/d\eta$ (Chiara, today)
  - Underlying event (Sara, tomorrow)

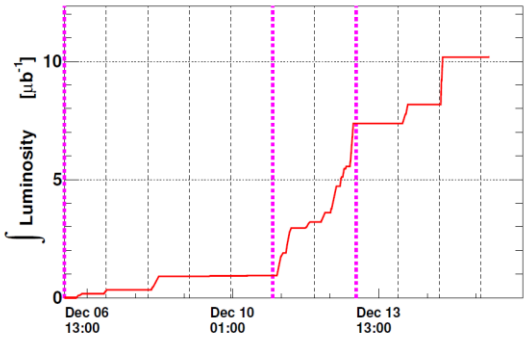
Pseudorapidity density and multiplicity distribution already discussed in previous meetings:
•EPJC: Vol. 65 (2010) 111
•EPJC: Vol. 68 (2010) 89
•EPJC: Vol. 68 (2010) 345

Publications since the last meeting:
•arXiv:1007.0719, accepted by PLB
•arXiv:1007.0516
•PRL 105 (2010) 072002

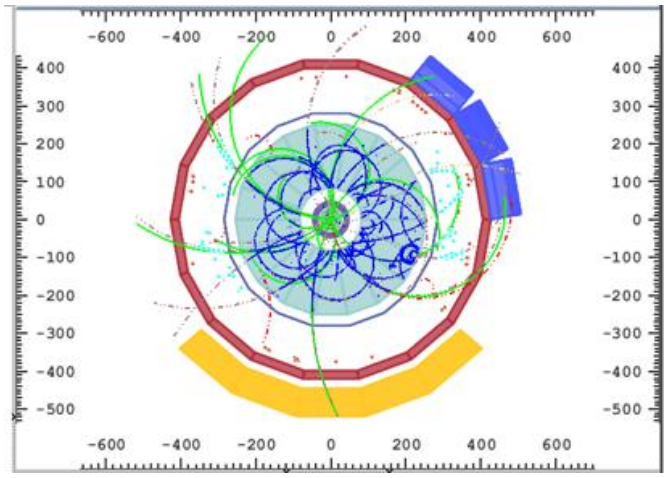
MC generator versions used:
D6T/Atlas: Pythia 6.4.14
Perugia-0: Pythia 6.4.21
Phojet 1.12 with Pythia 6.2.14

ALICE Running 2009 & 2010

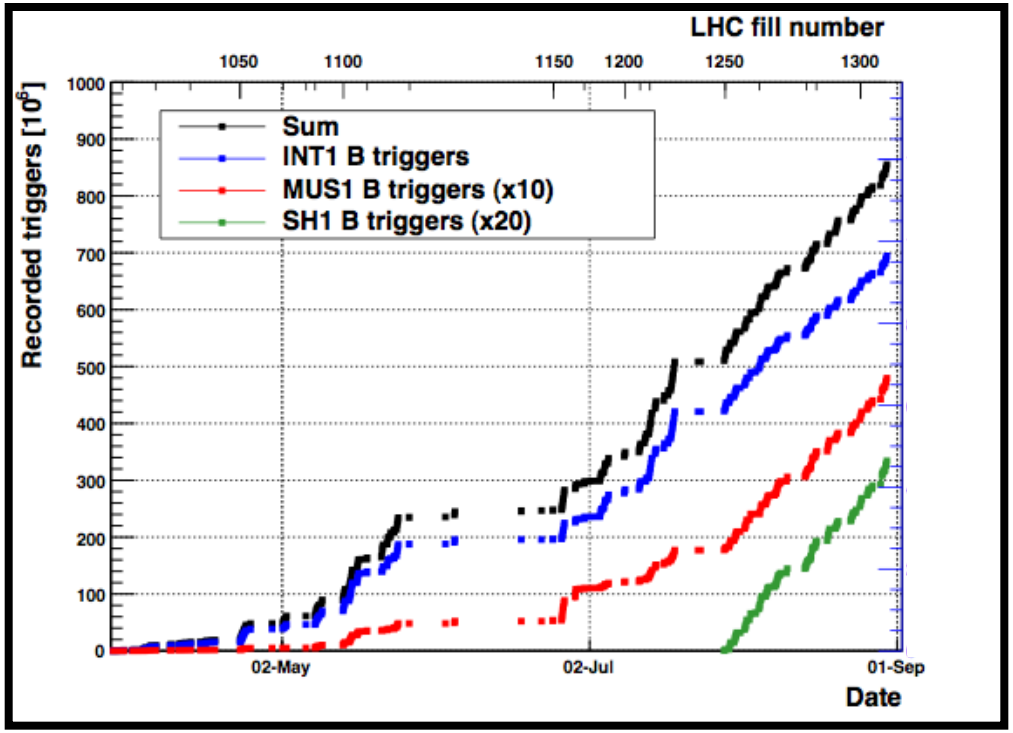
- 2009 (0.9 and 2.36 TeV)
  - ~10.3 μb^{-1}



  - ~ 500 k min bias

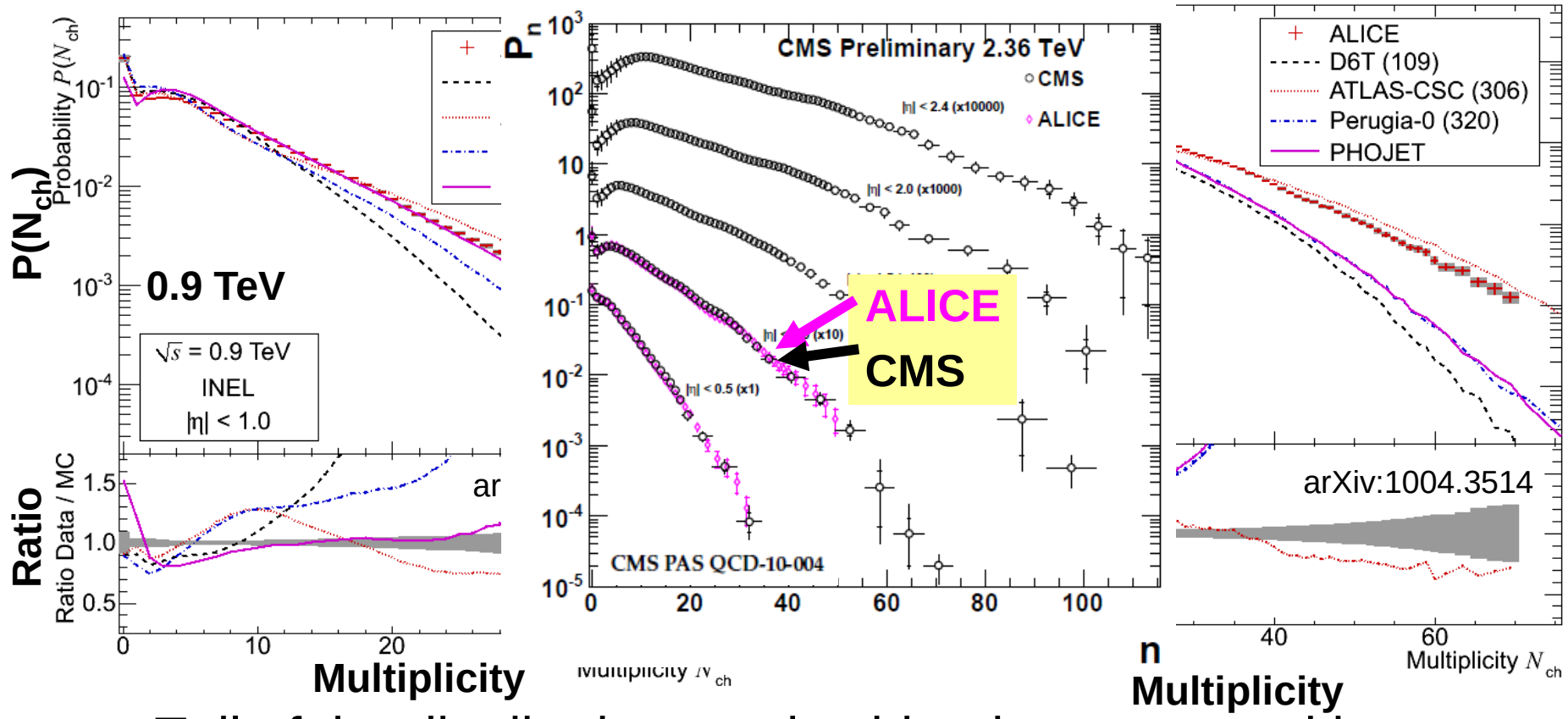


- 2010 (so far)



- ~ 700 M min bias triggers (10 nb^{-1})
- ~ 50 M single muon triggers (50 nb^{-1})
- ~ 15 M high multiplicity triggers

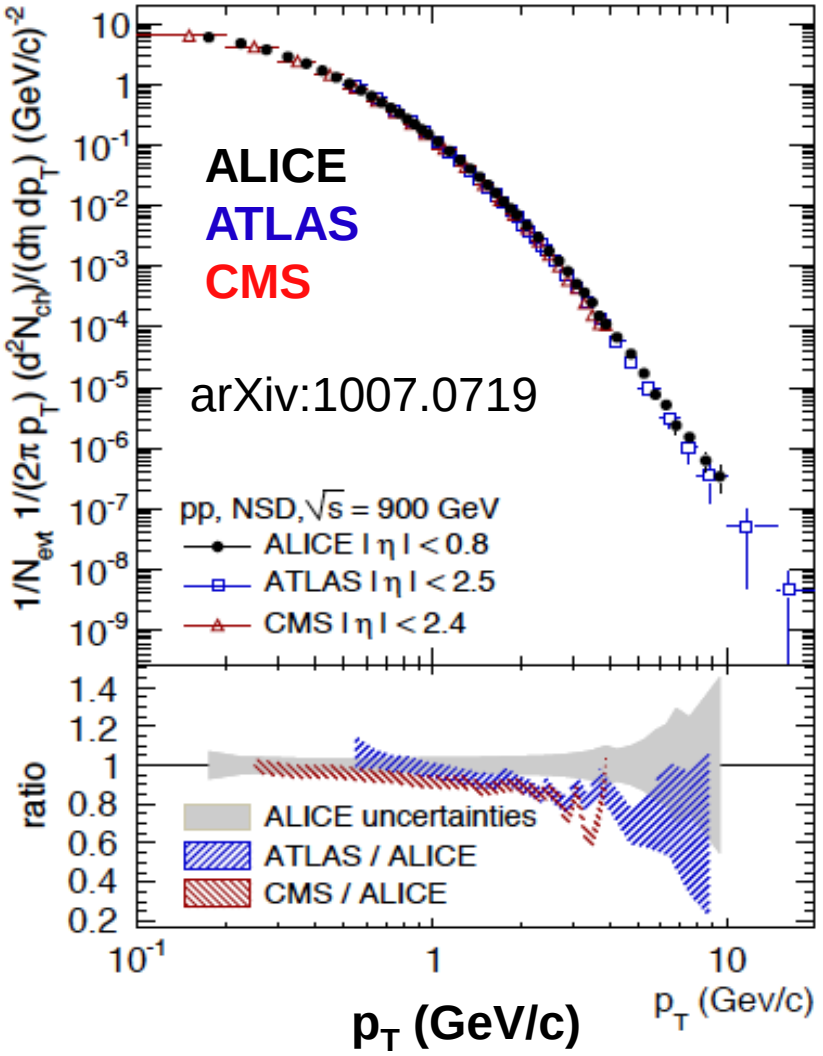
Multiplicity Distributions



- Tail of the distribution much wider than expected by many MCs
- Excellent agreement between ALICE and CMS

