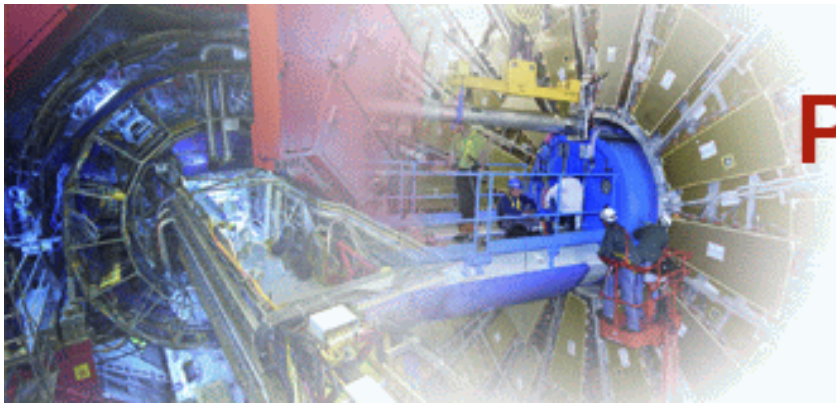

PHYSICS AT LHC 2010

7 - 12 June 2010

DESY, Hamburg

ALICE First Physics Results

Andrea Dainese

(INFN Padova)

on behalf of the ALICE Collaboration

Outline

- Particle multiplicity
  - $dN_{ch}/d\eta$ and dN/dN_{ch} measurements at 0.9, 2.36, and 7 TeV
- Momentum spectra
  - Charged particle p_t spectra at 0.9 TeV
- Baryon production
  - Anti-proton/proton ratio at 0.9 and 7 TeV
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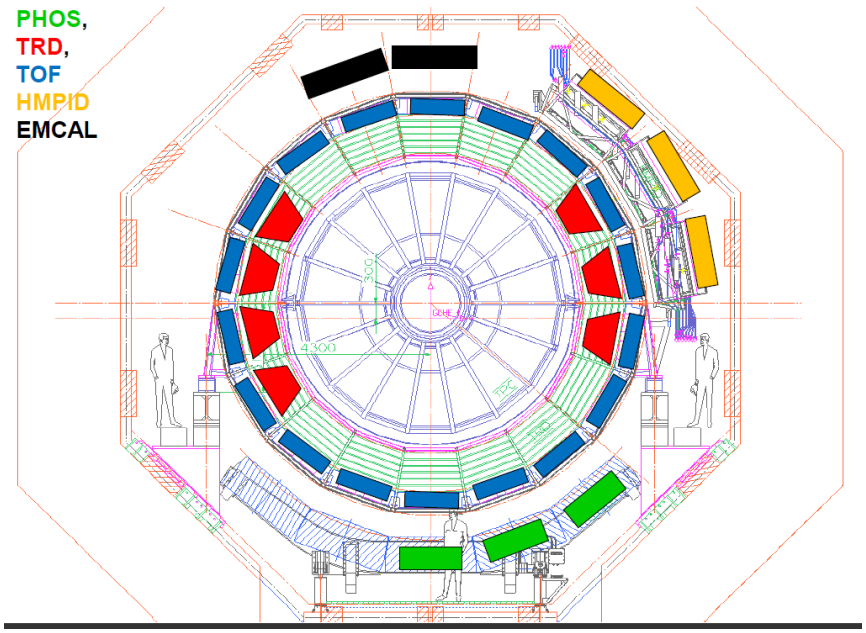
published

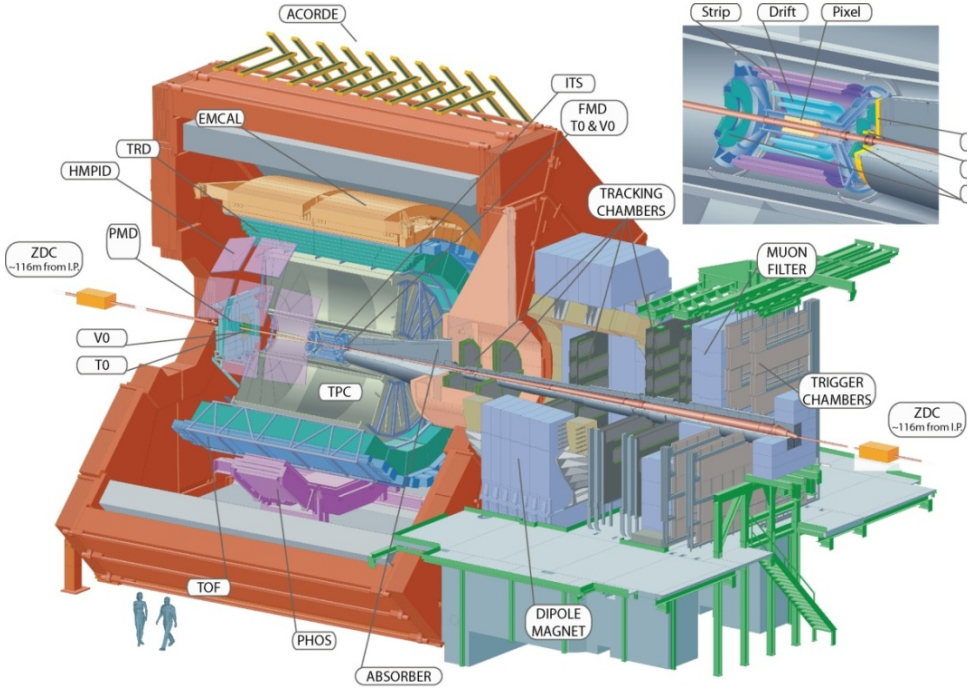
preliminary

in preparation

Detector configuration 2009/2010

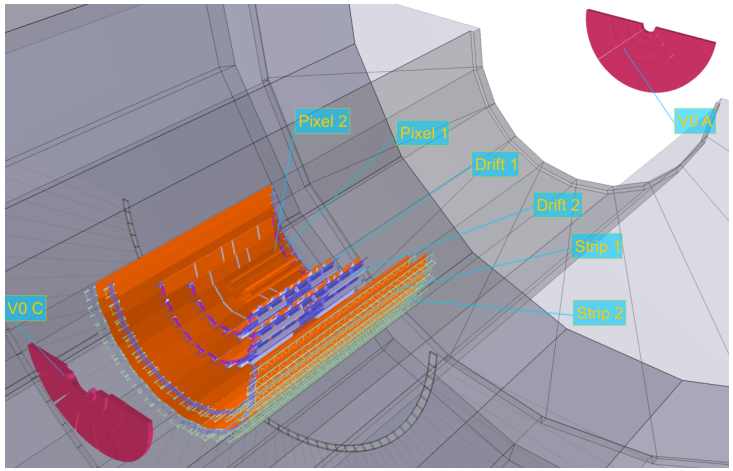
- ITS, TPC, TOF, HMPID, MUON, V0, T0, FMD, PMD, ZDC (100%)
- TRD (7/18)
- EMCAL (4/12)
- PHOS (3/5)





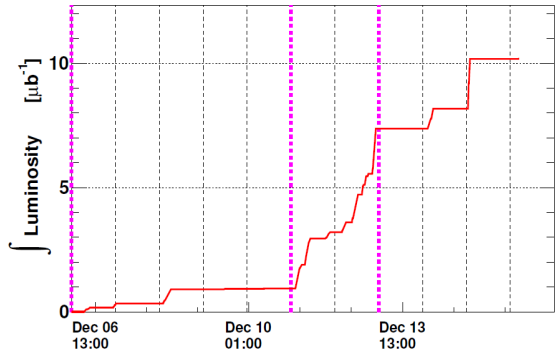
→ J.Schukraft

Trigger & Data samples

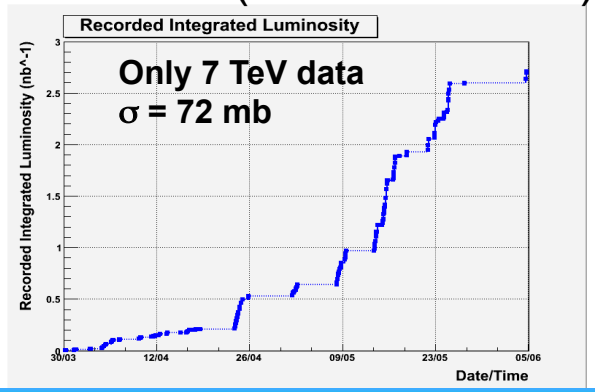


- **"Minimum bias"**, based on interaction trigger:
  - **SPD or V0-A or V0-C**
    - at least one charged particle in 8 η units
  - read out all ALICE
- **single-muon** trigger:
  - forward muon in coincidence with Min Bias
  - read out MUON, SPD, V0, FMD, ZDC
- Activated in coincidence with the BPTX beam pickups

- 2009 (0.9 and 2.36 TeV)
  - ~10.3 μb^{-1} (5×10^5 min bias)



- 2010, to June 8th (0.9 and 7 TeV)
  - ~2.7 nb^{-1} (2×10^8 min bias)



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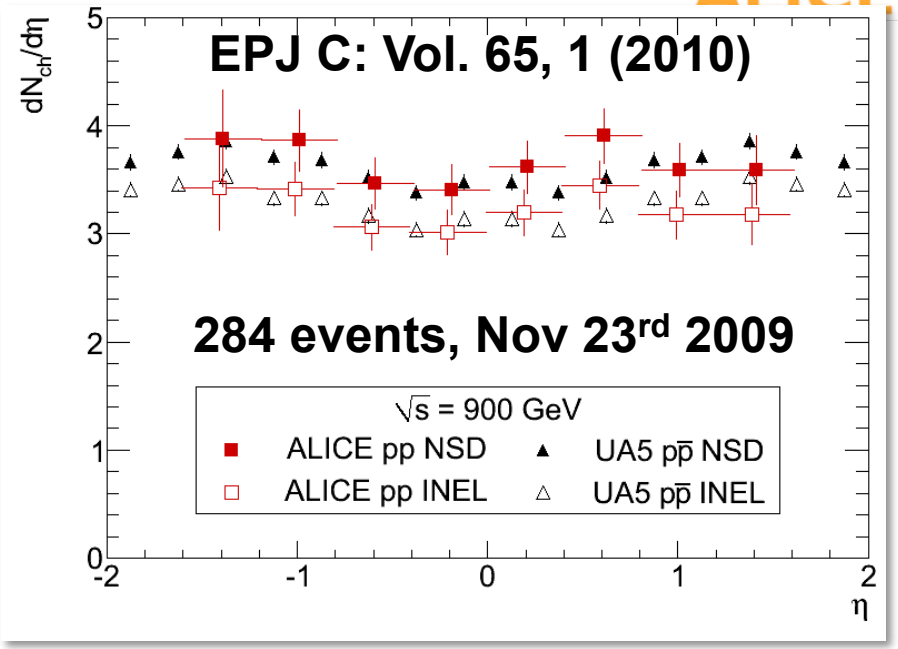
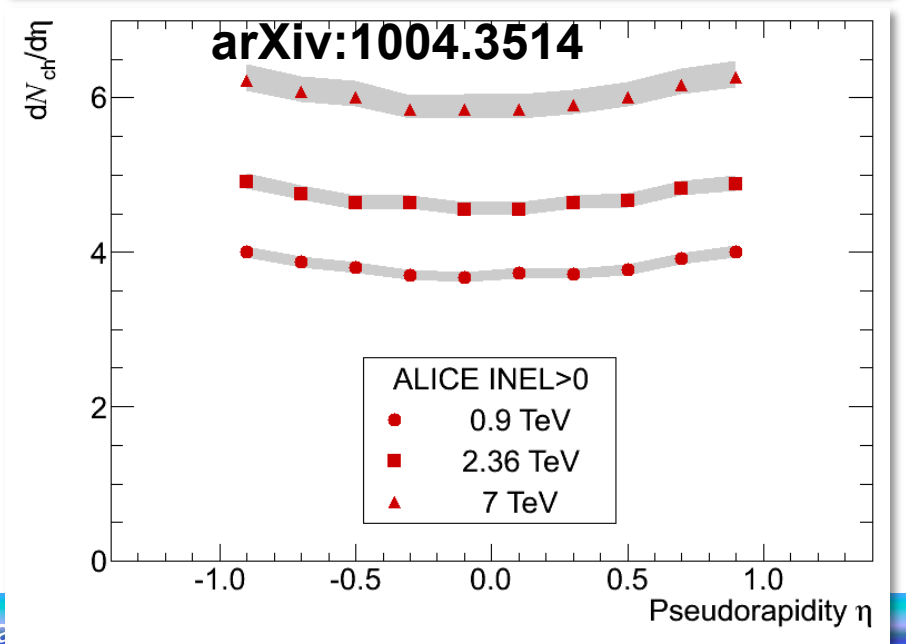
Multiplicity measurements

- Multiplicity measured using tracklets in the two pixel layers (R ~ 4 and 7 cm)
- ALICE has published the pseudorapidity density and multiplicity distribution at 0.9, 2.36, and 7 TeV
  - First LHC paper
  - First 7 TeV paper
  - All three papers accepted by EPJC

→ P.Hristov





Event Classes

0.9 and 2.36 TeV

- INEL and NSD
- Use measured cross sections for diffractive processes
- Change MC generator fractions (SD/INEL, DD/INEL) such that they match these fractions
- Use Pythia and Phojet to assess effect of different kinematics of diffractive processes

7 TeV

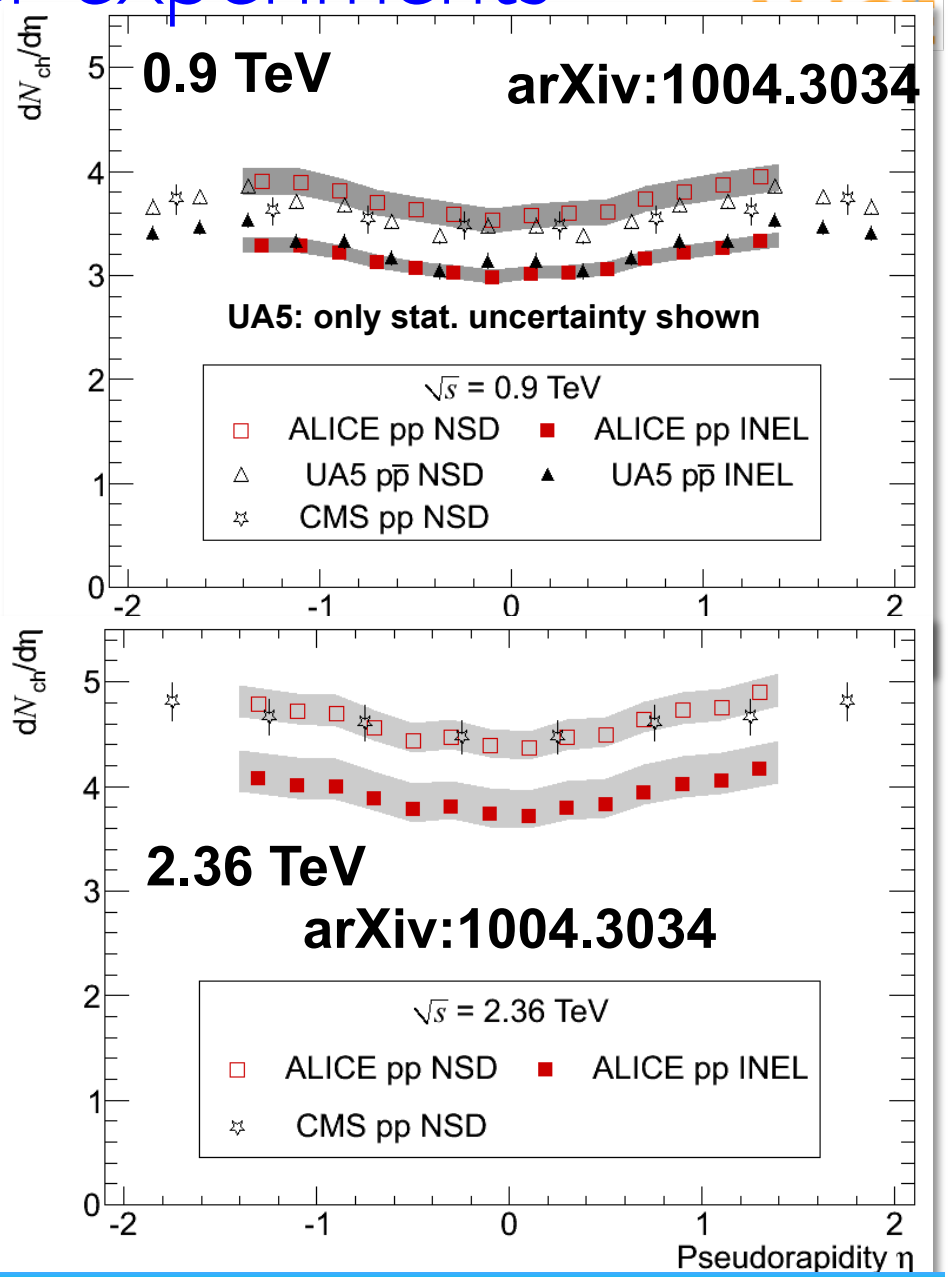
- Diffraction is quite unknown
- Hadron-level definition of events (similar to ATLAS first paper)
  - All events that have at least one charged primary particle in $|\eta| < 1$: "INEL>0"
  - Minimizes model dependence