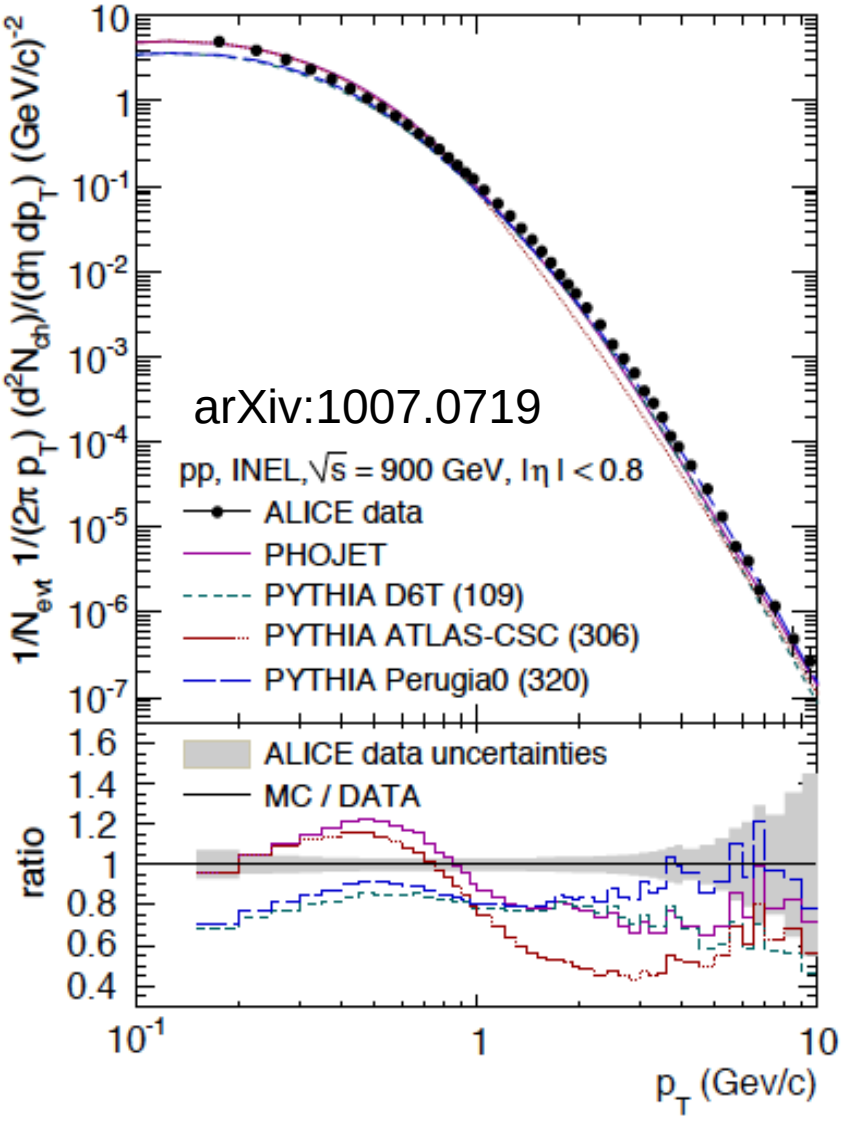
Momentum Distributions

- dN_{ch}/dp_T
  - ALICE measured charged particle p_T spectrum from 0.15 to 10 GeV at $\sqrt{s}$ = 0.9 TeV
  - Seems to get harder towards midrapidity / smaller rapidity window
  - Modified Hagedorn function fits full range
  - Exponential fits above 3 GeV/c



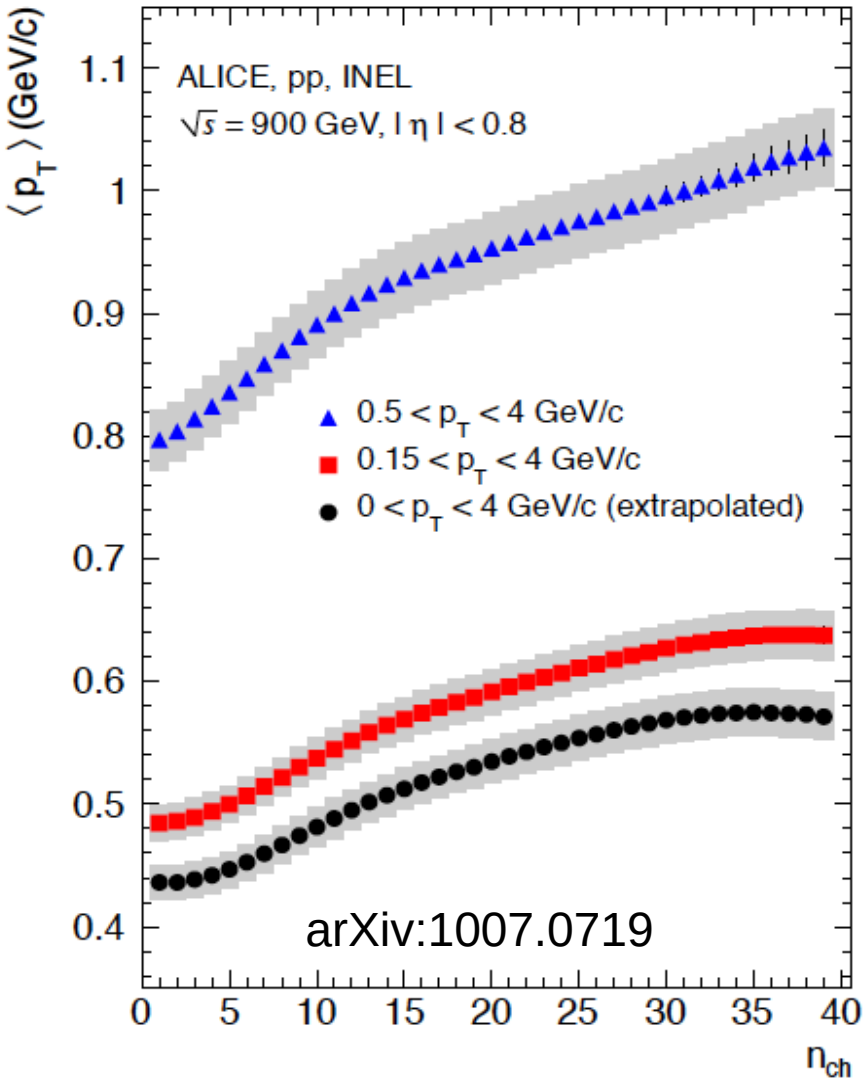
Momentum Distributions (2)

- PYTHIA Perugia0 and D6T tunes describe the shape best, only yield ~20% too low
- PHOJET (at 900 GeV) and PYTHIA ATLAS-CSC tune (at 2.36 and 7 TeV) gave best description of the multiplicity distributions



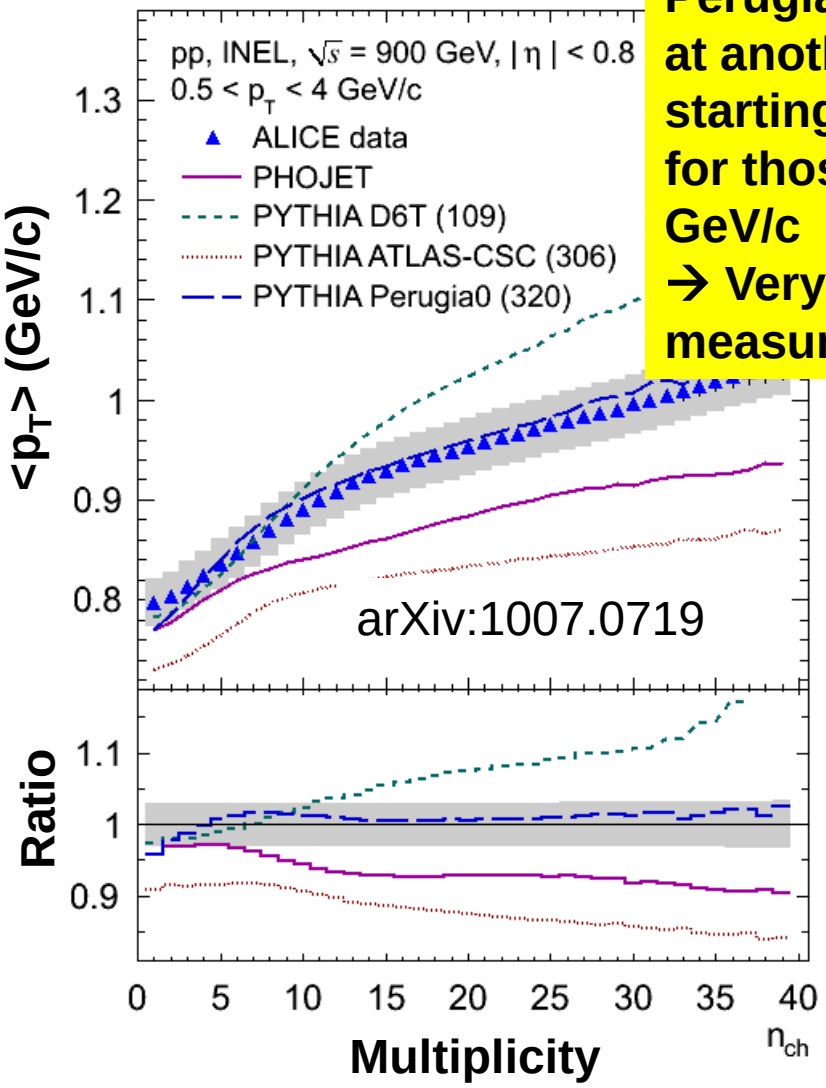
Average p_T vs. multiplicity

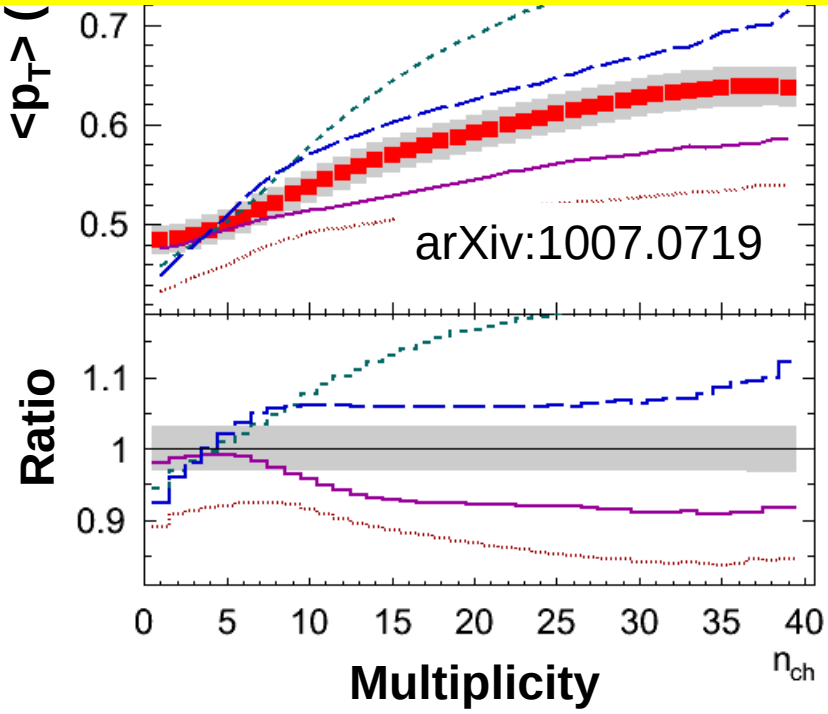
- ALICE measured $\langle p_T \rangle$ vs. multiplicity with a p_T cut of 0.15 and 0.5 GeV/c
  - Extrapolated to 0 GeV/c
- Stringent check for MCs because correlation has to be reproduced (not only multiplicity or p_T)



Average p_T vs. multiplicity (2)

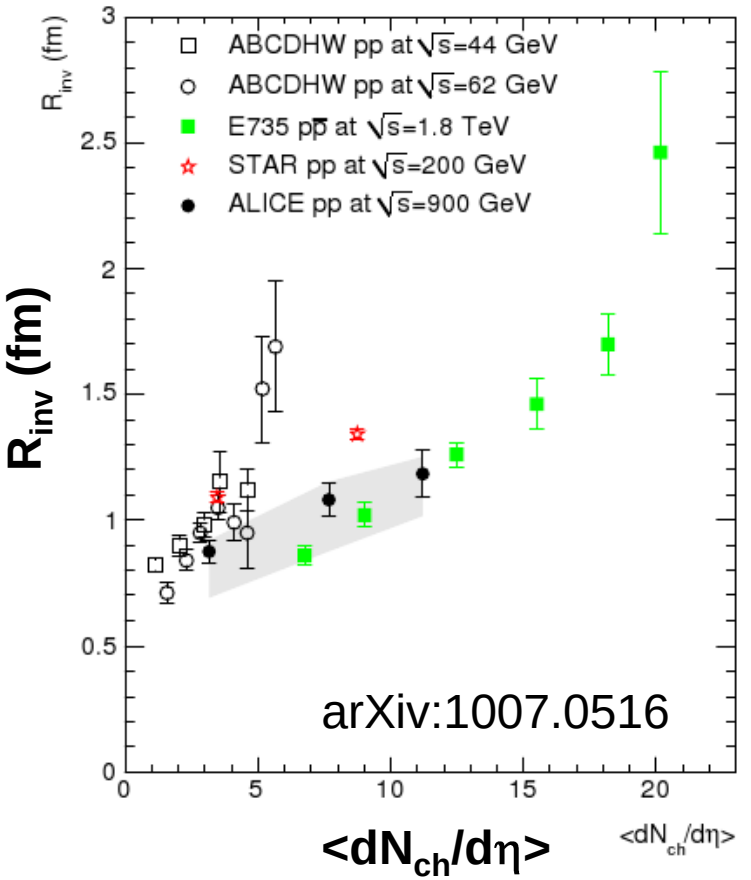
Perugia-0 which was tuned to this distribution at another energy works well for the data starting at 0.5 GeV/c (also in ATLAS), but not for those including particles down to 0.15 GeV/c
→ Very soft particle production important to measure





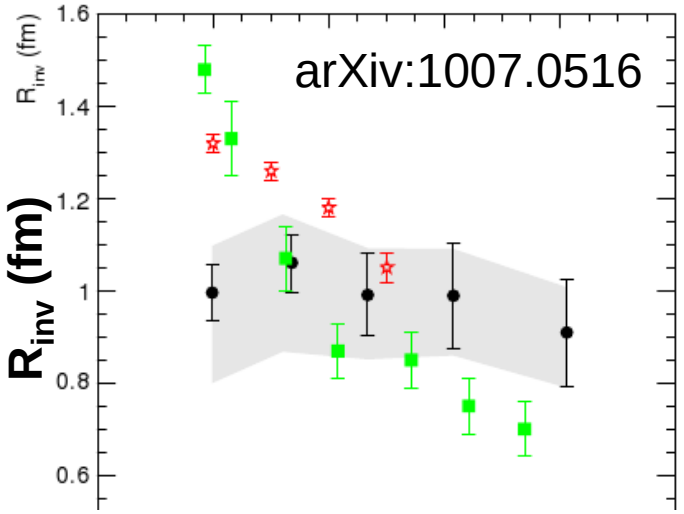
Two-Pion Bose-Einstein Correlations

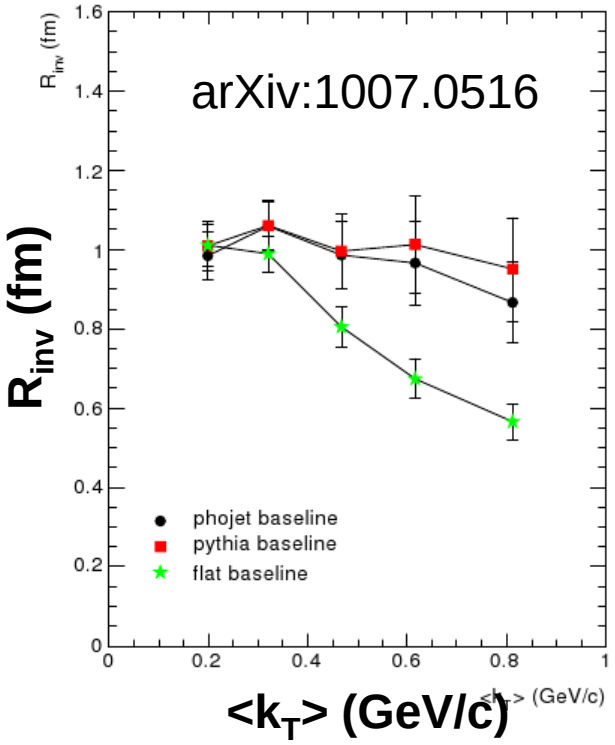
- Measure Bose-Einstein enhancement of identical-pion pairs to assess size of the emitting source
  - At small momentum differences $q = p_2 - p_1$ as function of multiplicity and pair momentum $k_T = |p_{T,1}+p_{T,2}|/2$
- Measure space-time evolution of the 'dense matter' system in heavy-ion collisions
  - Interpretation in 'small systems' (pp, e^+e^-) is less obvious...
- HBT radius R_{inv} increases with multiplicity



k_T Dependence

- R_{inv} practically constant as function of k_T
- Inconsistent with STAR and E735
- Very sensitive to baseline
  - ALICE sees similar k_T dependence using a flat baseline
  - STAR and E735 both used flat baseline
    - STAR investigated also other baselines





Antiproton-to-Proton Ratio

- Can one stop a proton ‘on its track’ at LHC?
- Where does the conserved baryon number reappear after the pp collision?

$z^a \sim e^{-a\Delta y} = e^{-(1-\alpha)\Delta y}$ ($\Delta y \gg 1$)

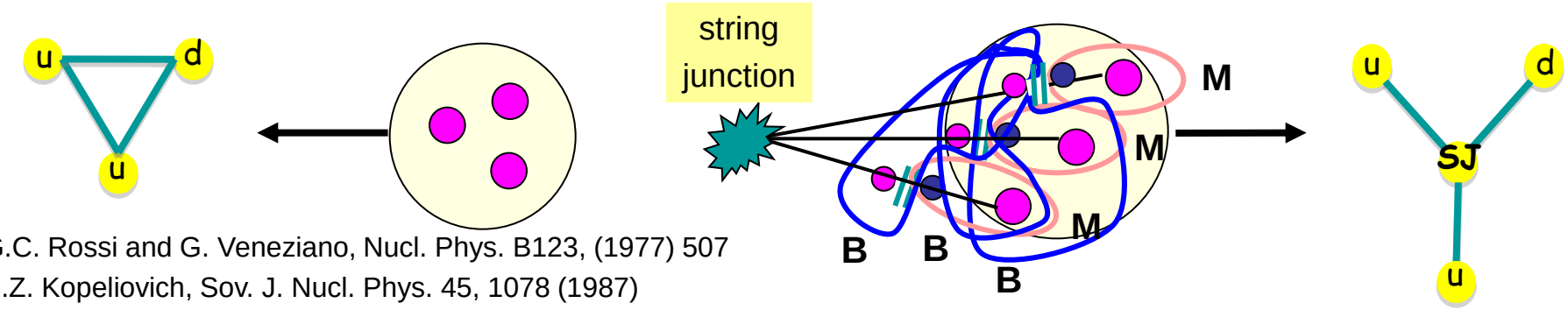
α = intercept of relevant Regge trajectory

$\Delta y = y_{beam} - y_{baryon}$ = ‘rapidity loss’

- Fragmentation function f(z) of baryon number
  - Di-quark qq: z^2 => α = -1 … -0.5, small Δy
  - Single q: $\sqrt{z}$ => α = 0.5, medium Δy
  - No valence q: α = ??; large Δy ??

Veneziano: $\alpha \approx 0.5$ others: $\alpha \approx 1$ (pQCD estimates, σ(p-pbar annihilation), ‘odderon’)

$\alpha \approx 1$ => f(y) = constant, pbar/p < 1 at all energies (< 0.93 at LHC)