INEL: MB_{OR} (SPD *OR* VZEROA *OR* VZEROC) *AND* offline background suppression

NSD: MB_{AND} (VZEROA *AND* VZEROC) *AND* offline background suppression
INEL>0: INEL *AND* at least one charged primary particle in $|\eta| < 1$

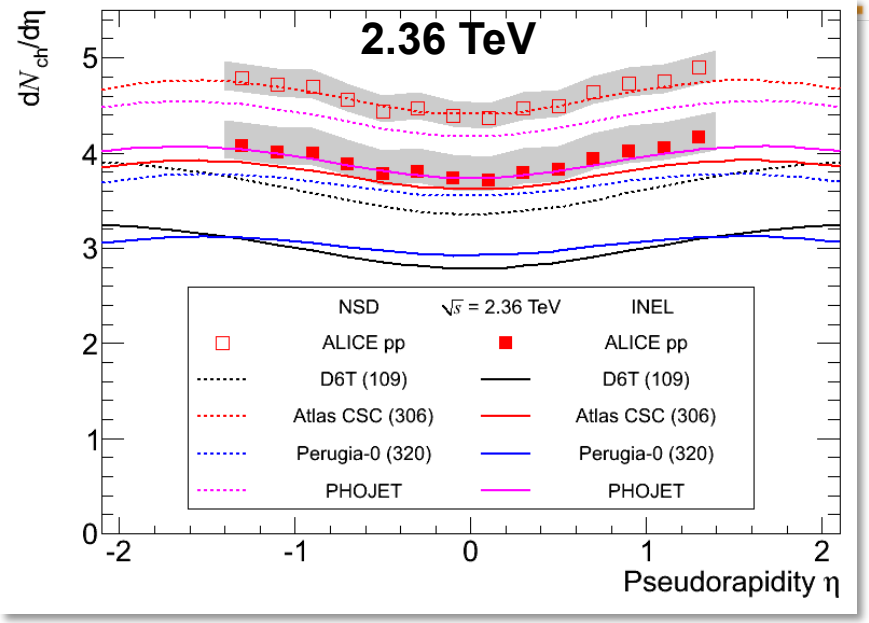
$dN_{ch}/d\eta$ vs. other experiments

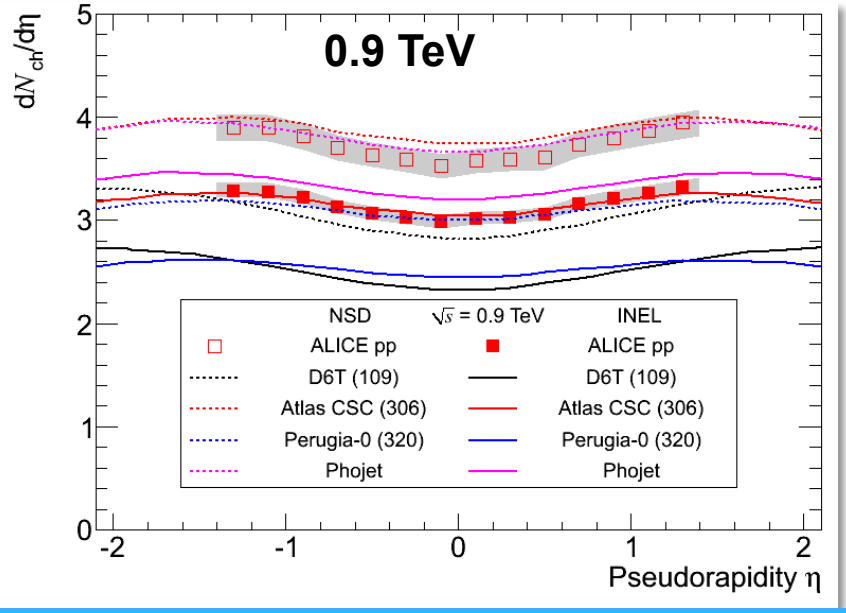
- Consistent with UA5
  - (only 900 GeV)
- Consistent with CMS
  - (only NSD)
  - does not include charged leptons → ~1.5 % difference

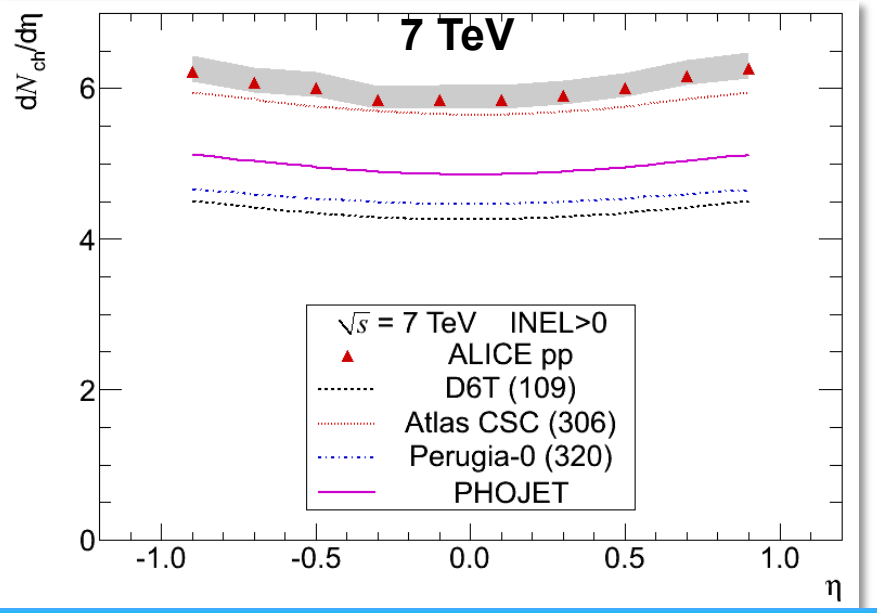


$dN_{ch}/d\eta$ vs. Monte Carlo

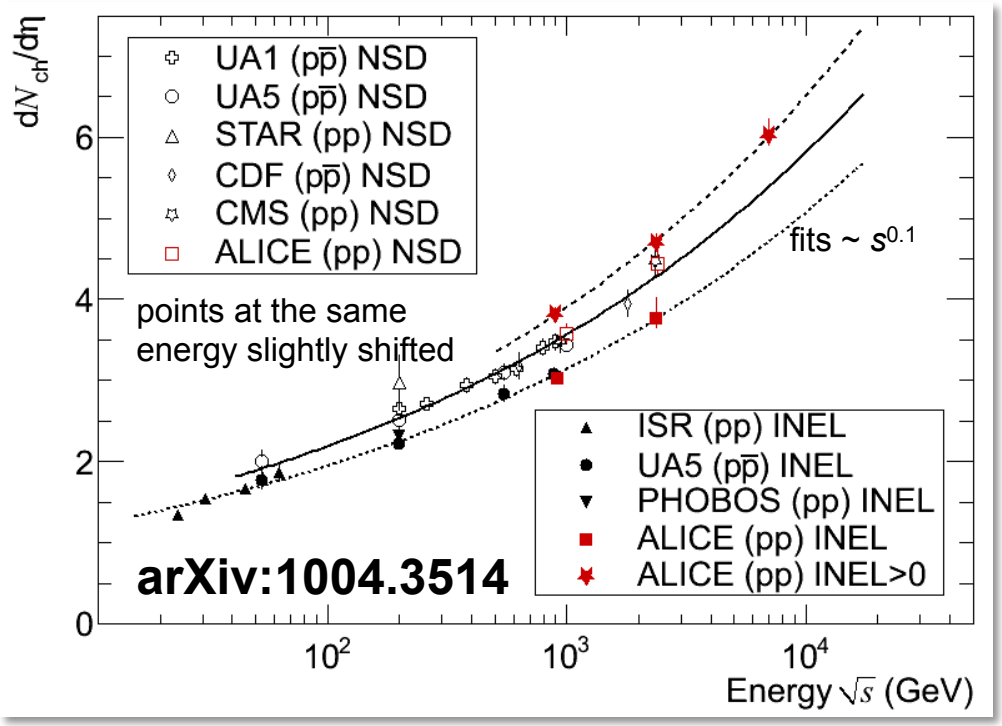
- Pythia D6T and Perugia-0 match neither INEL, NSD or INEL>0 at any energy
- Pythia ATLAS-CSC and Phojet reasonably close with some deviations at 0.9 and 2.36 TeV
- Only ATLAS-CSC close at 7 TeV





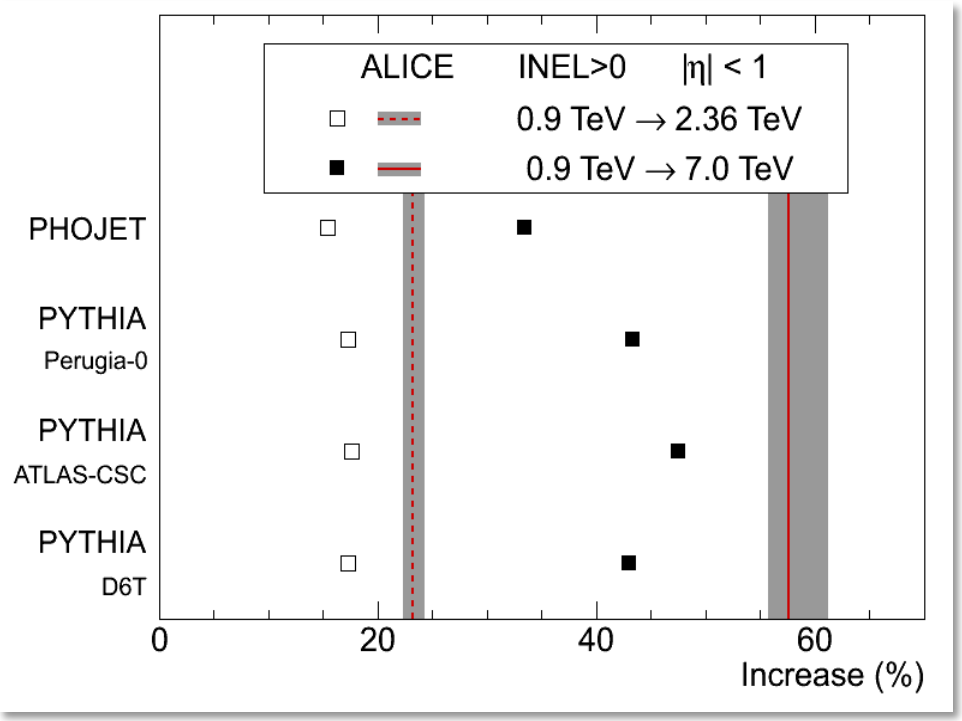


$dN_{ch}/d\eta$ vs. $\sqrt{s}$



Power law dependence fits well

arXiv:1004.3514



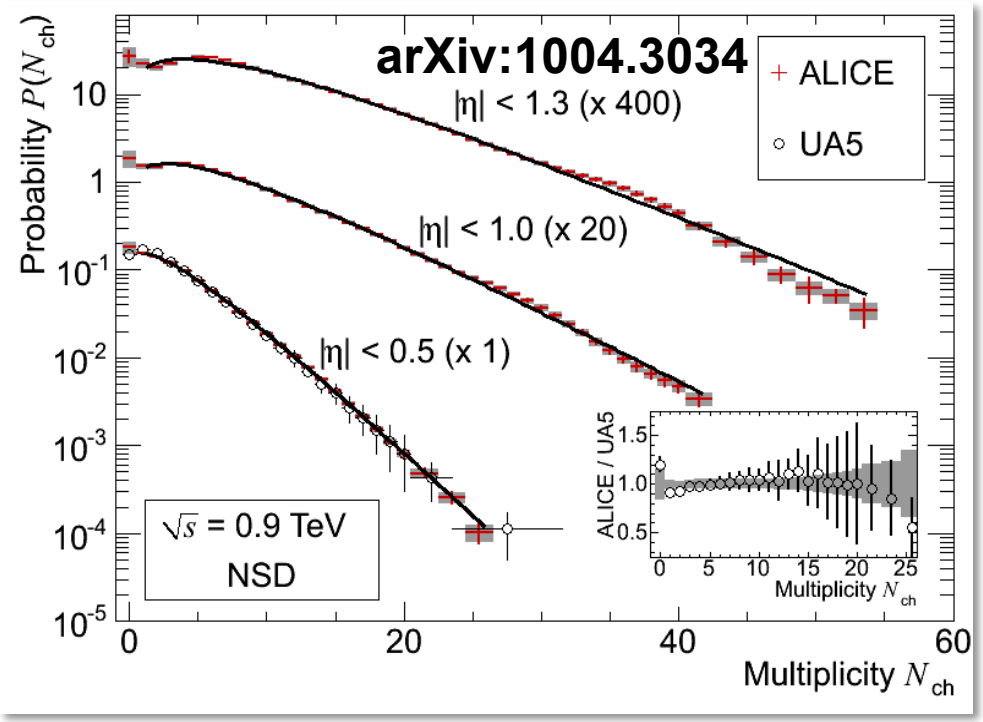
Significantly larger increase from 0.9 to 7 TeV than in MCs

Increase in dN_{ch}/dh in $\|\eta\| < 1$ for INEL > 0 arXiv:1004.3514	**√s**	**ALICE (%)**	**MCs (%)**
	0.9 → 2.36 TeV	**$23.3 \pm 0.4\ ^{+1.1}_{-0.7}$**	**15 – 18**
	0.9 → 7 TeV	**$57.6 \pm 0.4\ ^{+3.6}_{-1.8}$**	**33 – 48**