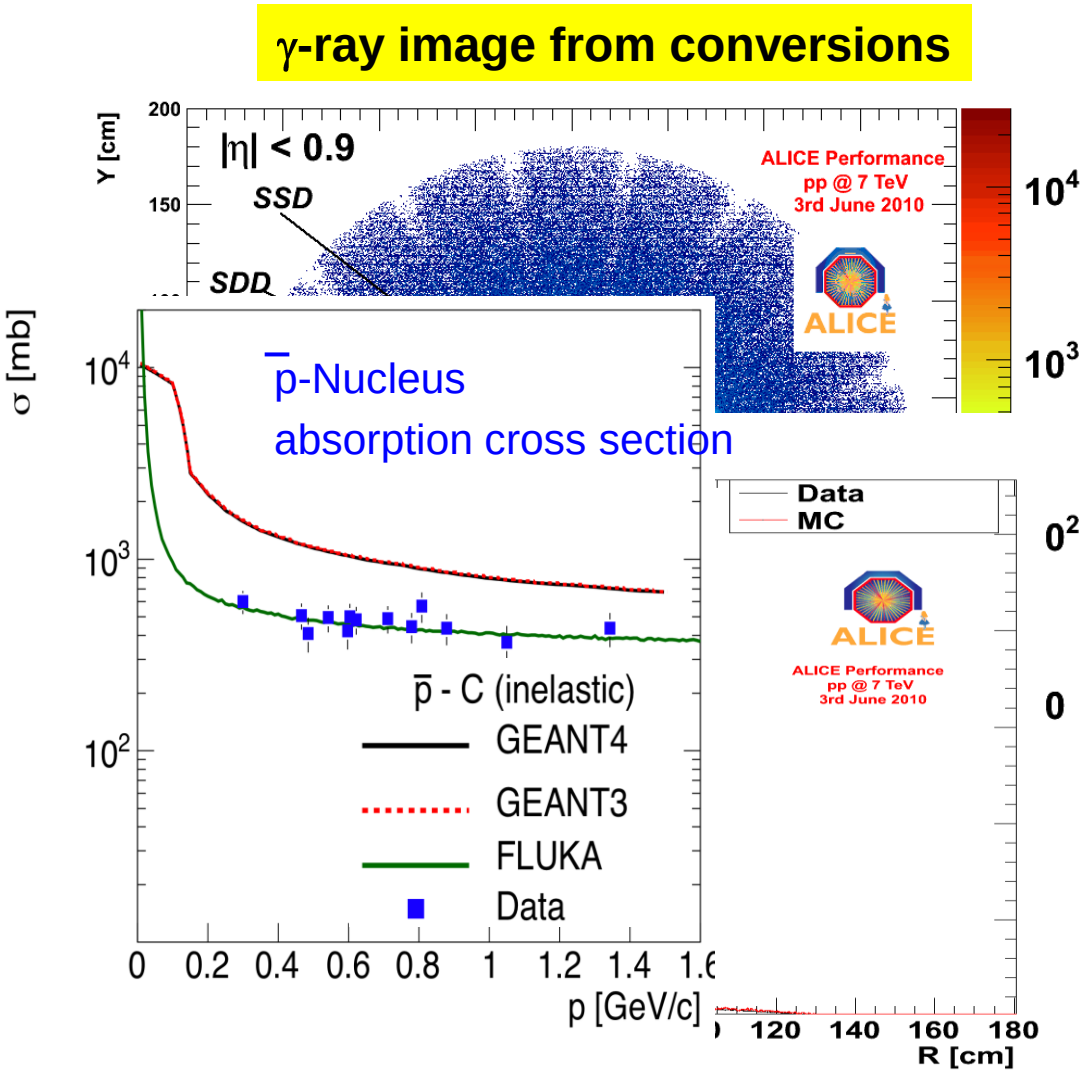


G.C. Rossi and G. Veneziano, Nucl. Phys. B123, (1977) 507

B.Z. Kopeliovich, Sov. J. Nucl. Phys. 45, 1078 (1987)

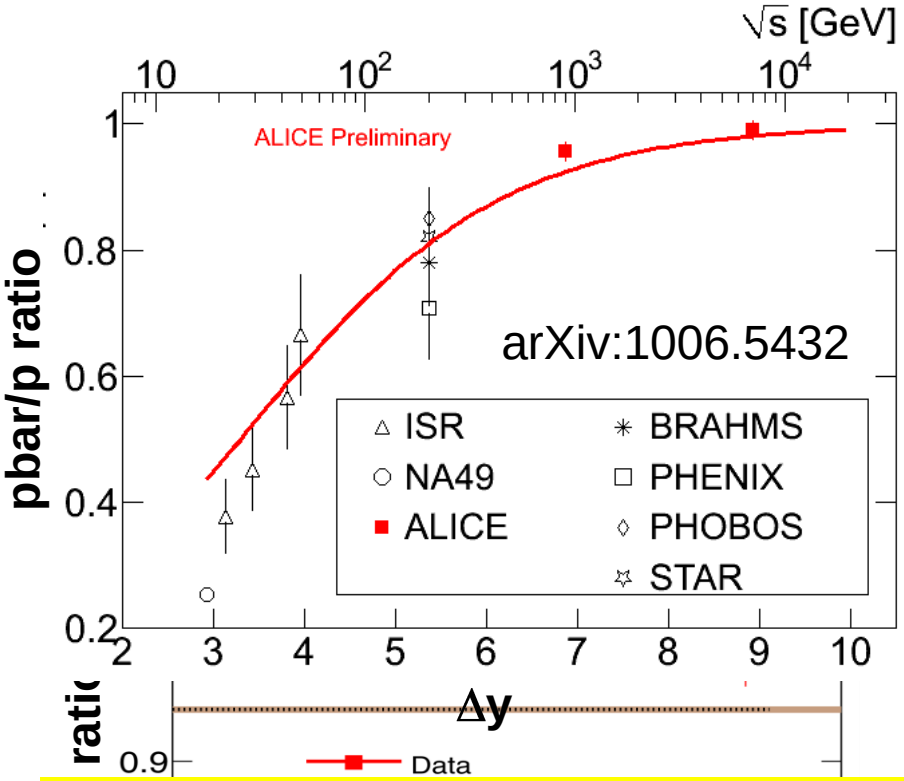
Antiproton-to-Proton Ratio (2)

- Very challenging measurement
  - Measure the ratio to 1% precision
- Assess material budget from data
- Nucleus-pbar cross-section not consistent between transport codes



Antiproton-to-Proton Ratio (3)

- Results show no p_T dependence for both energies
  - Results are compared with model predictions with different BN transport mechanisms
    - MCs with enhanced stopping do not reproduce data
- Energy dependence of the ratio parameterized based on the contribution of different diagrams describing the p(bar) production (pair production at mid-rapidity and BN transfer)
  - Junction intercept set to 0.5
  - Little room for additional diagrams which transport baryon number over large rapidity gaps

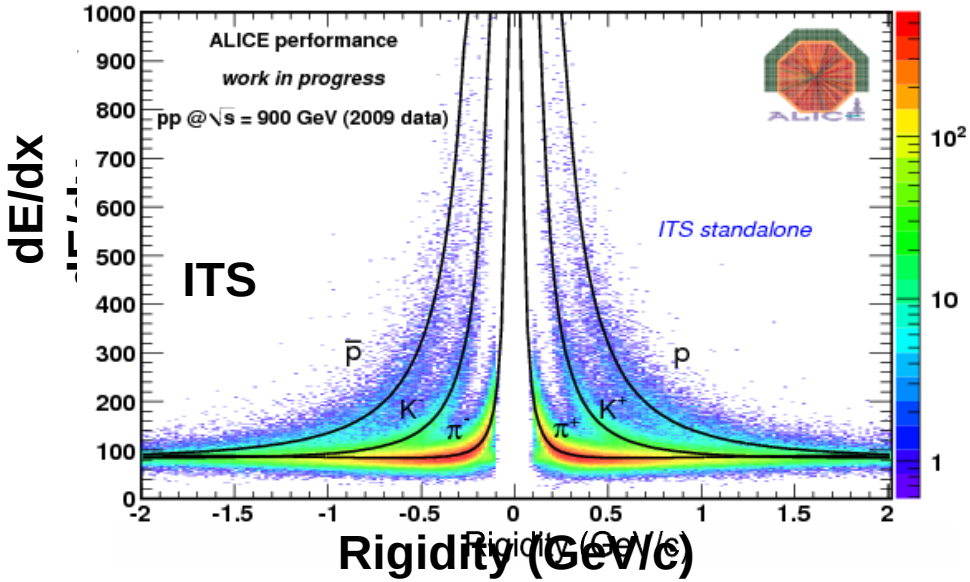


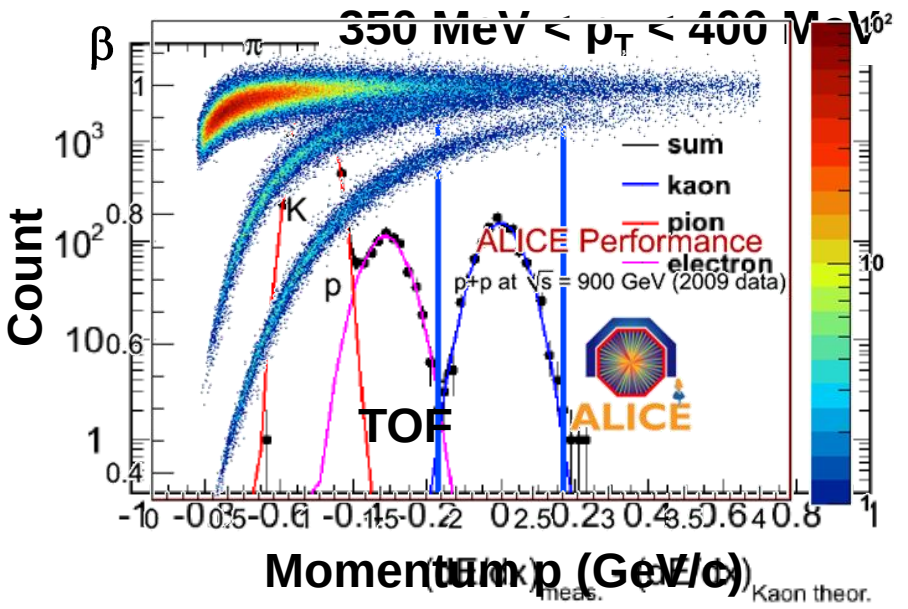
Fit function:

$$\left(\frac{\bar{p}}{p}\right) = \frac{1}{1 + C \cdot e^{(\alpha_J - \alpha_P)\Delta y}} \rightarrow \begin{cases} a_J = 0.5\ (fixed) \\ a_P = 1.2\ (fixed) \\ C = 10.0 \pm 1.0 \end{cases}$$

Particle Identification

- Use ITS, TPC and TOF for identification of charged hadrons
- Identified particle spectra
  - Base line for HI
  - Hadrochemistry (statistical model) may allow to extract freeze-out temperatures and baryochemical potential
  - Tuning of MC generators
- Identified particles used in further analysis (e.g. strange particles)



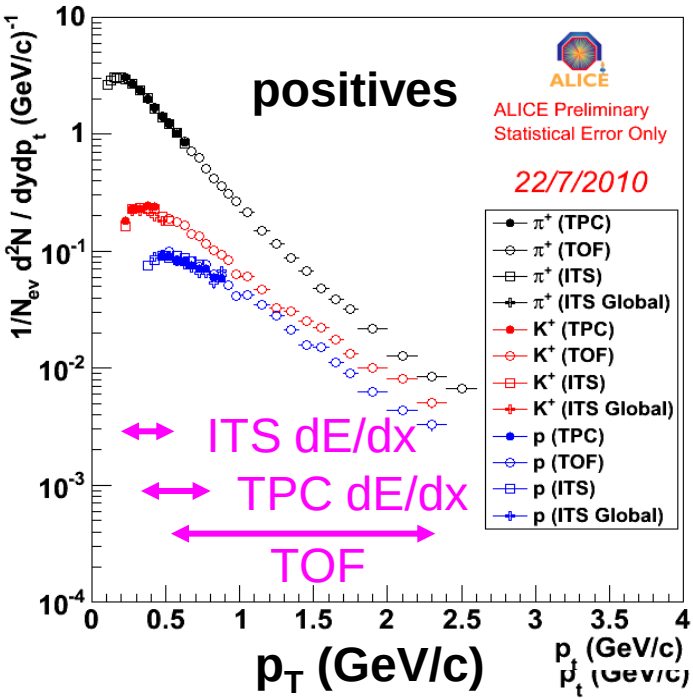


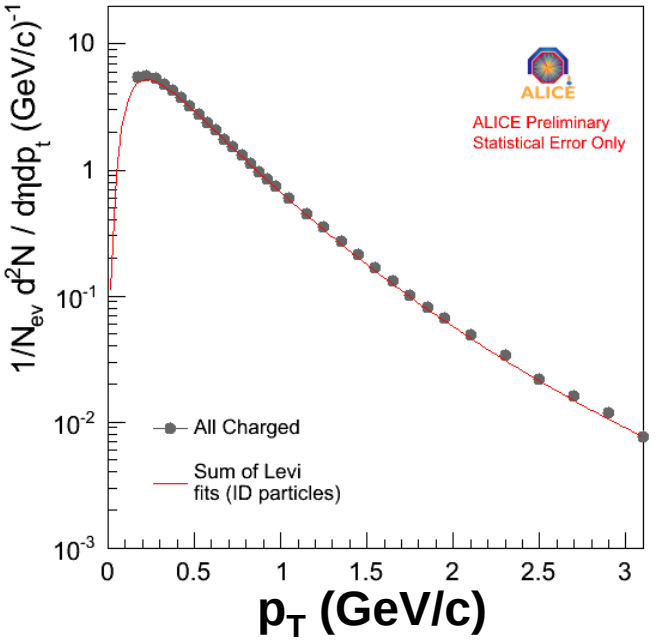
Identified Particle Spectra

- Spectra from different detectors consistent
- Levi (Tsallis) function fits the data at low p_T

$$\frac{dN}{dp_T} \alpha\ p_T \left(1 + \frac{m_T - m}{nT_l}\right)^{-n}$$

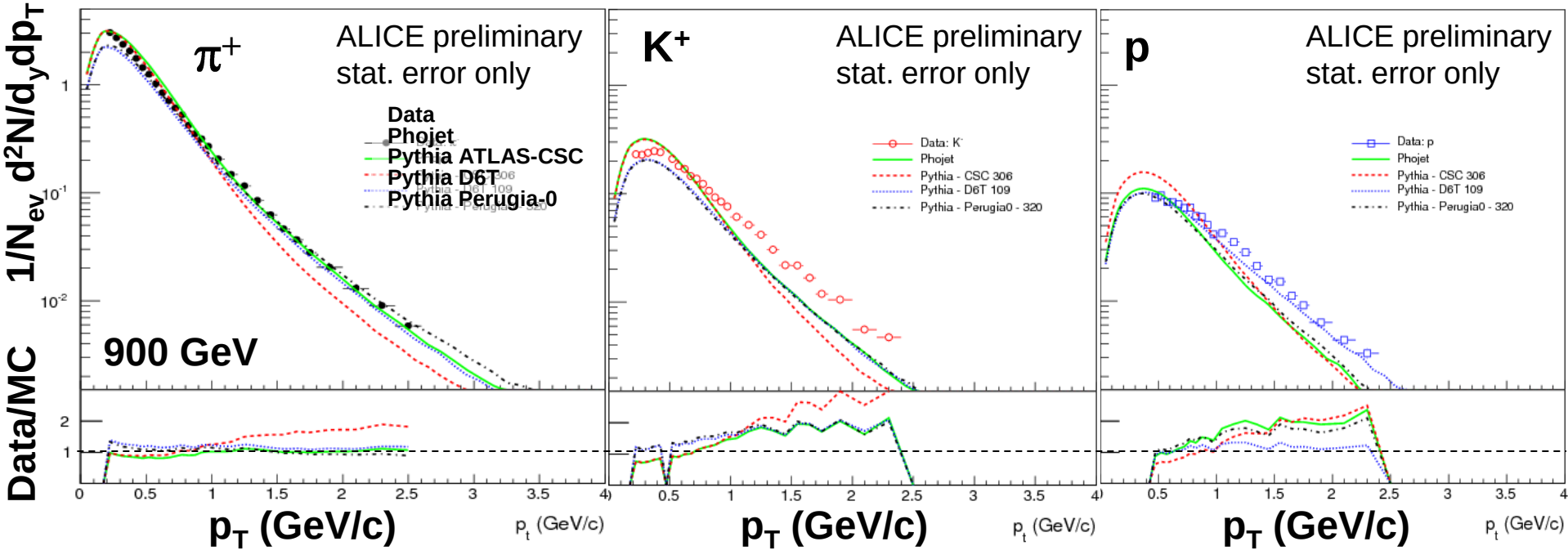
- Sum of fits (π+K+p) matches well with dN_{ch}/dp_T (all charged) result
- Fit also allows to extract integrated yields





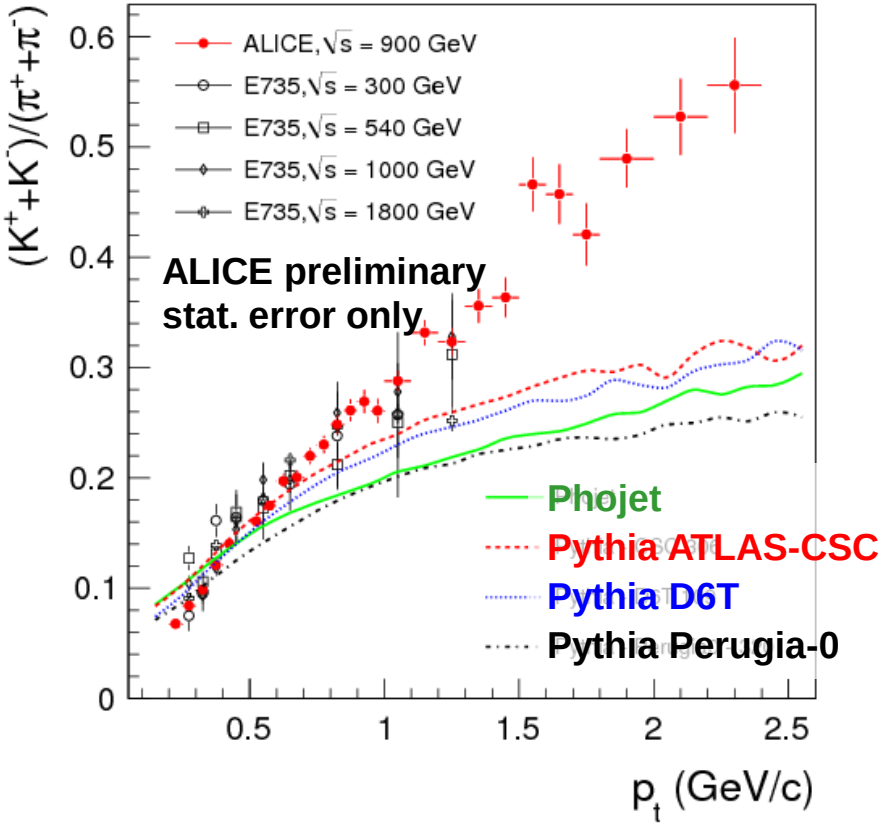
Hadron Yields

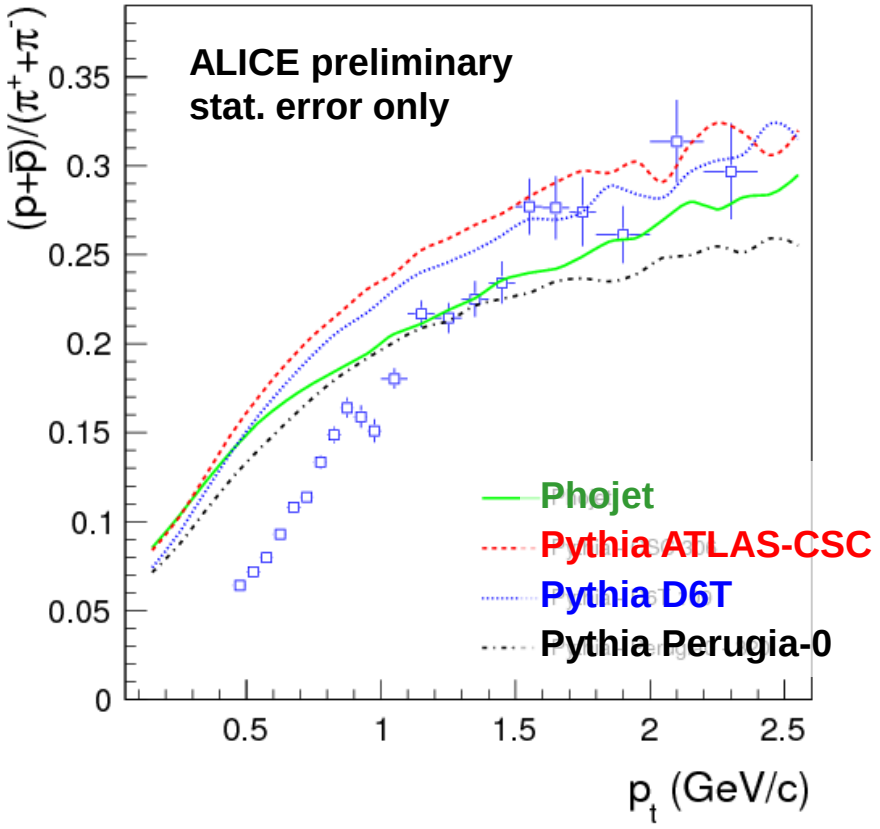
- Yields of π, K, p as function of p_T (here for pos. particles, similar for neg.)
- Pions reasonably described by Phojet, Pythia D6T, Perugia-0
- Kaon yield underestimated above p_T of 1 GeV/c
- Proton yield underestimated except by Pythia D6T