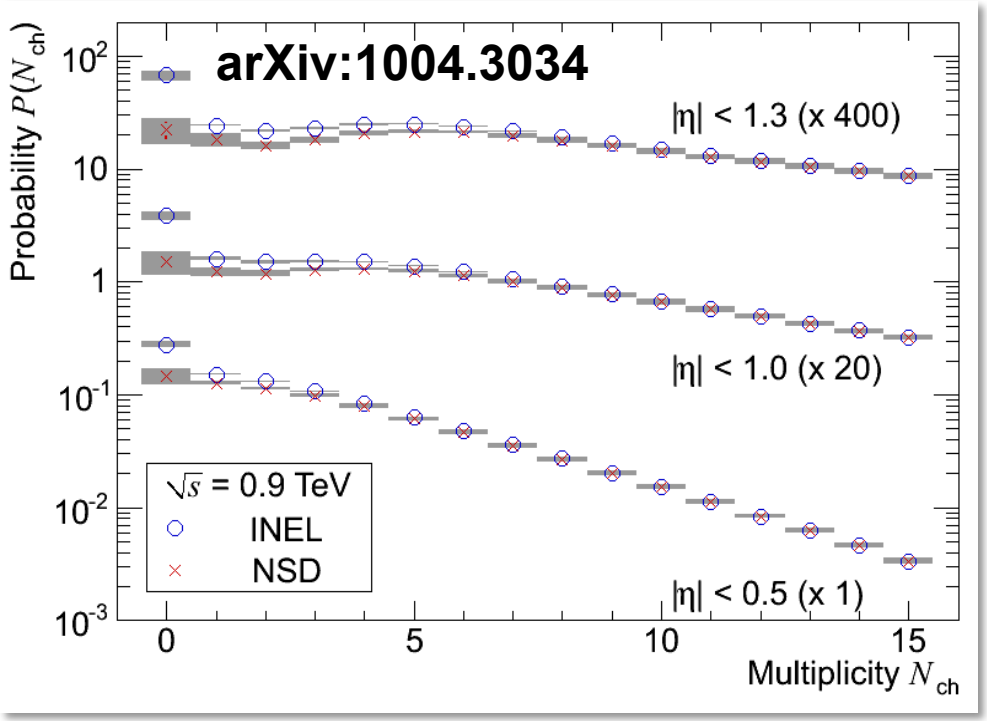
Multiplicity Distributions

- Distributions in three η-regions
- Consistent with UA5 ($|\eta|<0.5$)
- Fits with one negative binomial work well in limited η-regions
  - clan-based model of production production
- Difference between INEL and NSD in low-multiplicity region

0.9 TeV: ALICE vs. UA5



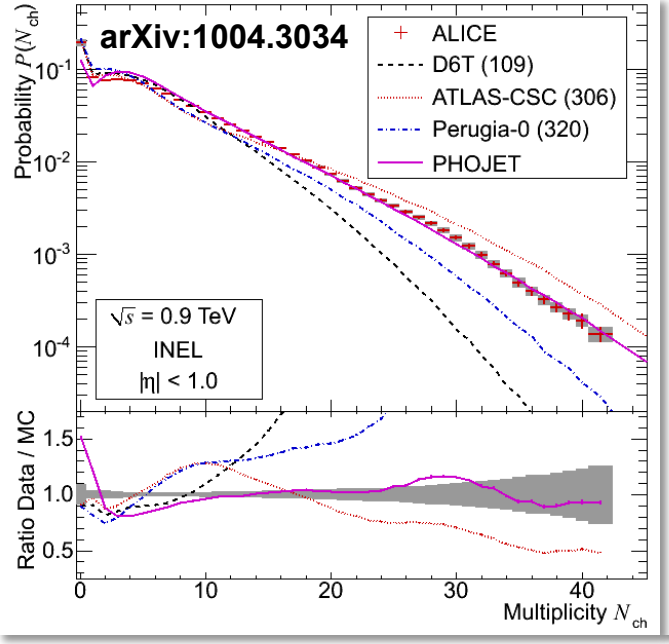
0.9 TeV: INEL vs. NSD



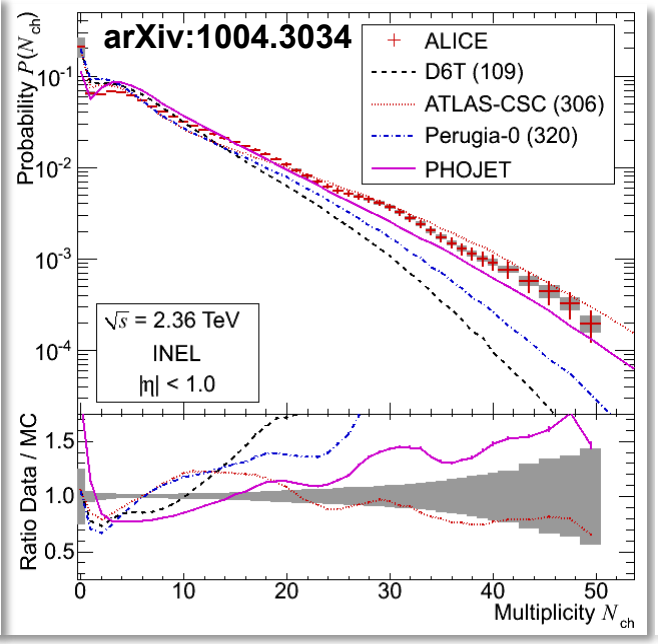
dN/dN_{ch}: vs. Monte Carlo

- Phojet
  - provides a good description at 900 GeV
  - fails at 2.36 and 7 TeV
- Pythia Atlas CSC
  - fails at 0.9 TeV
  - reasonably close at 2.36 and 7 TeV but deviations around 10-20
- Pythia D6T and Perugia-0 far from the distribution at all energies

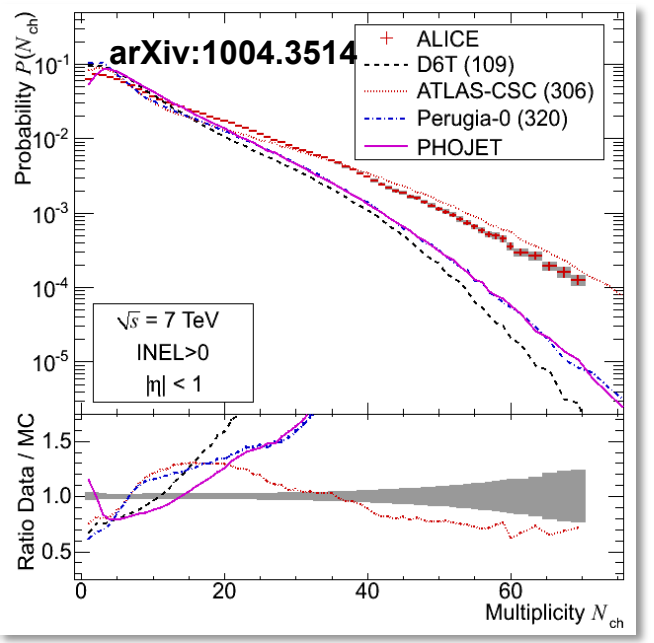
0.9 TeV



2.36 TeV



7 TeV



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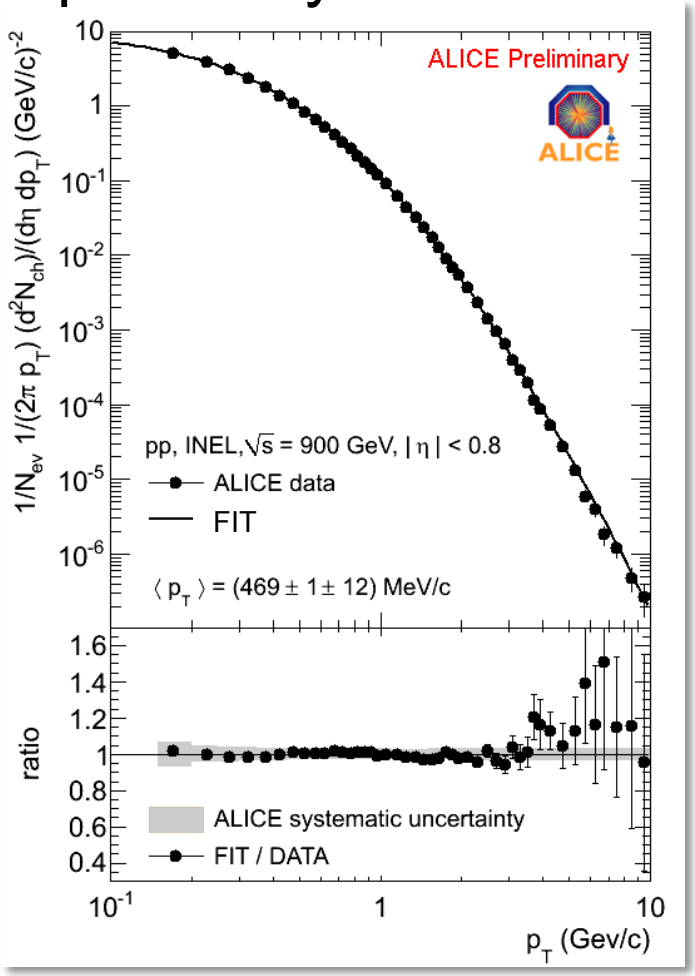
published

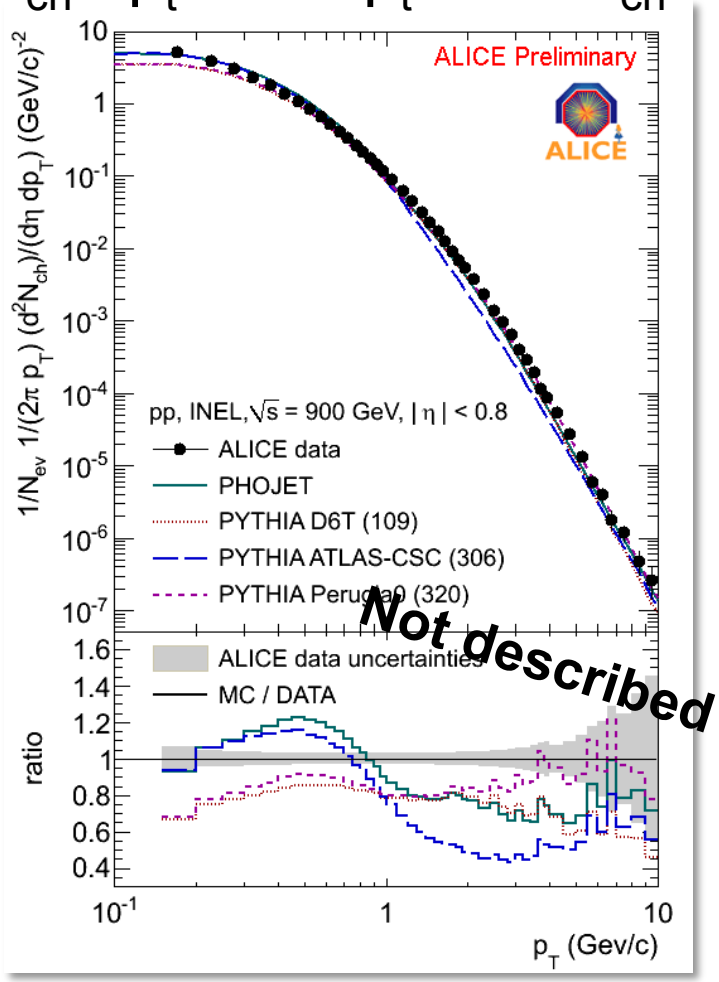
preliminary

in preparation

dN_{ch}/dp_t at 0.9 TeV

- Paper ready for submission: dN_{ch}/dp_t and $\langle p_t \rangle$ vs. N_{ch}





Not described by MCs

$$\frac{1}{p_T}\frac{d^2N_{ch}}{d\eta dp_T} \propto \left(1+\frac{E_T}{nT}\right)^{-n}$$

$$E_T = \sqrt{m_\pi^2 + p_T^2} - m_\pi$$

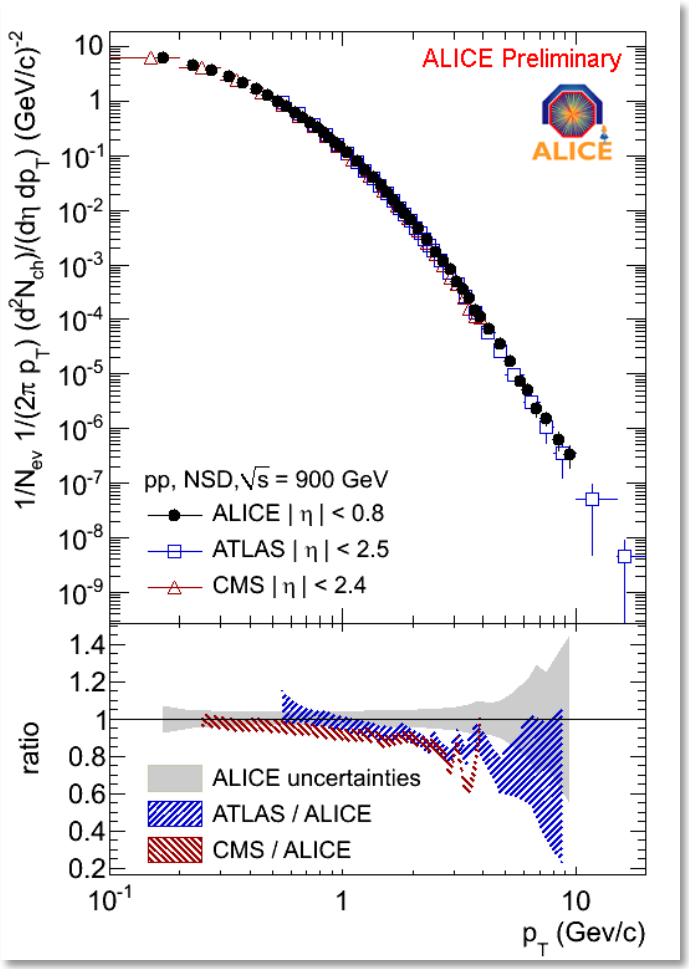
$$\frac{E_T}{nT} << 1 :\sim \exp\left(-\frac{E_T}{T}\right)$$