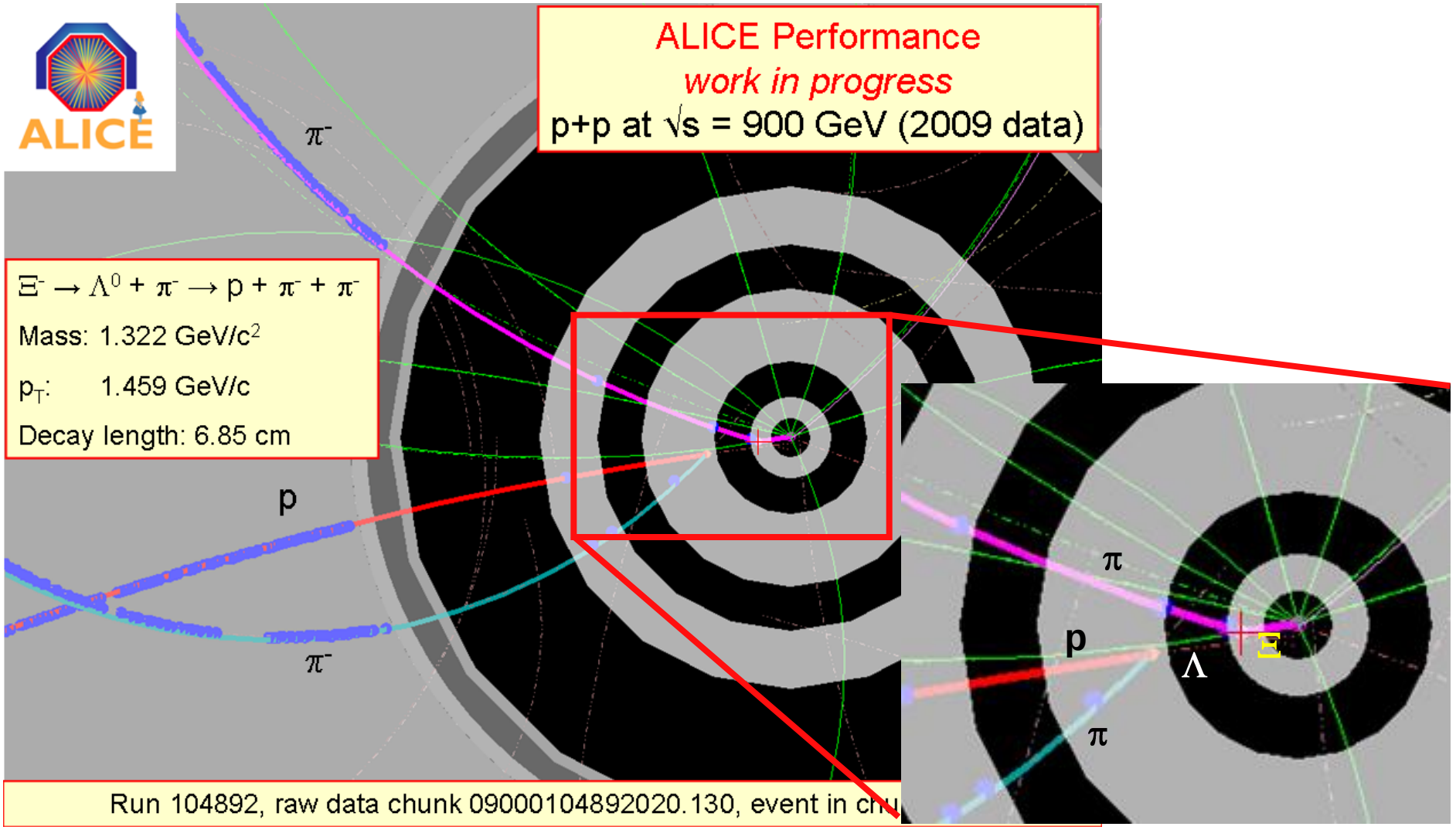
Hadron Yield Ratios

- No agreement with MCs
- K/π ratio fairly independent of √s



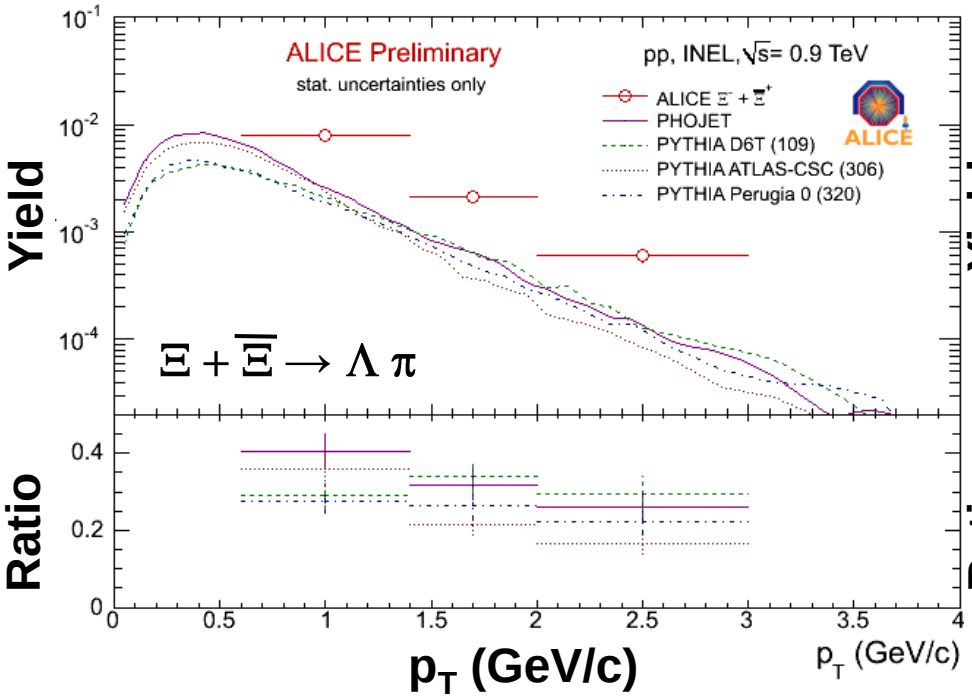


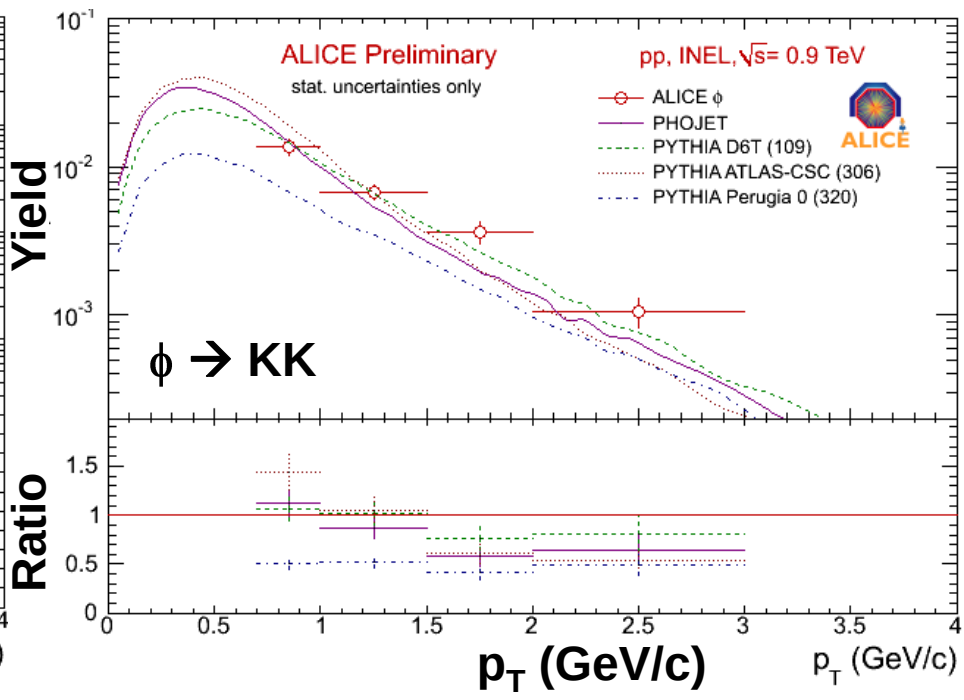
Cascades…


ALICE Performance
work in progress
p+p at √s = 900 GeV (2009 data)
Ξ⁻ → Λ⁰ + π⁻ → p + π⁻ + π⁻
Mass: 1.322 GeV/c²
p_T: 1.459 GeV/c
Decay length: 6.85 cm
π⁻
p
π⁻
π
p
Λ
Ξ
π
Run 104892, raw data chunk 09000104892020.130, event in chu

Strange Particle Yields

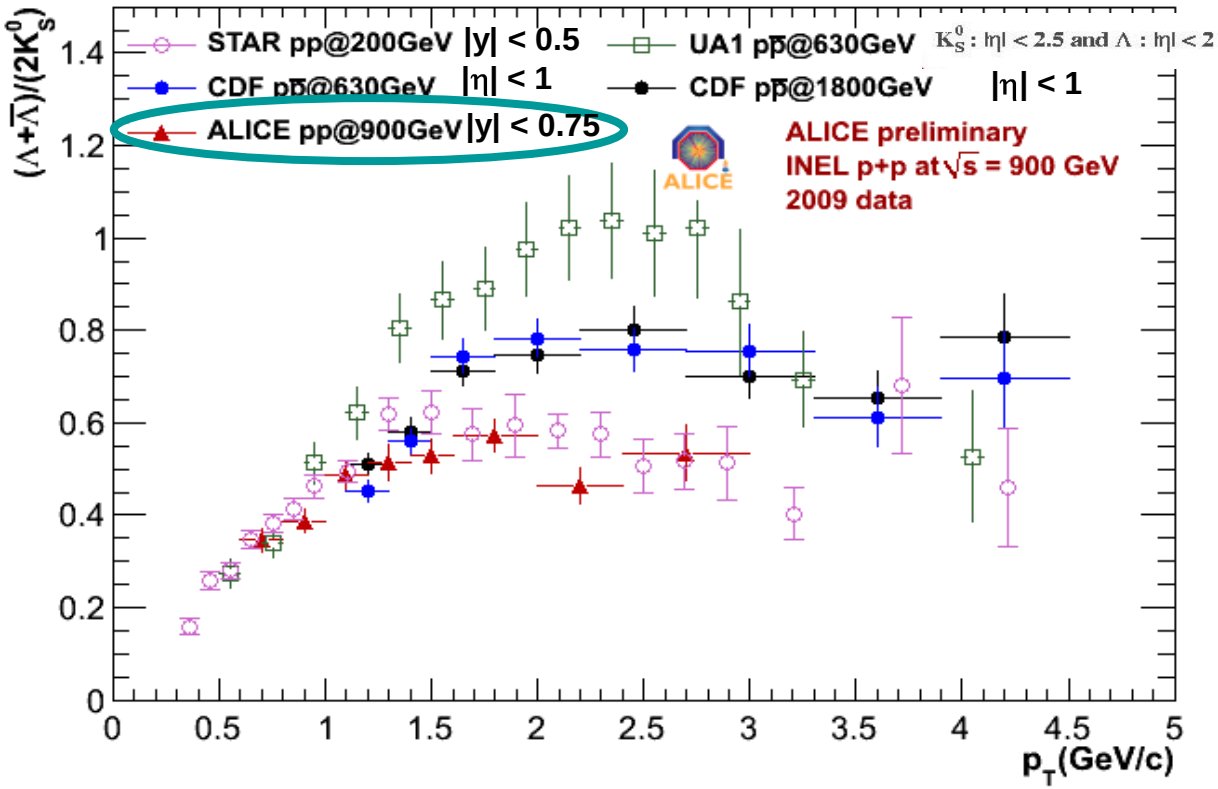
- Yields of K_0^S, Λ, Ξ as function of p_T
- Pythia 6 (D6T, ATLAS-CSC, Perugia-0) and Phojet underestimate overall yields
- Larger discrepancy with increasing particle mass, strangeness and p_T
- But the ϕ is ~ ok within uncertainties





Λ/K_0^S Ratio

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

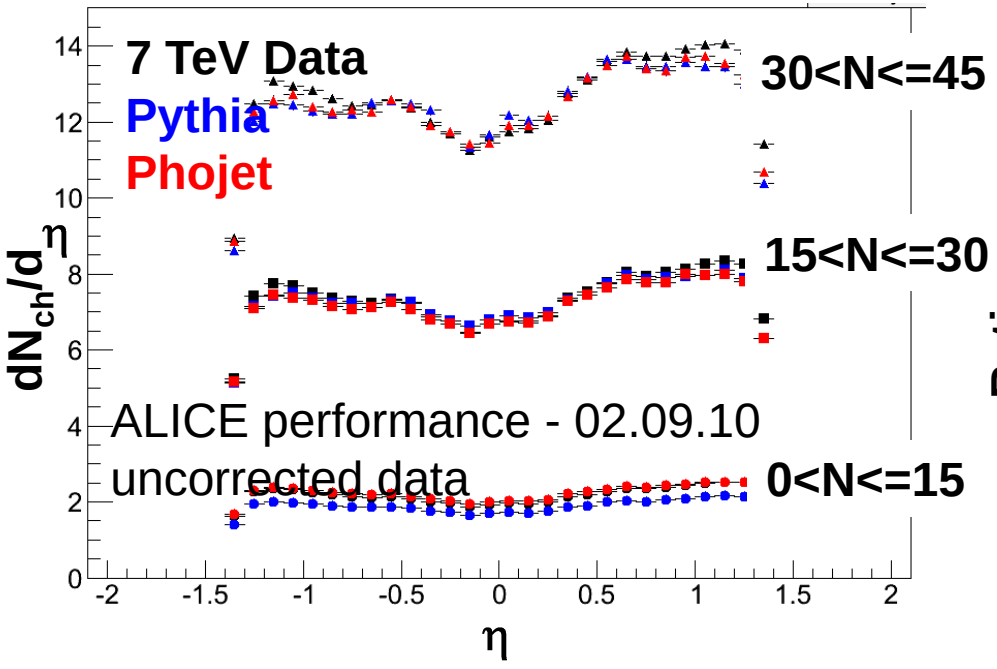


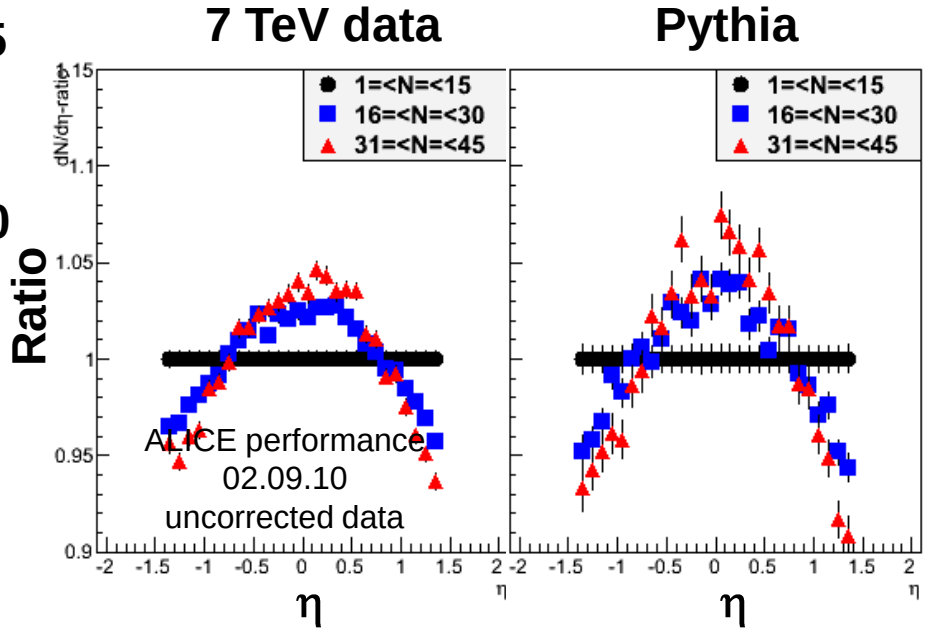
Multiplicity Dependence of $dN_{ch}/d\eta$

- Study $dN_{ch}/d\eta$ in multiplicity bins
- At present: on raw data level
  - Detector effects clearly visible
  - Compute ratios to take out detector effects

Summer student project
Martin Sparre

15<N<=30 / 0<N<=15
30<N<=45 / 0<N<=15



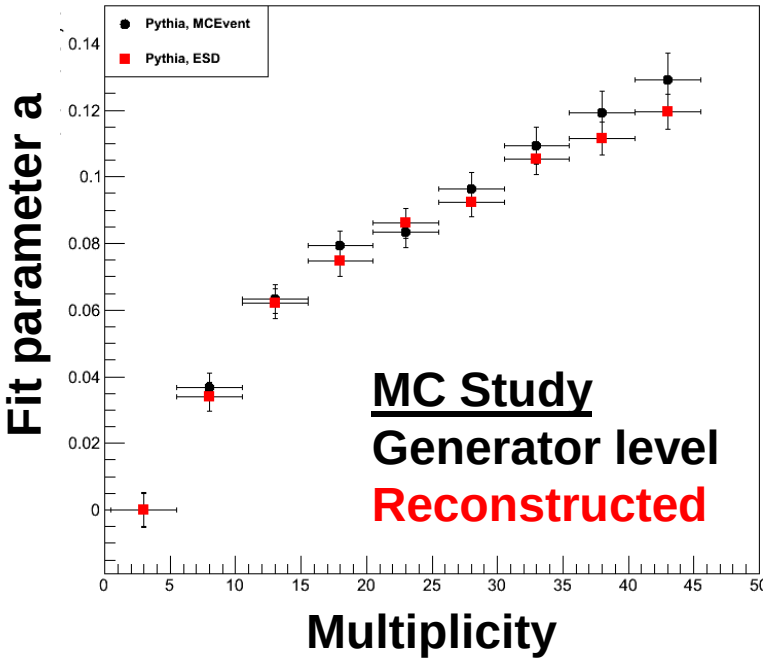


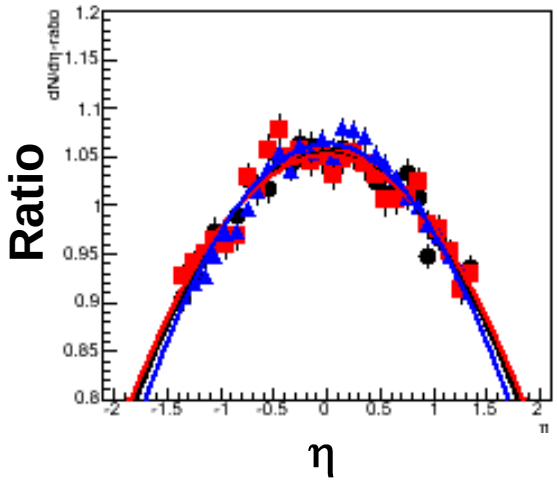
Multiplicity Dependence of $dN_{ch}/d\eta$ (2)

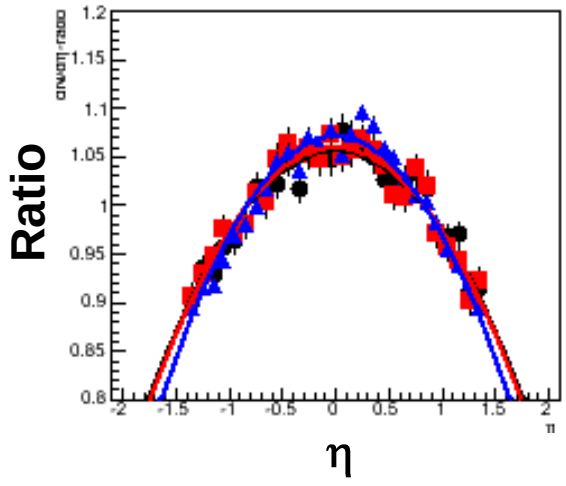
- Fit ratios for quantitative comparison

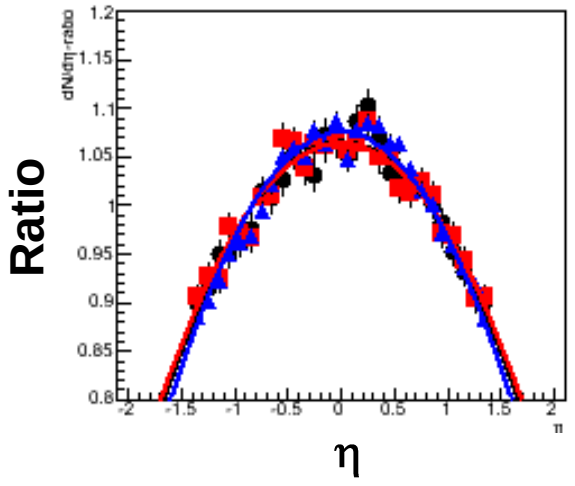
  $b - ax^2$

- Comparison between fit parameters before and after detector simulation indicate that detector effects cancel in ratio



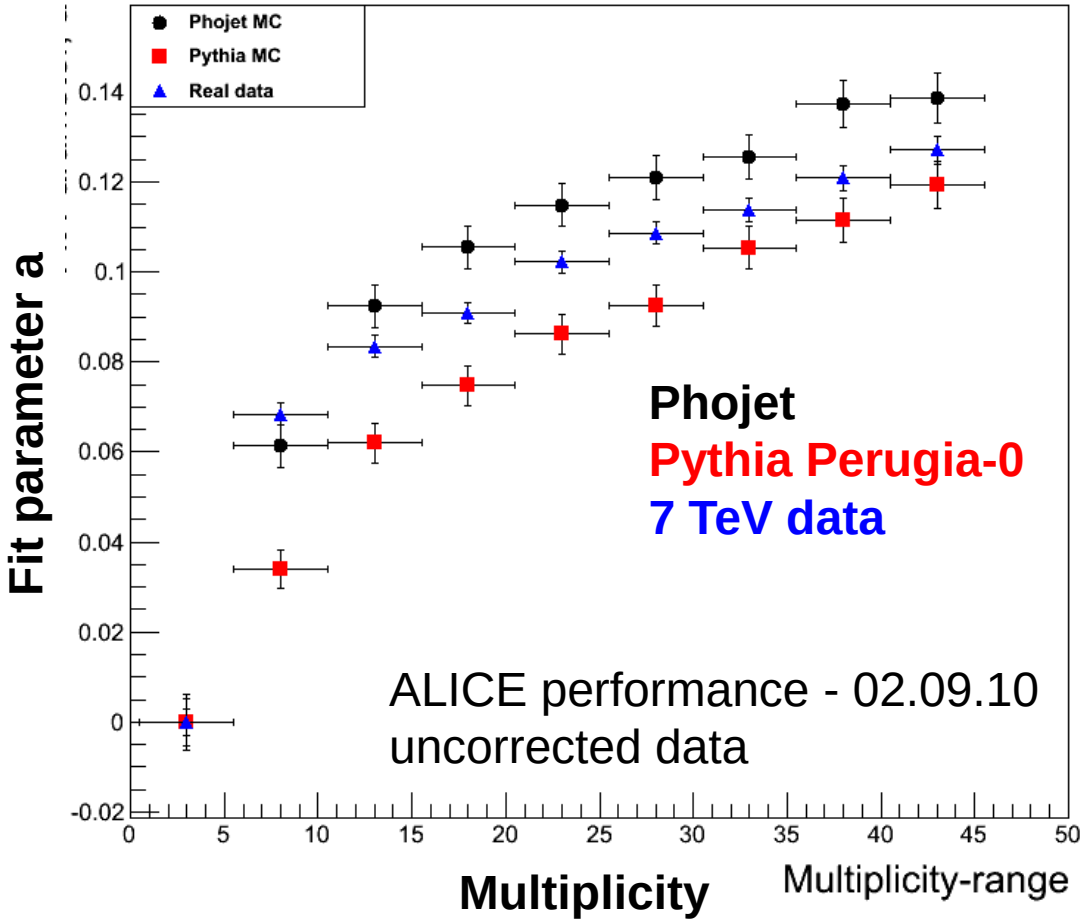






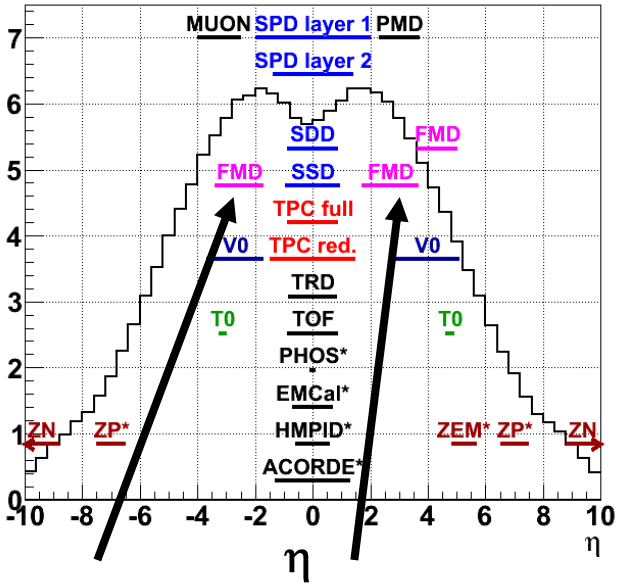
Multiplicity Dependence of $dN_{ch}/d\eta$ (3)