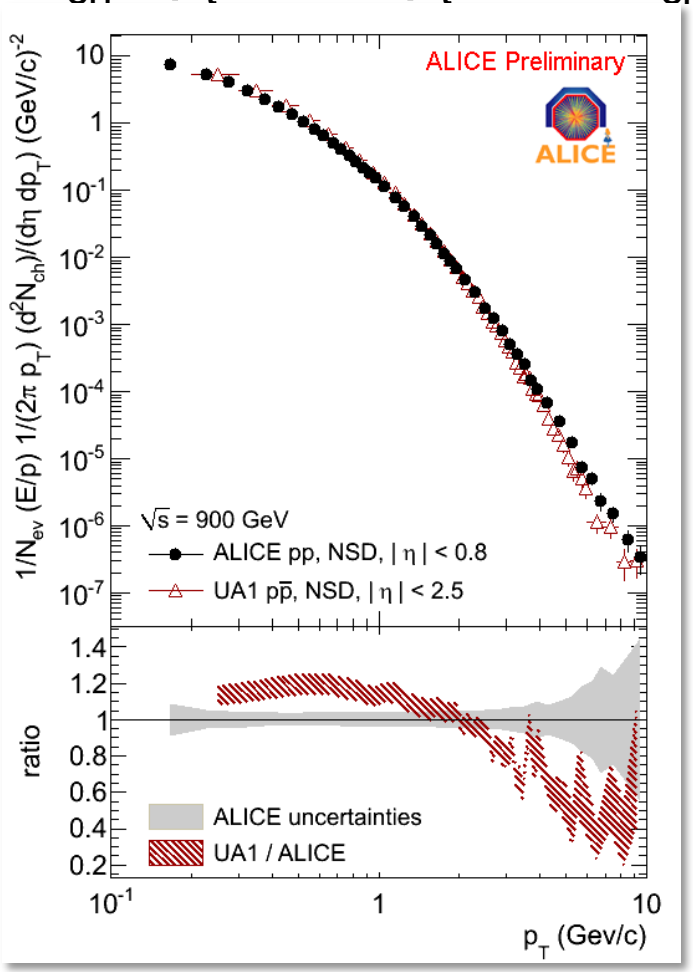
$$\frac{E_T}{nT} >> 1 :\sim p_T^{-n}$$

PHOJET (at 900 GeV) and PYTHIA ATLAS-CSC tune (at 2.36 and 7 TeV) gave best description of the multiplicity distributions

dN_{ch}/dp_t at 0.9 TeV

- Paper ready for submission: dN_{ch}/dp_t and $\langle p_t \rangle$ vs. N_{ch}

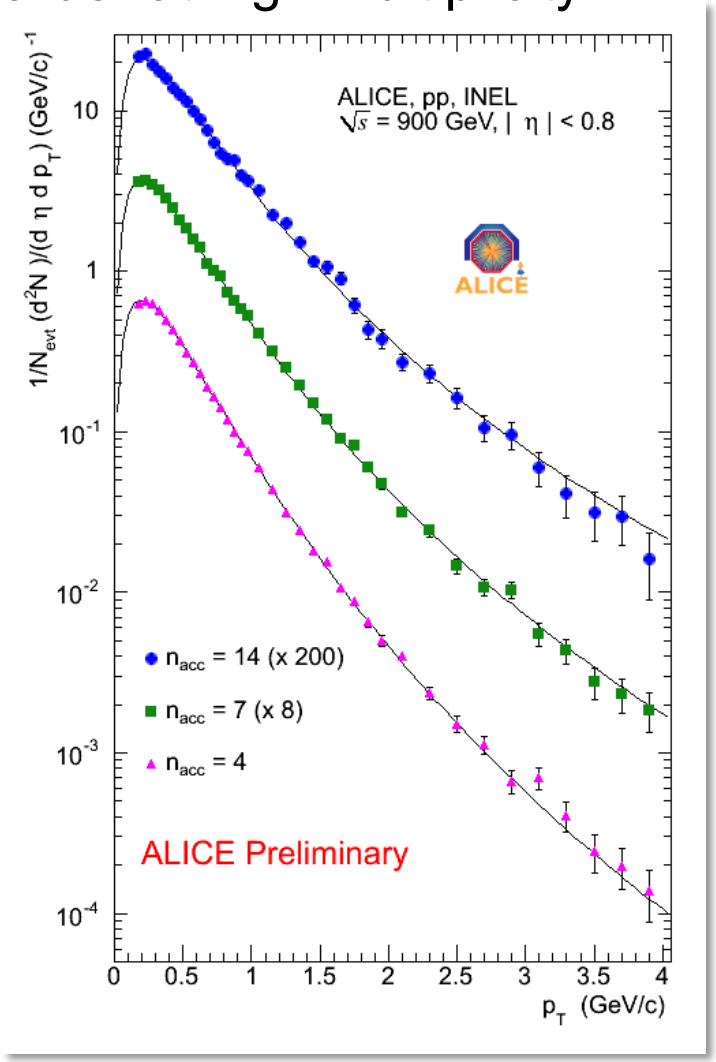




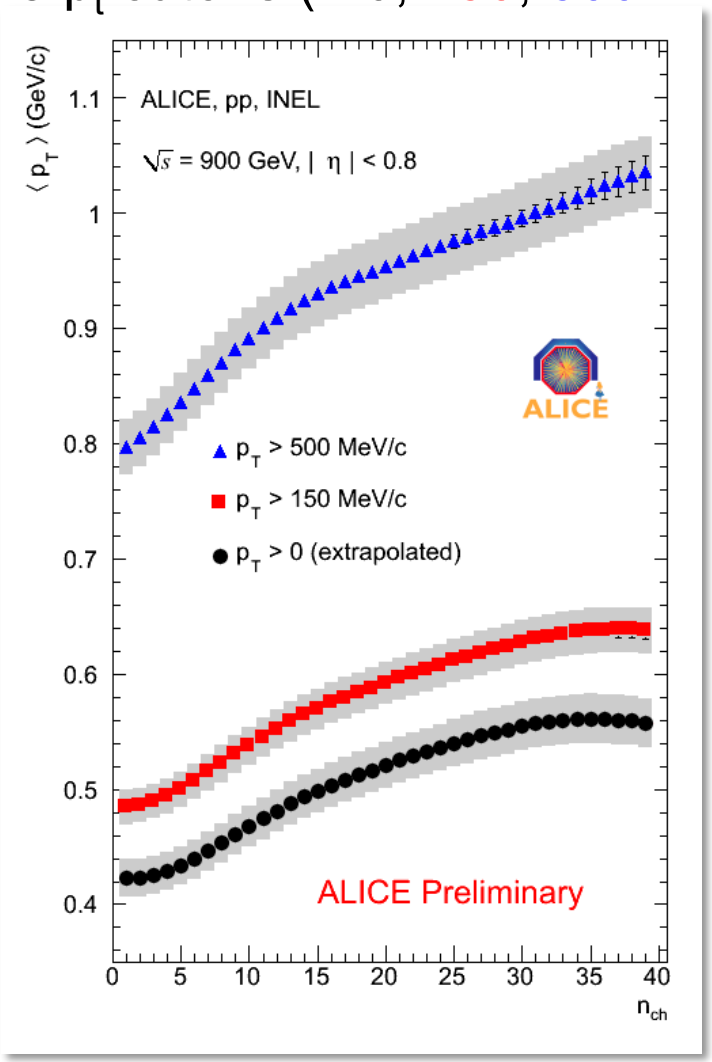
→ALICE measures harder spectrum than CMS, ATLAS, UA1 (narrower window at central rapidity)

$\langle p_t \rangle$ vs multiplicity (0.9 TeV)

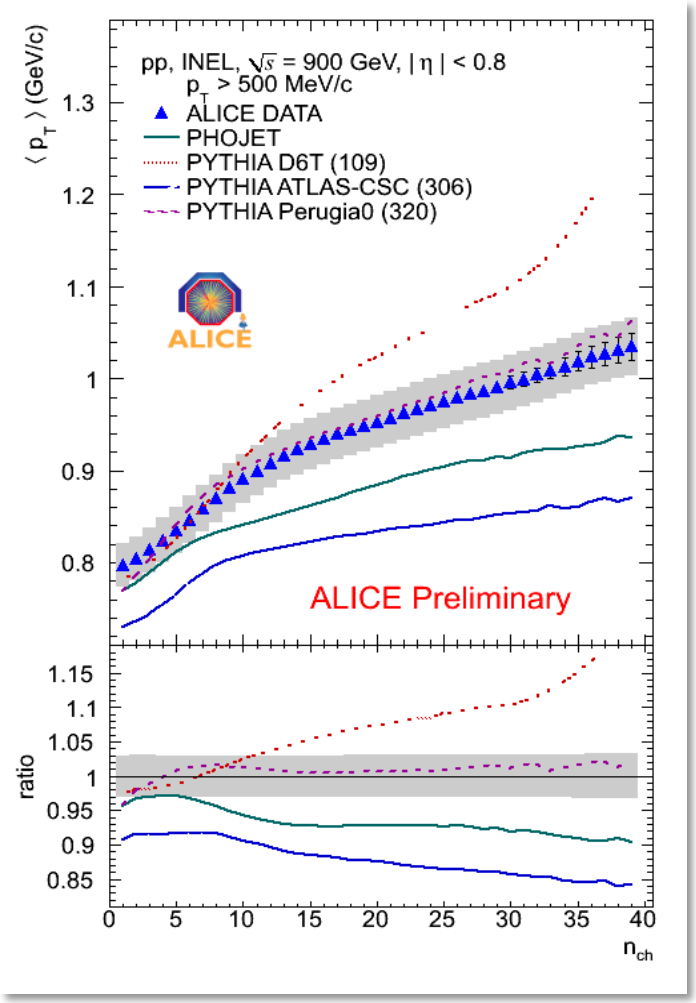
- "Power-law"-like tail becomes harder at high multiplicity

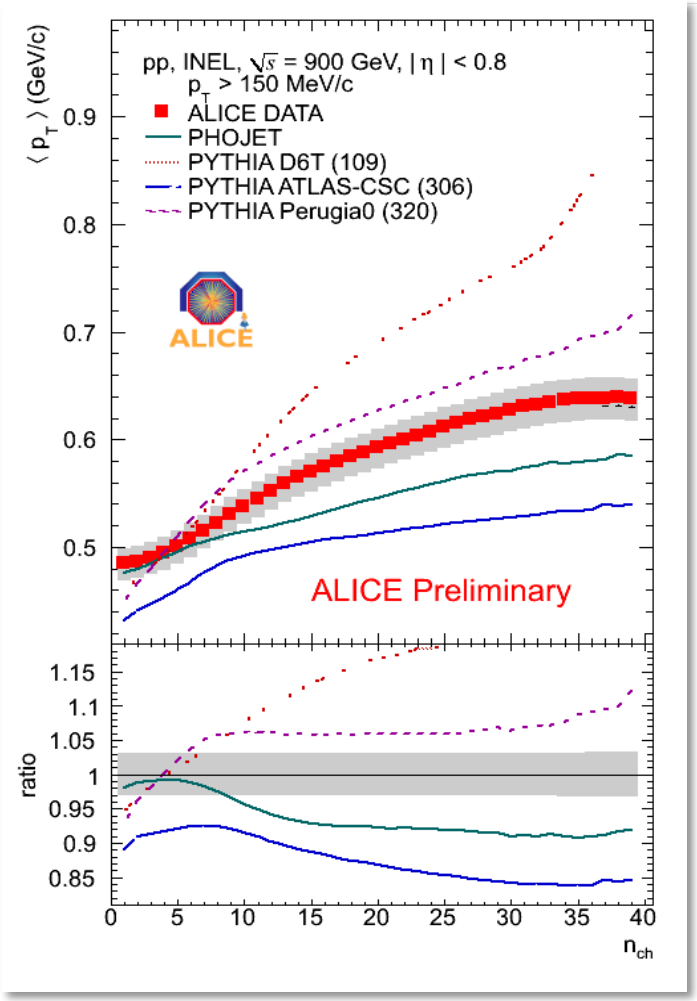


- $\langle p_t \rangle$ vs N_{ch} from fit function, with 3 p_t cutoffs (> 0, 150, 500 MeV/c)



<p_t> vs multiplicity (0.9 TeV)





- **Perugia-0** (which fails for multiplicity) describes well <p_t>, but only for p_t>500 MeV/c (ATLAS found agreement for p_t > 500 MeV/c)
- **Phojet** (which describes multiplicity) fails for <p_t>

Comparison to MCs: summary

$\sqrt{s}$ = 0.9 TeV

MC/TUNE	D6T	Perugia0	CSC	PHOJET
η	-20%	-17%	+3%	-2%
N_{ch}	$N_{ch}>10$	$N_{ch}>5$	$N_{ch}>15$	$N_{ch}>10$
p_t		$p_t>4$Gev	$p_t>1$GeV	$p_t>1$GeV
$<p_t>$				

- MC << data
- MC >> data
- MC ≈ data

→ 0.9 TeV: PHOJET better for N_{ch}, Perugia-0 for p_t

$\sqrt{s}$ = 2.36 TeV

η	-24%	-21%	-2%	-8%
N_{ch}	$N_{ch}>10$	$N_{ch}>5$	$N_{ch}>20$	$N_{ch}>15$

$\sqrt{s}$ = 7 TeV

η	-27%	-24%	-4%	-17%
N_{ch}			$N_{ch}>30$	

→ 2.36, 7 TeV: CSC better for N_{ch}

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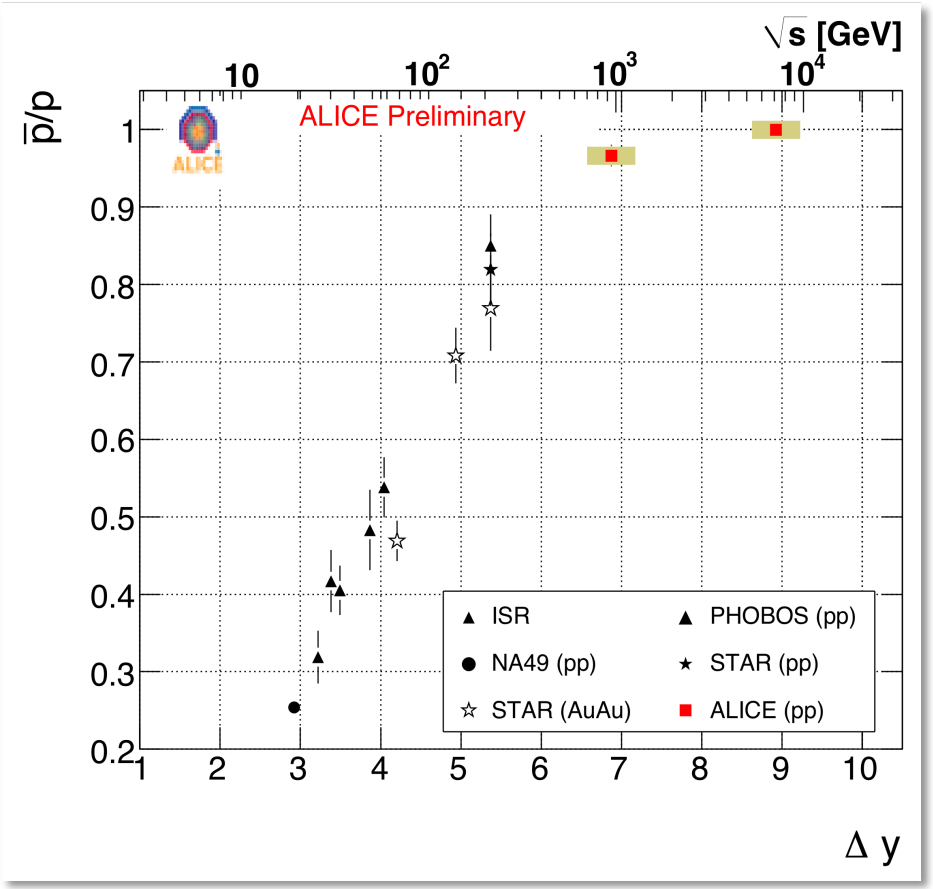
$\bar{p}/p$ measurement at mid-rapidity

- Proton identification with TPC dE/dx
- Special care for secondaries and absorption corrections
- pbar/p at $|y| < 0.5$ and $0.45 < p_t < 1.05$ GeV/c