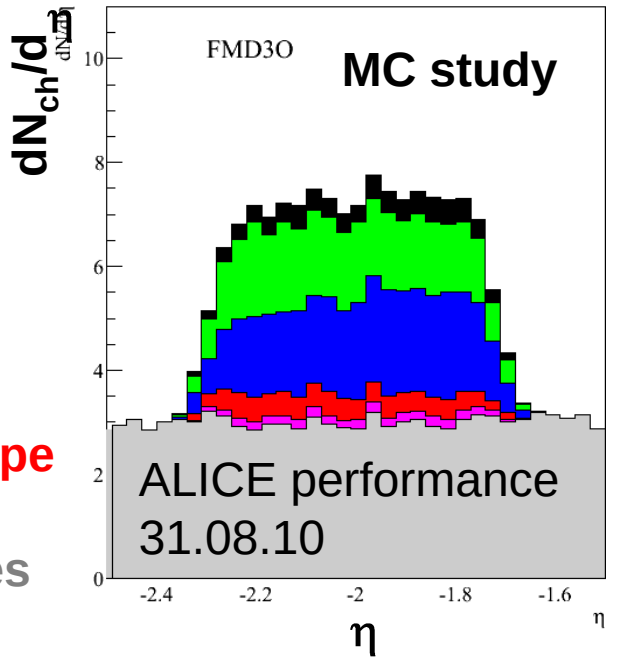
- Comparison of fit parameter at 7 TeV with Phojet and Pythia Perugia-0
- NB: this is a raw data study
  - Systematics to be assessed
  - Trivial effects (change of $\langle m_T \rangle$) to be disentangled from difference in η(y) distribution



Extend $dN_{ch}/d\eta$ acceptance

- Using the Forward Multiplicity Detector
  - $-3.4 < \eta < -1.7$ and $1.7 < \eta < 5$
- Challenging measurement
  - Material due to services of Inner Tracking System
    → Significant progress in understanding of material budget since beginning of data-taking
  - No tracking, just hits
- Overlap in η with Silicon Pixel Detector allows cross-check



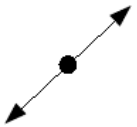


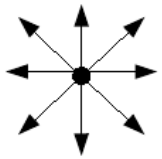
FMD
ITS
Beam pipe
Decays
Primaries
Other

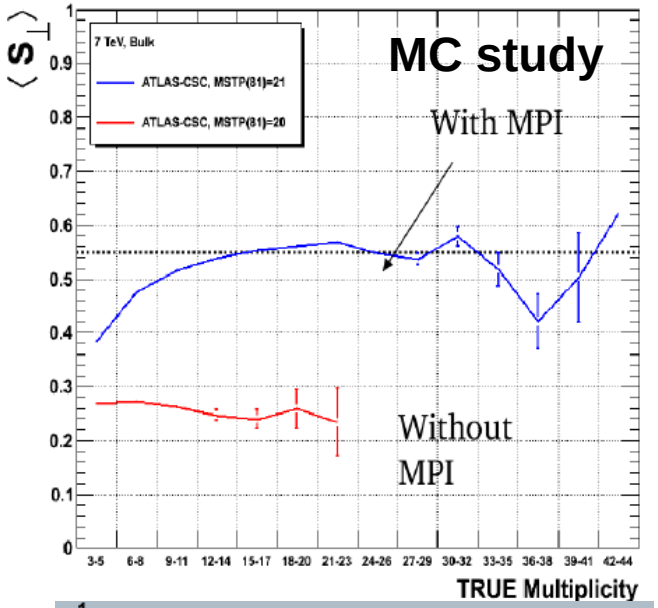
Event Topologies

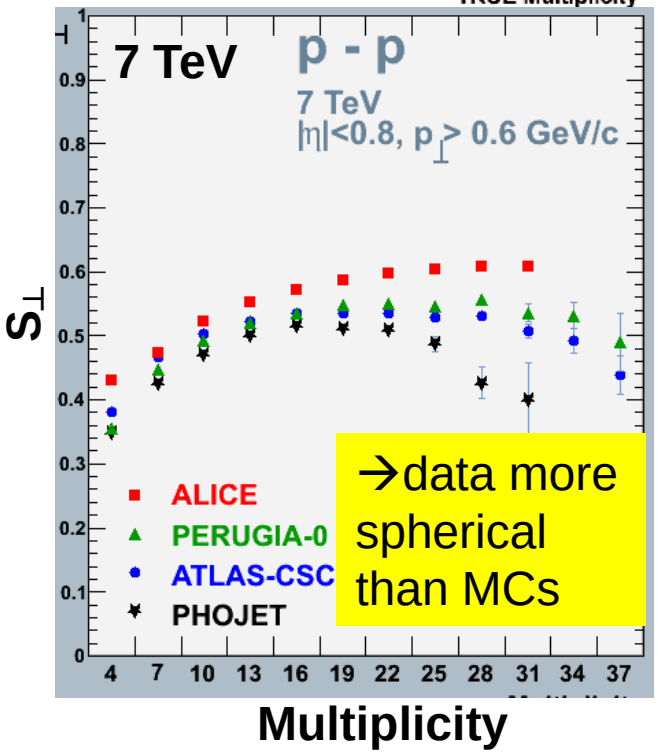
- In addition to UE analysis (discussed tomorrow), classify events into topologies
  - Study fraction e.g. as function of multiplicity
- Transverse sphericity
- Eigenvalues of the momentum tensor S_{xy}

$$\mathbf{S_{xy}} = \sum_i \begin{pmatrix} p_x^{(i)2} & p_x^{(i)} p_y^{(i)} \\ p_x^{(i)} p_y^{(i)} & p_y^{(i)2} \end{pmatrix} \qquad S_\perp \equiv \frac{2\lambda_2}{\lambda_2 + \lambda_1}$$

small $S_\perp$: 

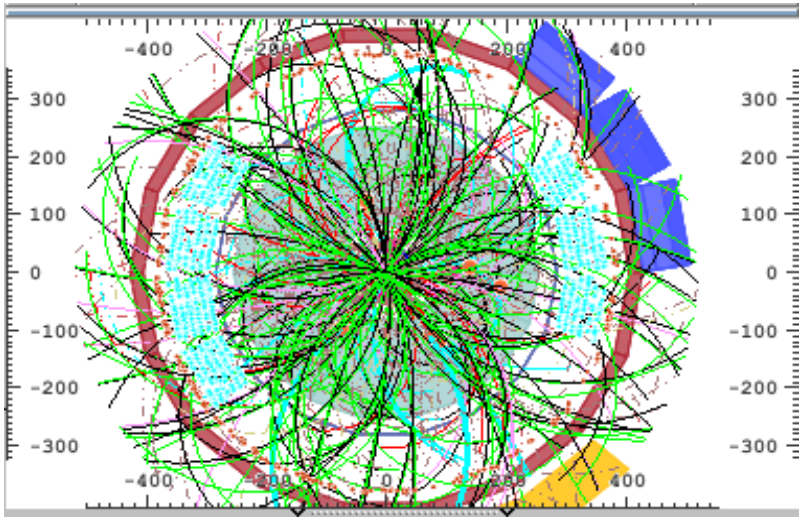
large $S_\perp$: 

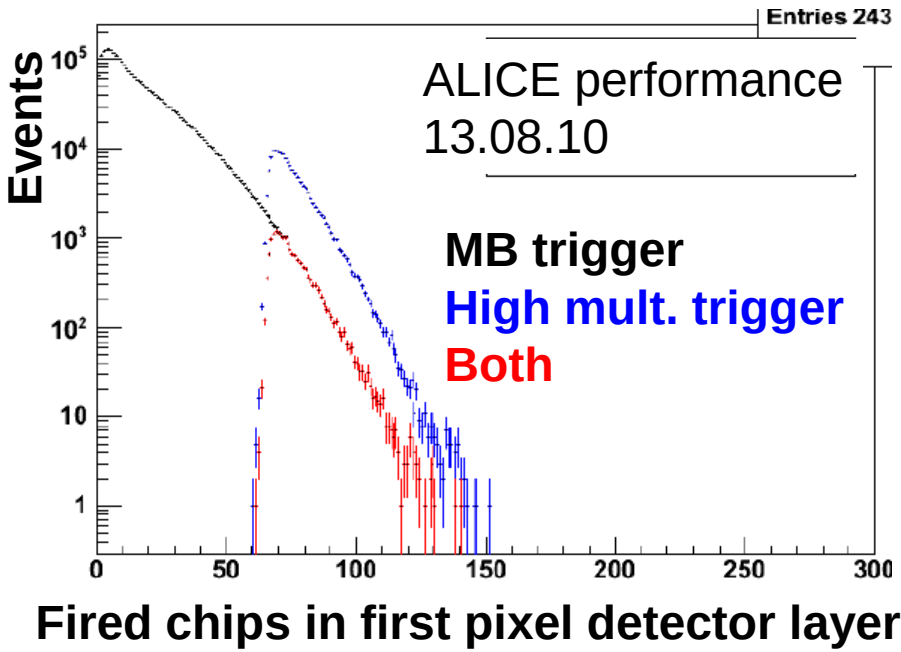




Outlook: High Multiplicity Trigger

- ALICE uses high-multiplicity trigger (pixel hits at L0) since July
  - Displaced beams → low pile-up
  - About 15M events collected
- Trigger efficiency and bias under study
- Do high-multiplicity events resemble the bulk properties of MB events?
  - $\langle p_T \rangle$
  - Particle yields
  - Strangeness





Summary Min-Bias Results

	Other Normalization		*Common Plot* Normalization	
	0.9 TeV	7 TeV	0.9 TeV	7 TeV
MB1 $dN_{ch}/d\eta$	INEL/NSD/INEL>0 (p_T>0) EPJC 68 (2010) 89 and 345	INEL>0 EPJC 68 (2010) 345	See Chiara's presentation	
MB2 dN_{ch}/dp_T	INEL/NSD arXiv:1007.0719			
MB3 multiplicity	INEL/NSD/INEL>0 (p_T>0) EPJC Vol. 68 (2010) 89 and 345	INEL>0 EPJC 68 (2010) 345		
MB4 $\langle p_T \rangle$ vs. N_{ch}	INEL (p_T>0.15) arXiv:1007.0719		arXiv:1007.0719	

Summary

- Momentum Spectra
  - $\langle p_T \rangle$ vs. N_{ch} not explained by common MC models and tunes
- Two-Pion Bose-Einstein Correlations
  - Source size increases with multiplicity, no k_T dependence
- Antiproton-to-Proton Ratio
  - Baryon-number transfer to mid-rapidity suppressed at 7 TeV
- Identified particle yields
  - Kaon and proton yield underestimated by MCs
- Strangeness
  - MC underestimate yield of K_0, Λ, Ξ with increasing particle mass, strangeness and p_T
- Multiplicity
  - $dN_{ch}/d\eta$ being extended up to $-3.4 < \eta < 5$
  - $dN_{ch}/d\eta$ being studied as function of N_{ch}
- Event topology
  - Data more „spherical“ (less back-to-back-ish) than MCs
- High-multiplicity data being analyzed
- Still some work and approval for the common plots needed

ALICE is a happy girl right now…