- Baryon-stopping at low

  $\Delta y = y_{beam} - y_{CM}$

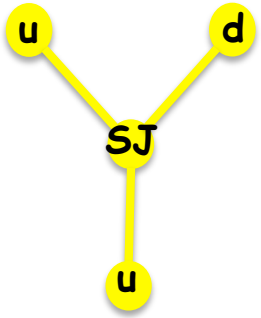
  Vanishes at high LHC energy



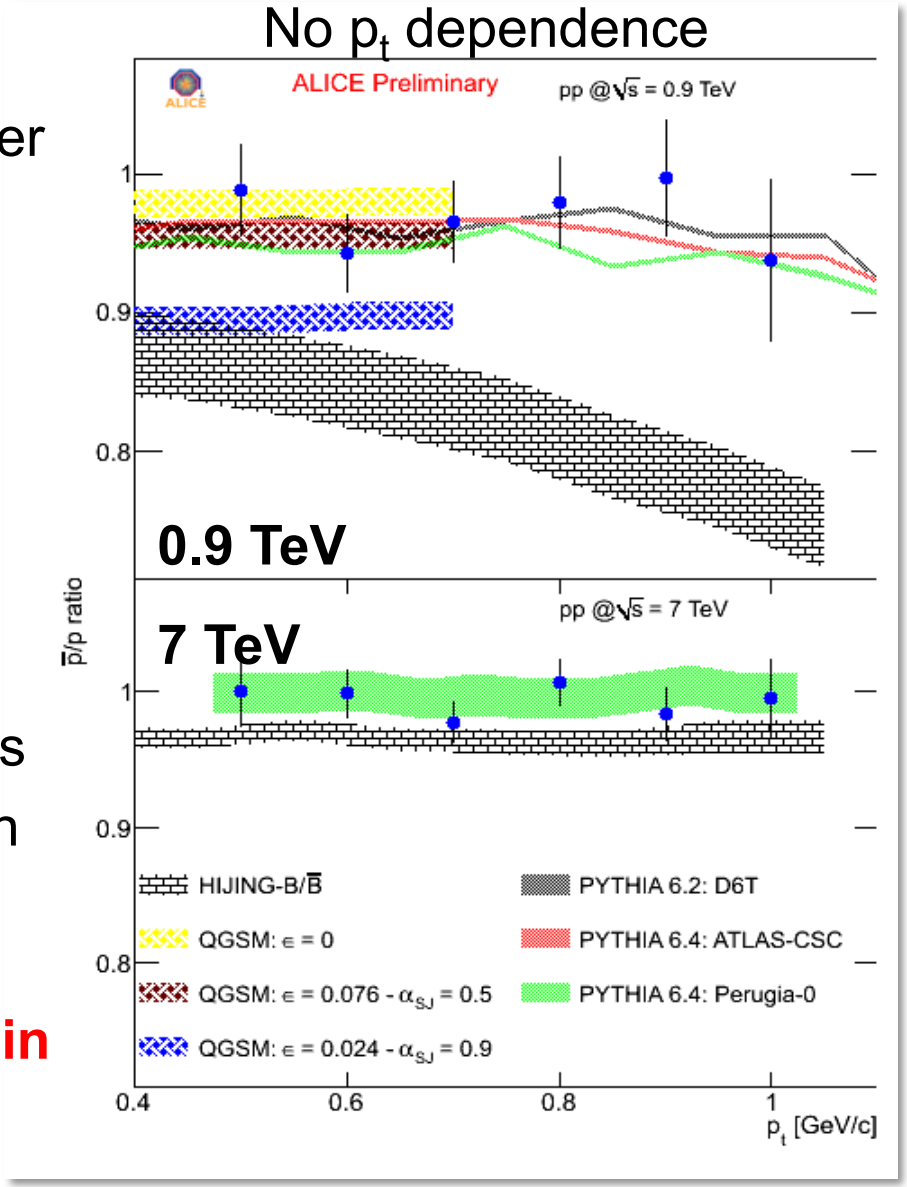
→ **M.Broz**

$\overline{p}/p$ measurement vs. MCs

- Baryon number transport is usually explained by a String Junction transfer (gluon field)



- What is the intercept of the corresponding Regge trajectory
  - (α_{SJ} = ½ or 1?)
- Data described well by PYTHIA tunes
- Other models (HIJING-B, QGSM with α_{SJ} ~ 1) underestimate the data
- **Data show suppression baryon transport over large rapidity gaps in pp collisions**



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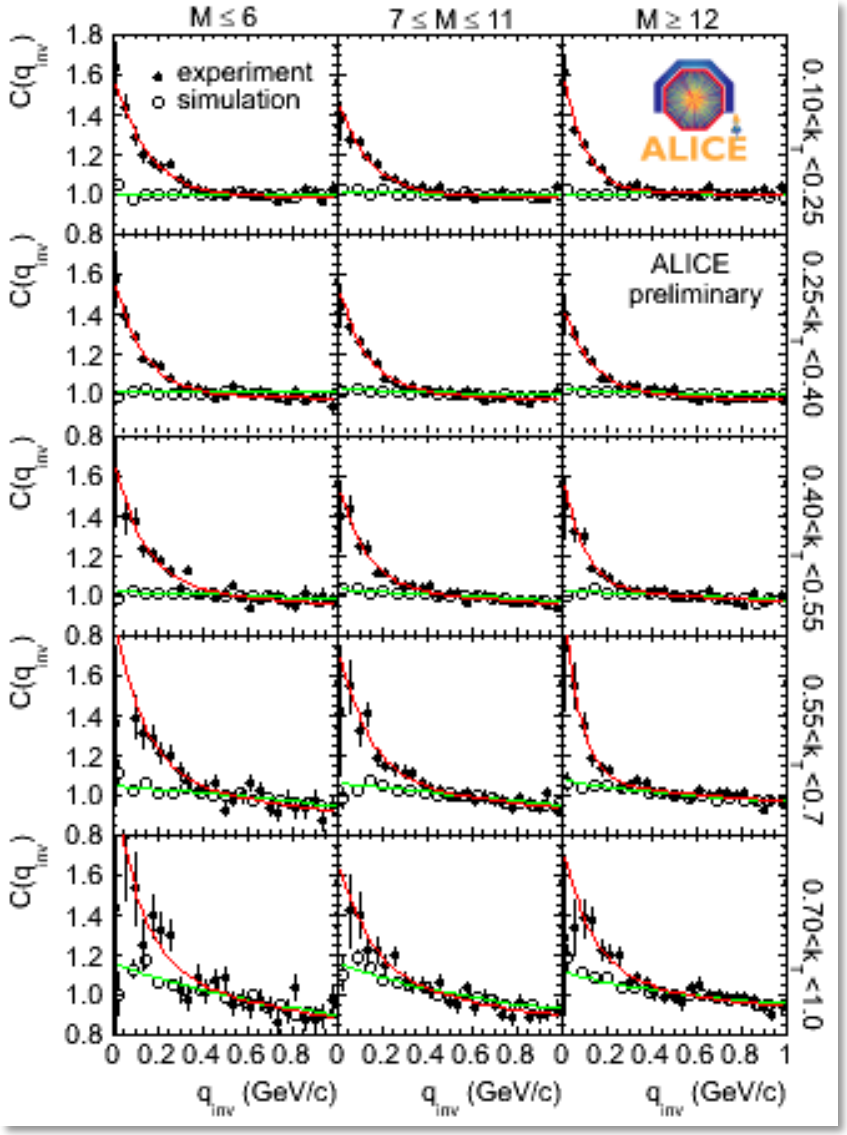
Femtoscopy: particle emitting source

0.9 TeV

- Assess the space-time evolution of the system that emits particles in pp collisions
- Measure the Bose-Einstein enhancement for pairs of pions (identical bosons) at low momentum difference $q_{inv}=|\mathbf{p}_1-\mathbf{p}_2|$, vs. event multiplicity and pair $k_t = |\mathbf{p}_{t1}+\mathbf{p}_{t2}|/2$
- Fit with a Gaussian

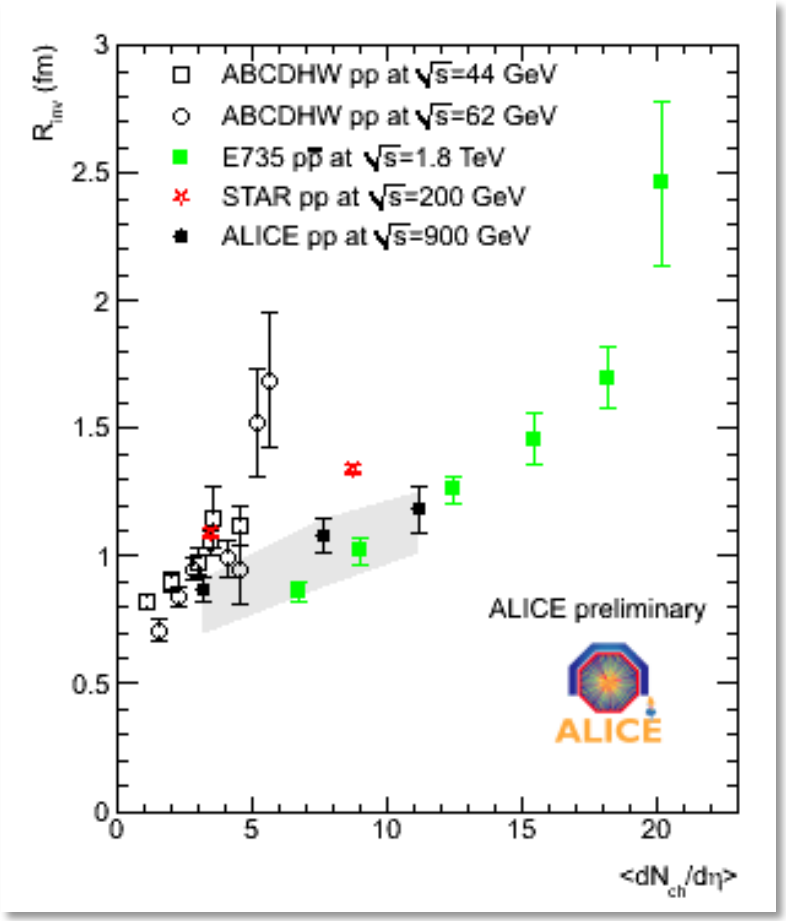
$$C(q_{inv})=1+\lambda\exp(-q_{inv}^2 R^2)$$

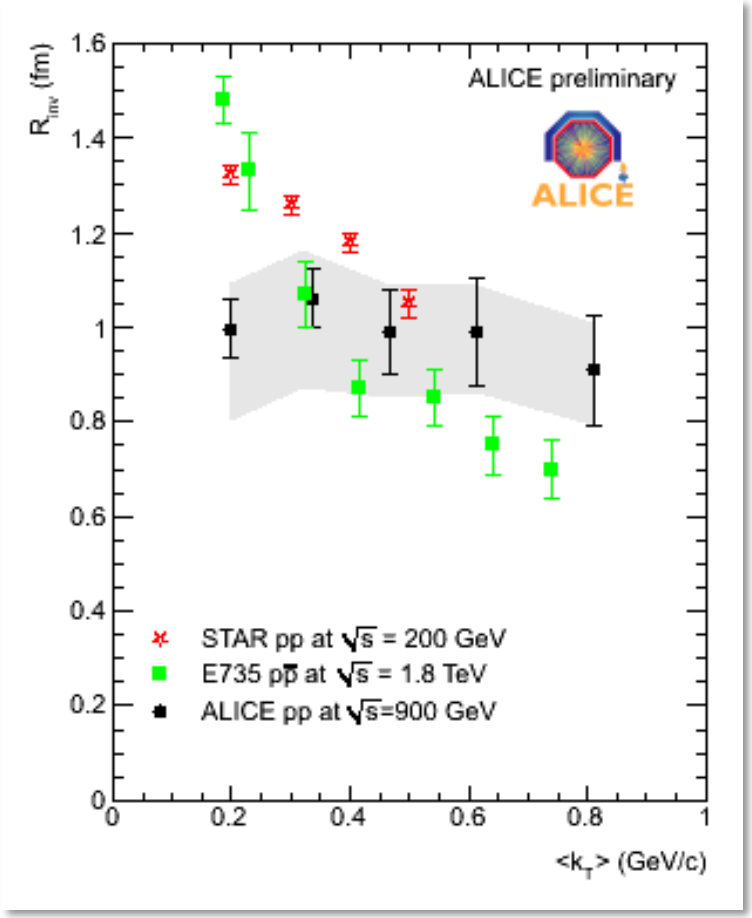


→ **D.Miskowiec**

Femtoscopy results at 0.9 TeV

- Radius grows with $dN_{ch}/d\eta$: consistent with other data and expectations (larger correlation volume at large multiplicities)
- No visible k_t dependence





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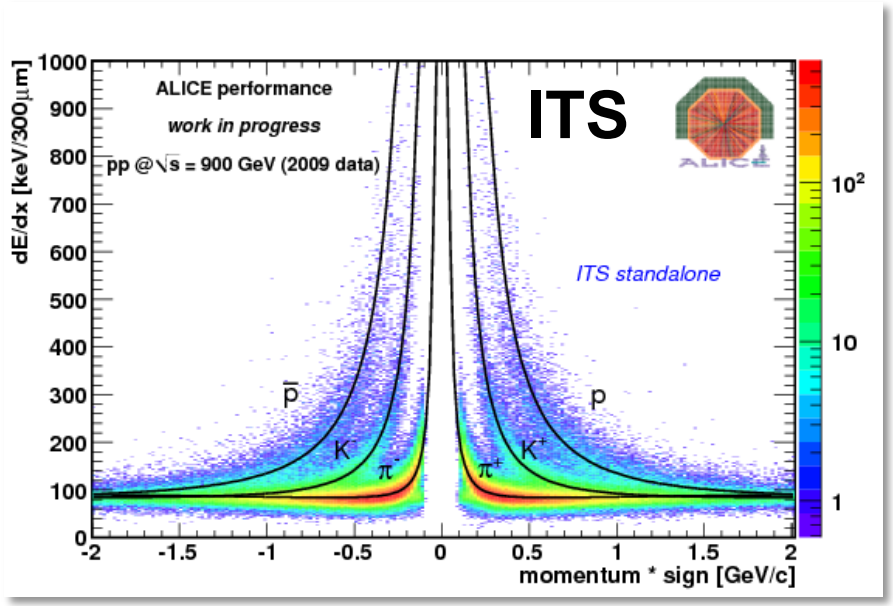
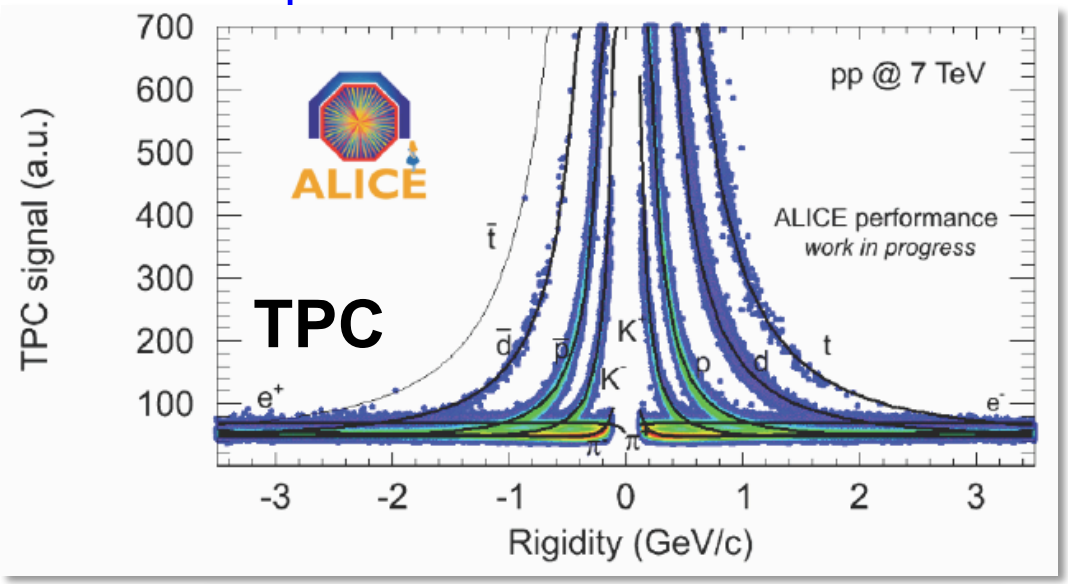
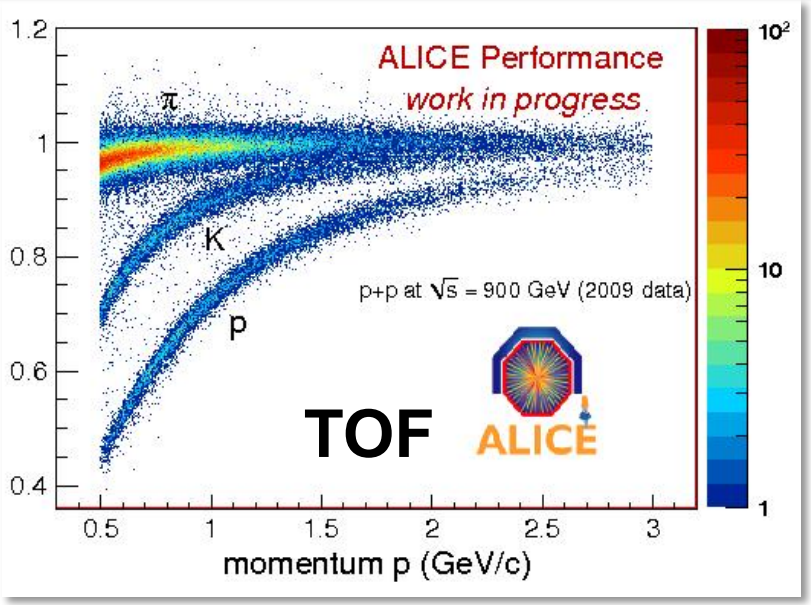
Identified spectra: one of ALICE's specials

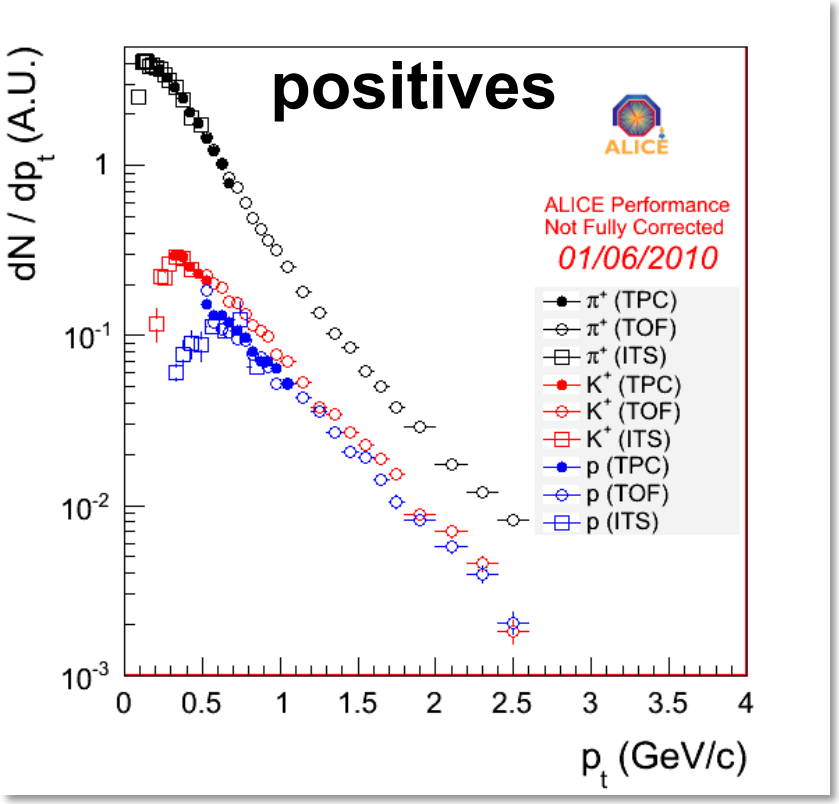


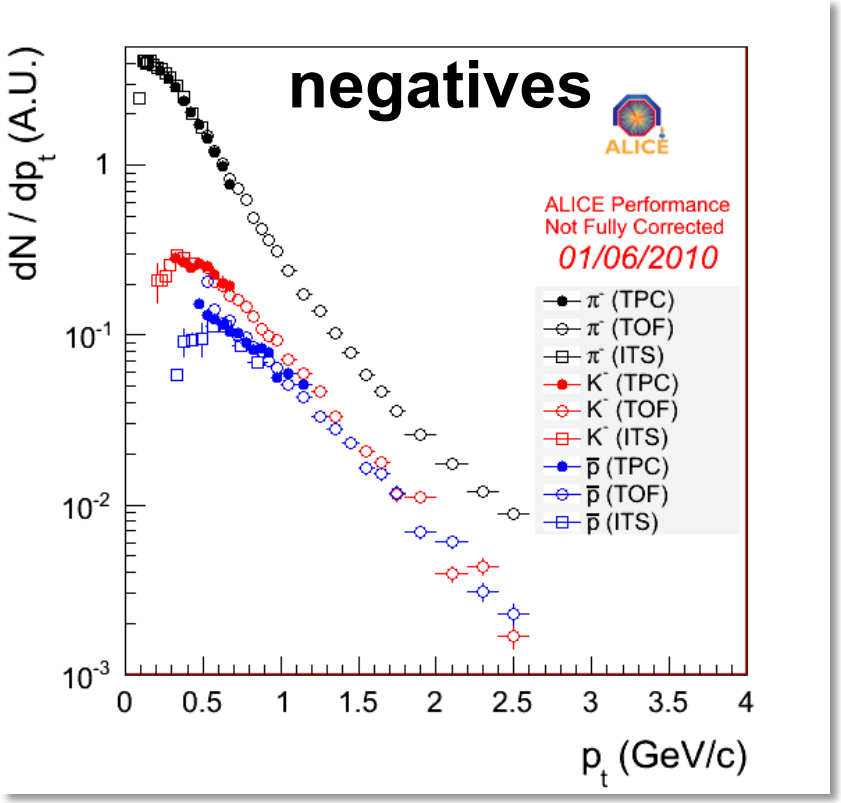




Identified spectra at 0.9 TeV

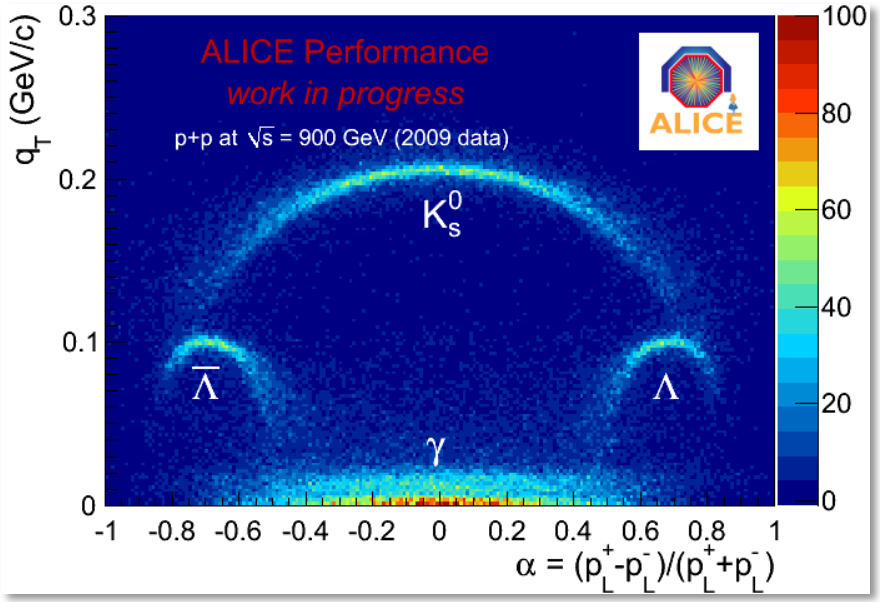
- Analysis in progress (spectra not fully corrected yet)
- Good agreement between the 3 detectors (ITS, TPC, TOF)
- Shows that detectors' calibration/understanding is OK

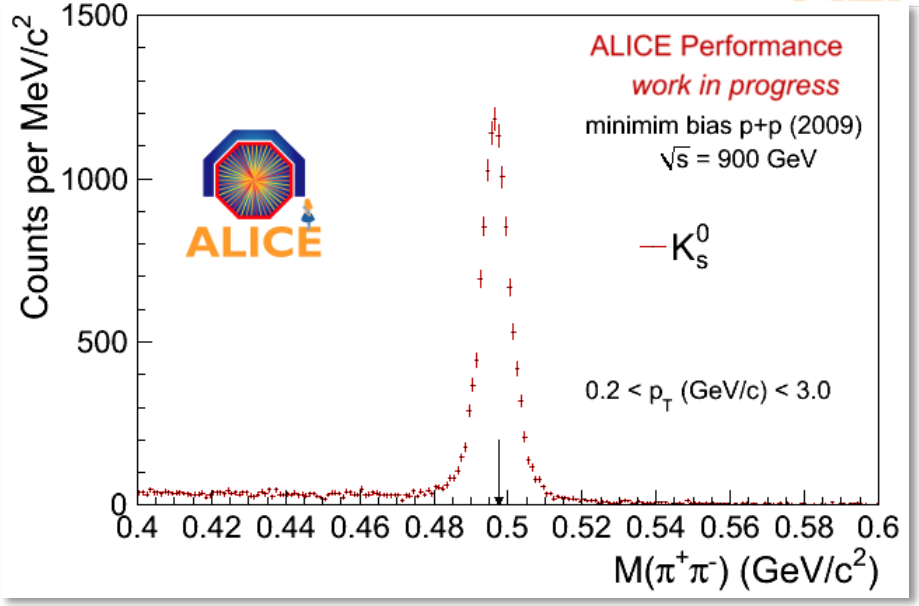


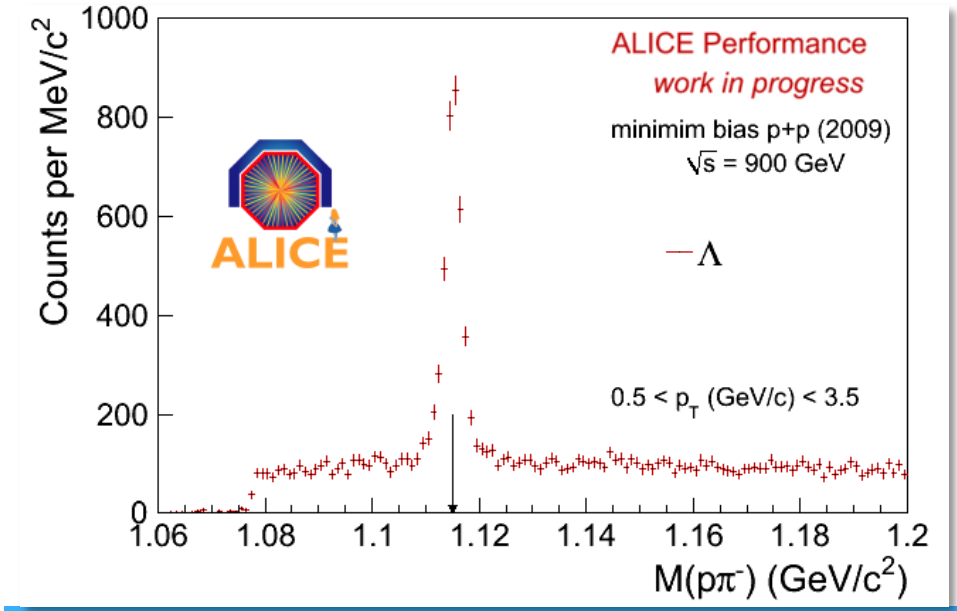


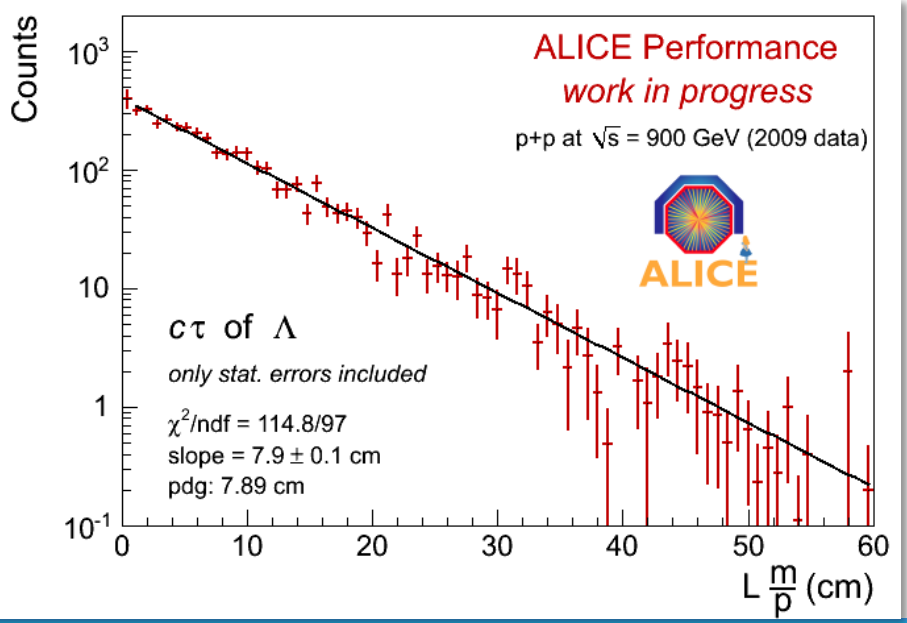
Strangeness at 0.9 TeV

→A.Maire

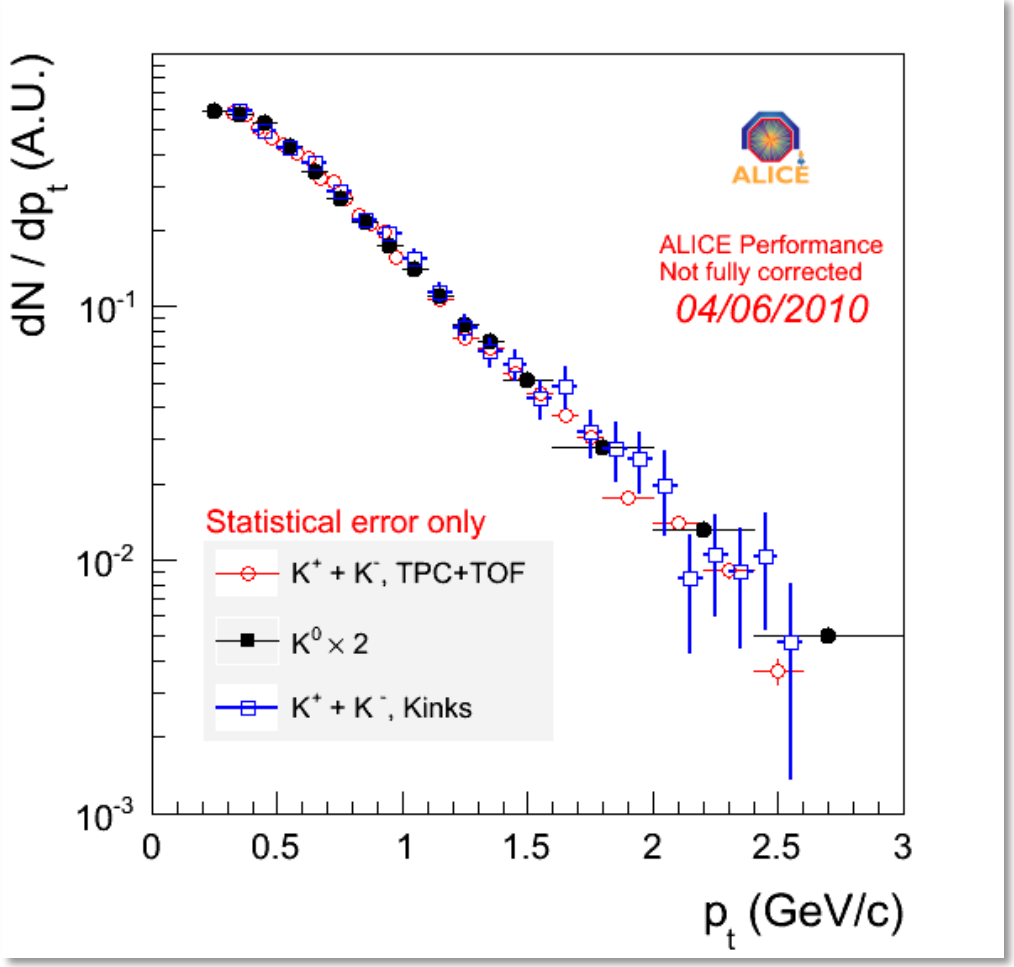








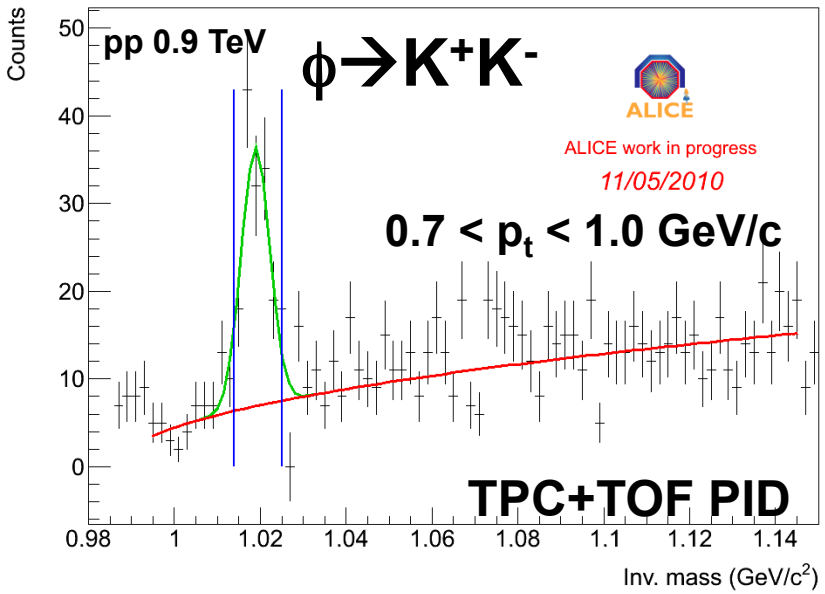
The three ways to kaons

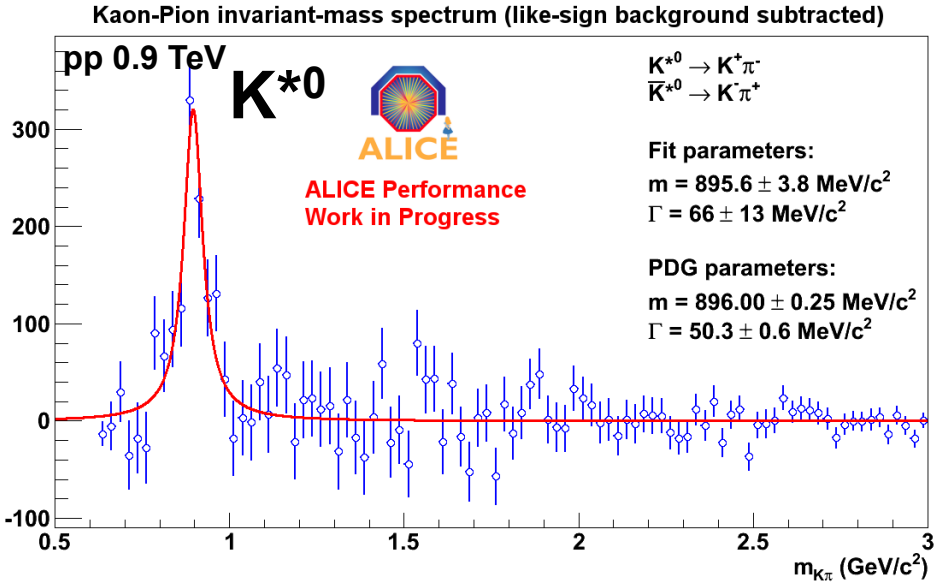


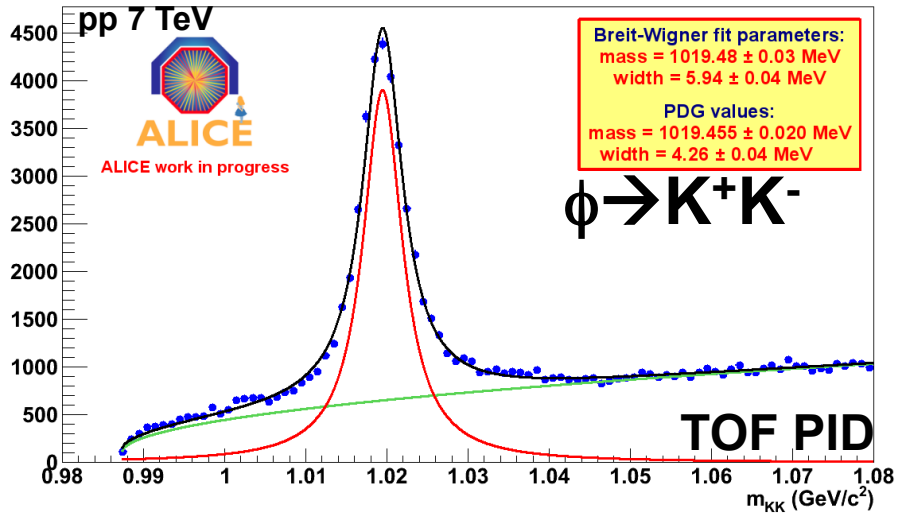
- $K^{\pm}$ TPC+TOF PID
- K^0_S vertex reconstruction
- $K^{\pm} \rightarrow \mu^{\pm}\nu$ kink reconstruction

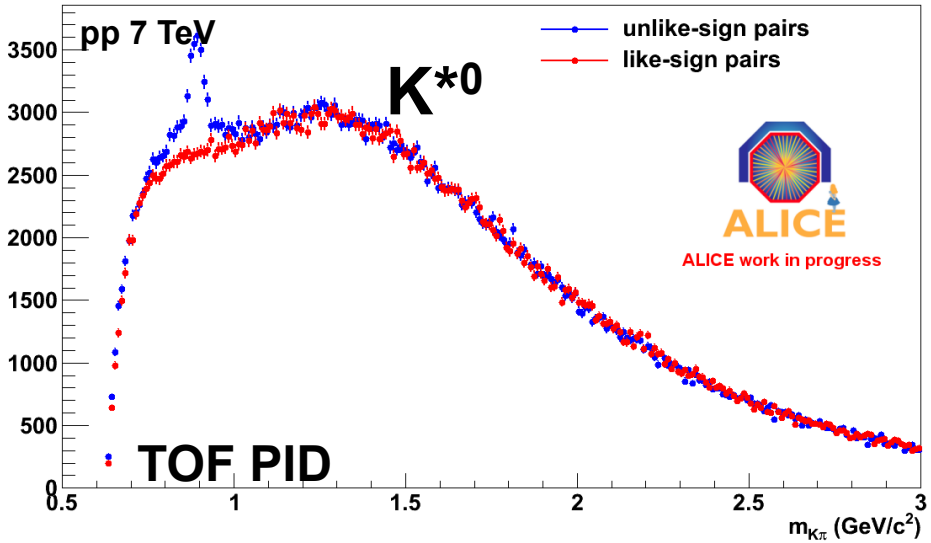
- Spectra not fully corrected
- Good internal constency

ϕ and K^{*0} at 0.9 and 7 TeV

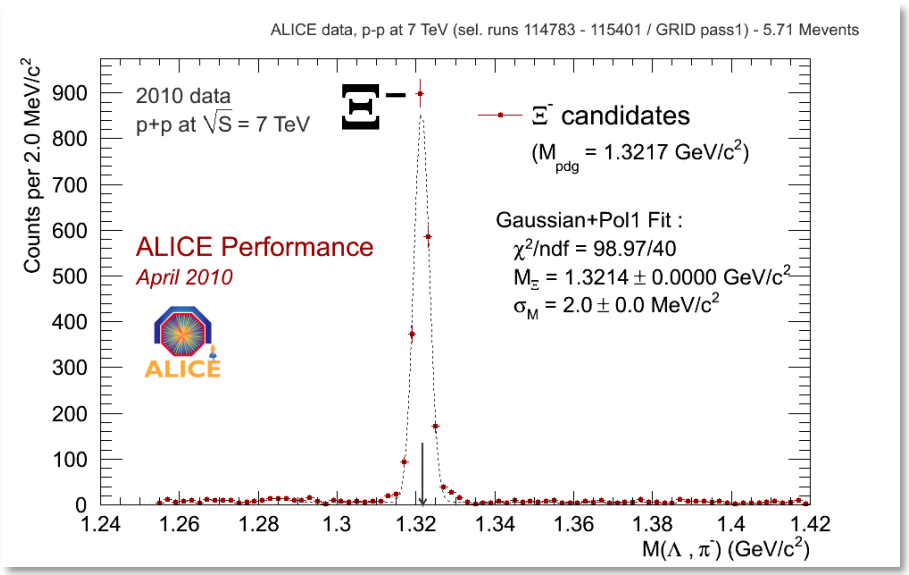


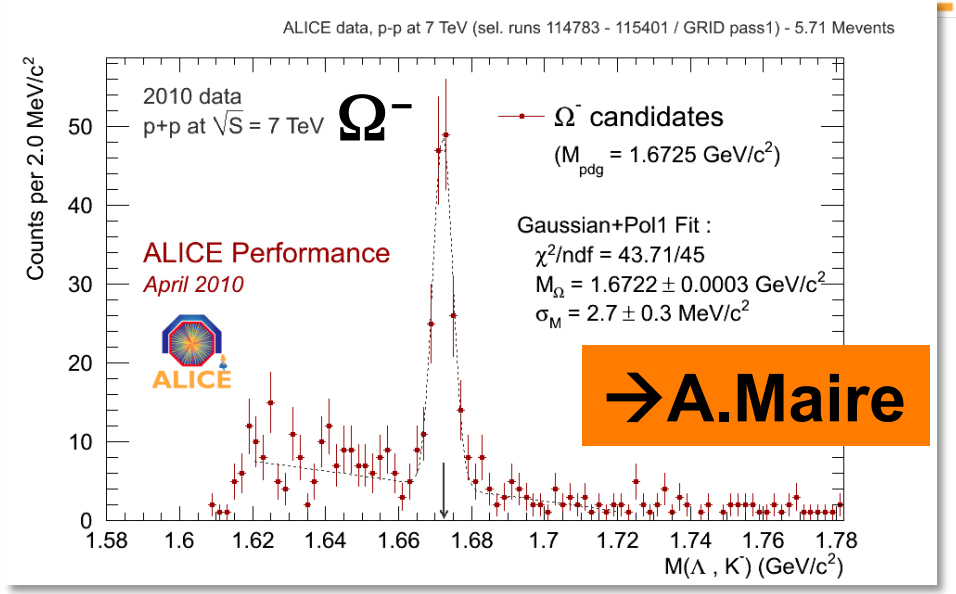






Multi-strange baryons at 7 TeV



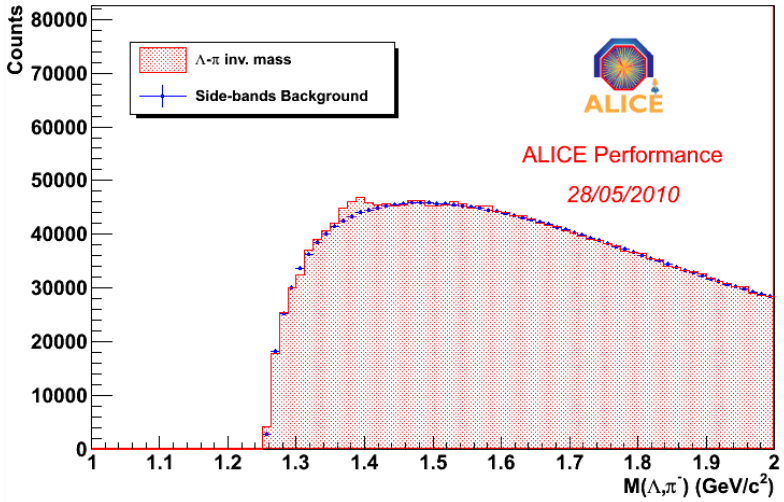


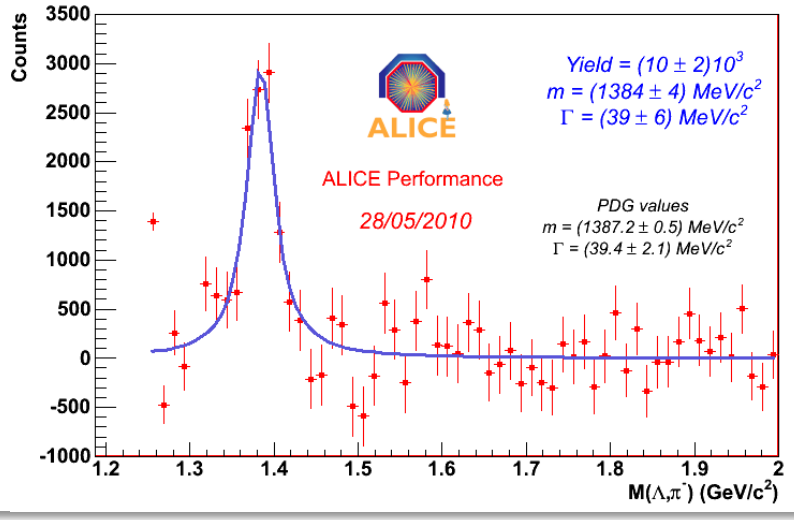
→A.Maire

Λ π⁻ invariant mass spectrum with side-bands background

Σ*⁻ → Λπ⁻

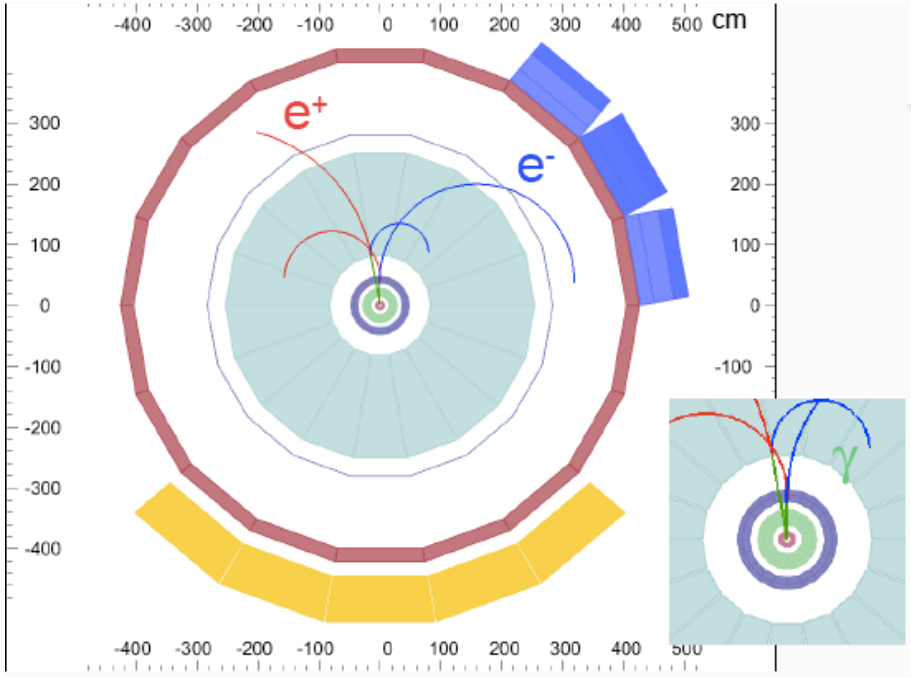
Λ π⁻ invariant mass spectrum (side-bands background subtracted)

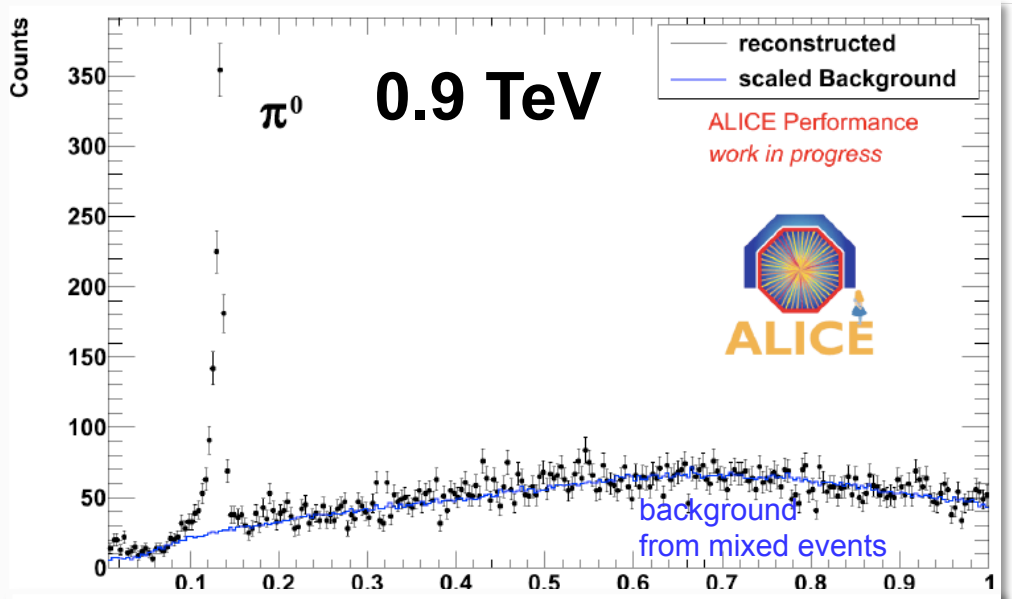


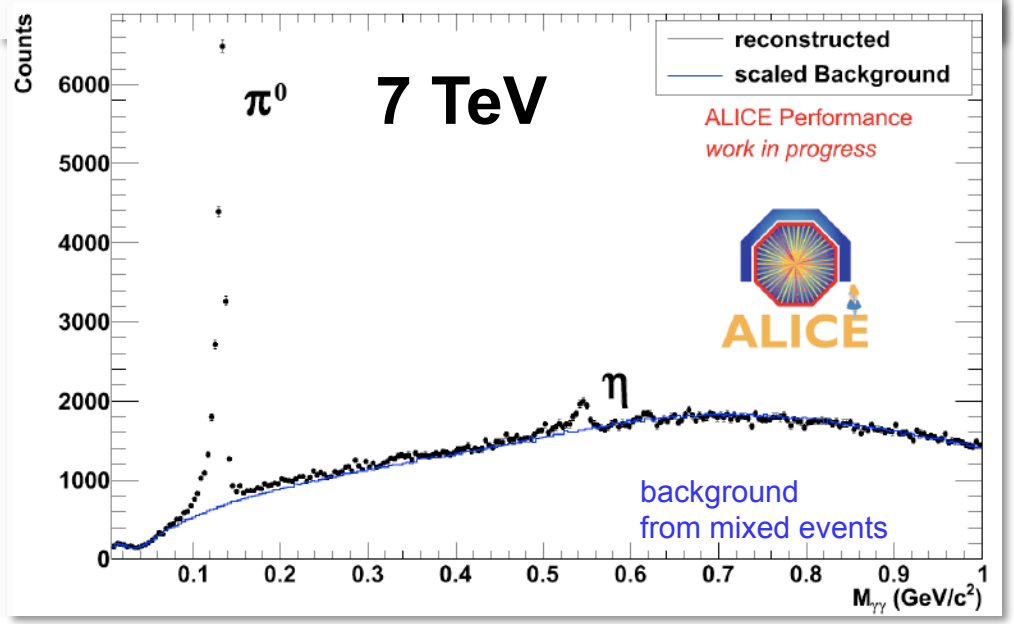


Prospects for π^0: conversions

- Electron ID in TPC
  - TRD to join soon
- Conversion reconstruction in TPC+ITS
  - also very important for material budget scan
- For π^0 and η: double conversion







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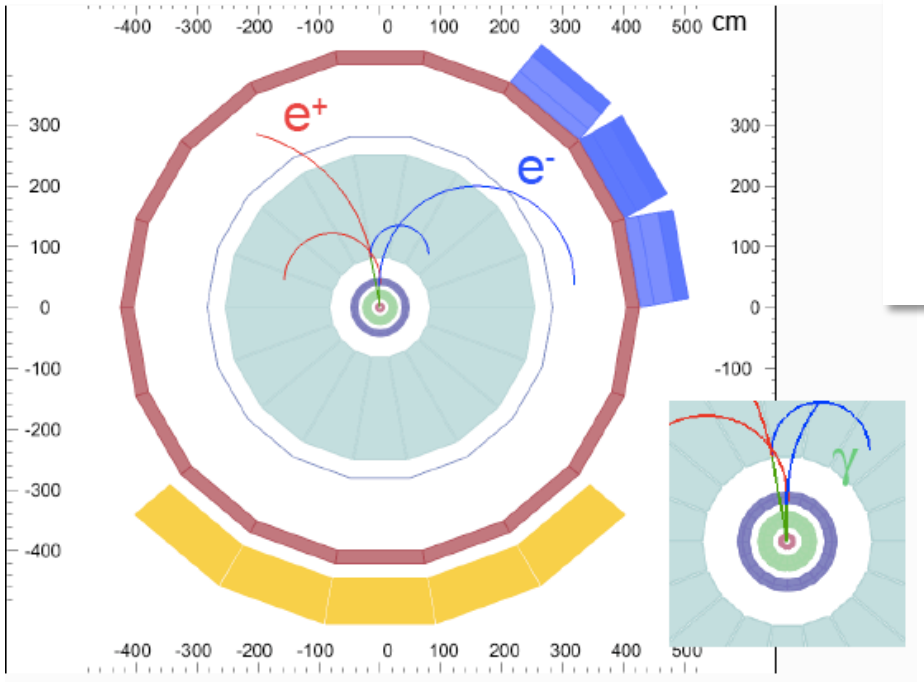
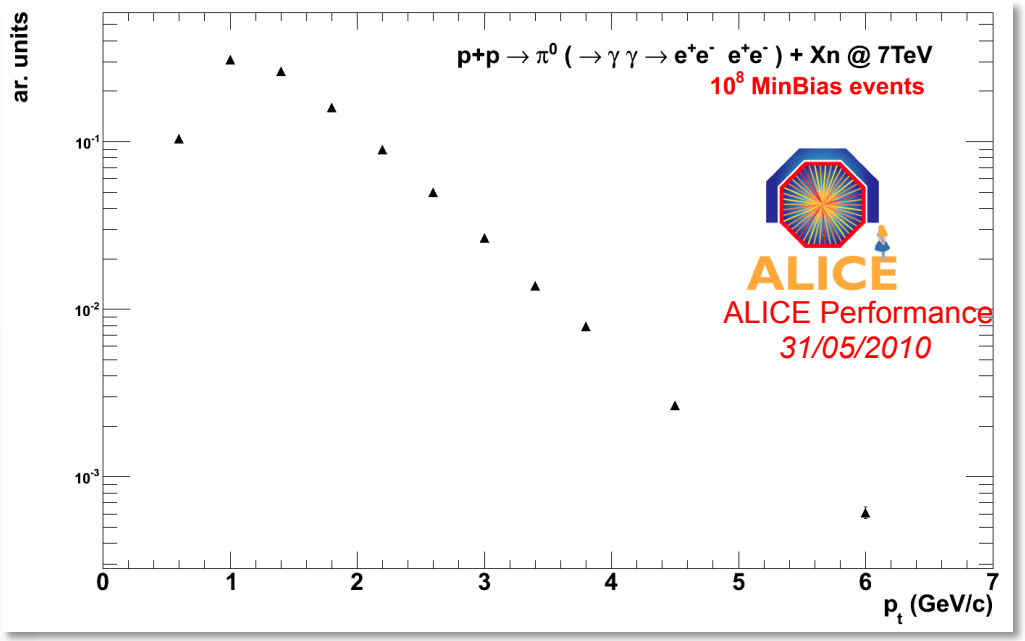


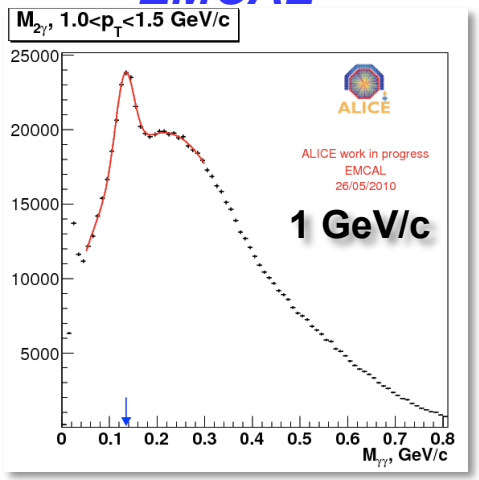
Raw π^0 dN/dp$_t$

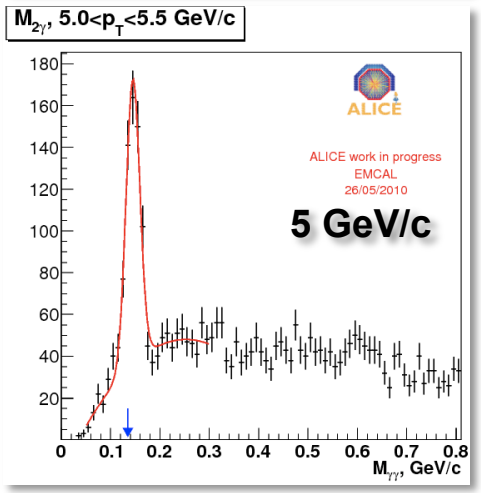


Prospects for π^0: EM calorimeters

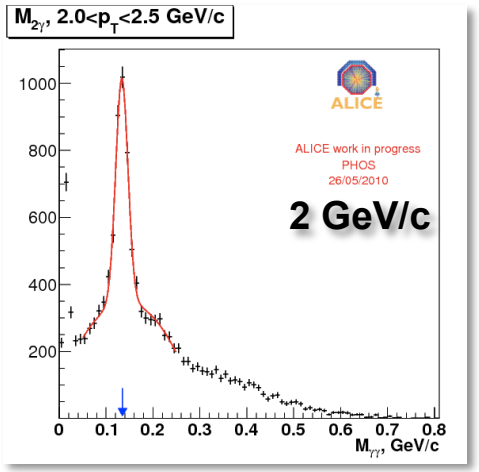
- Two EM calorimeters (back-to-back): EMCAL, PHOS
- Calibration ongoing, but already nice π^0 signals

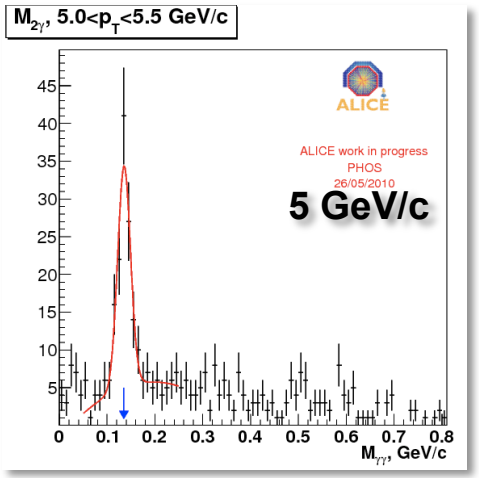
EMCAL





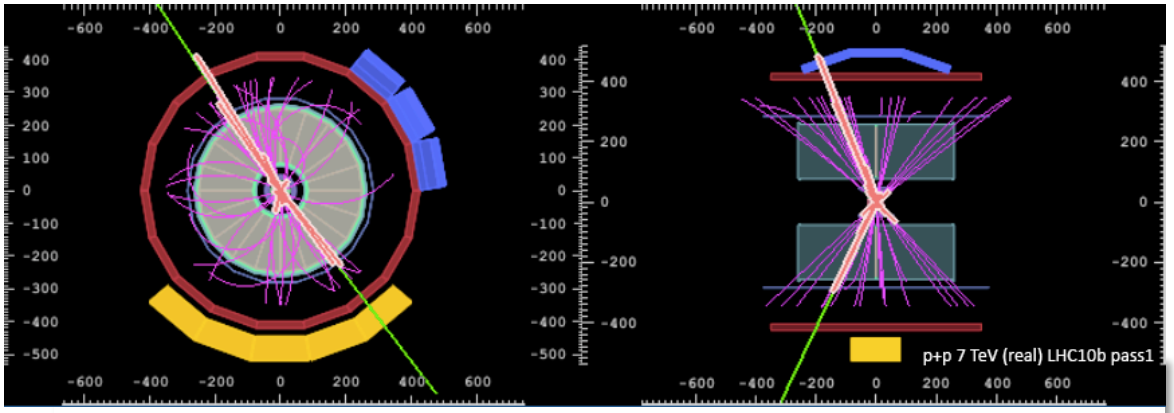
PHOS

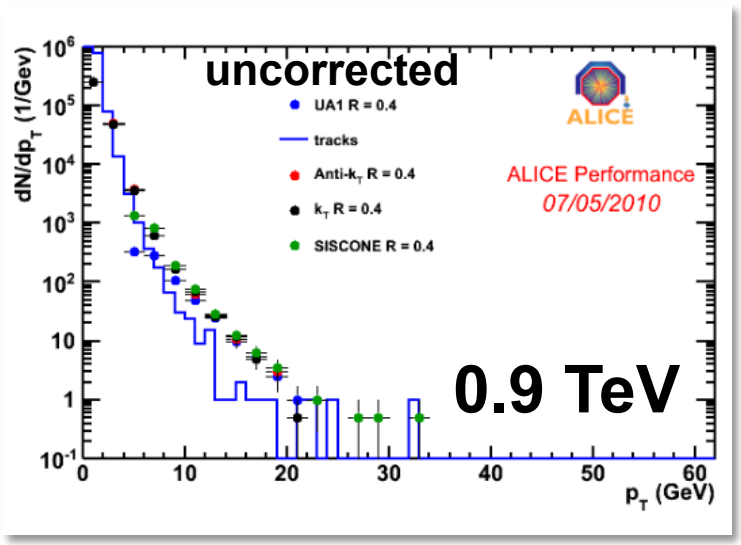


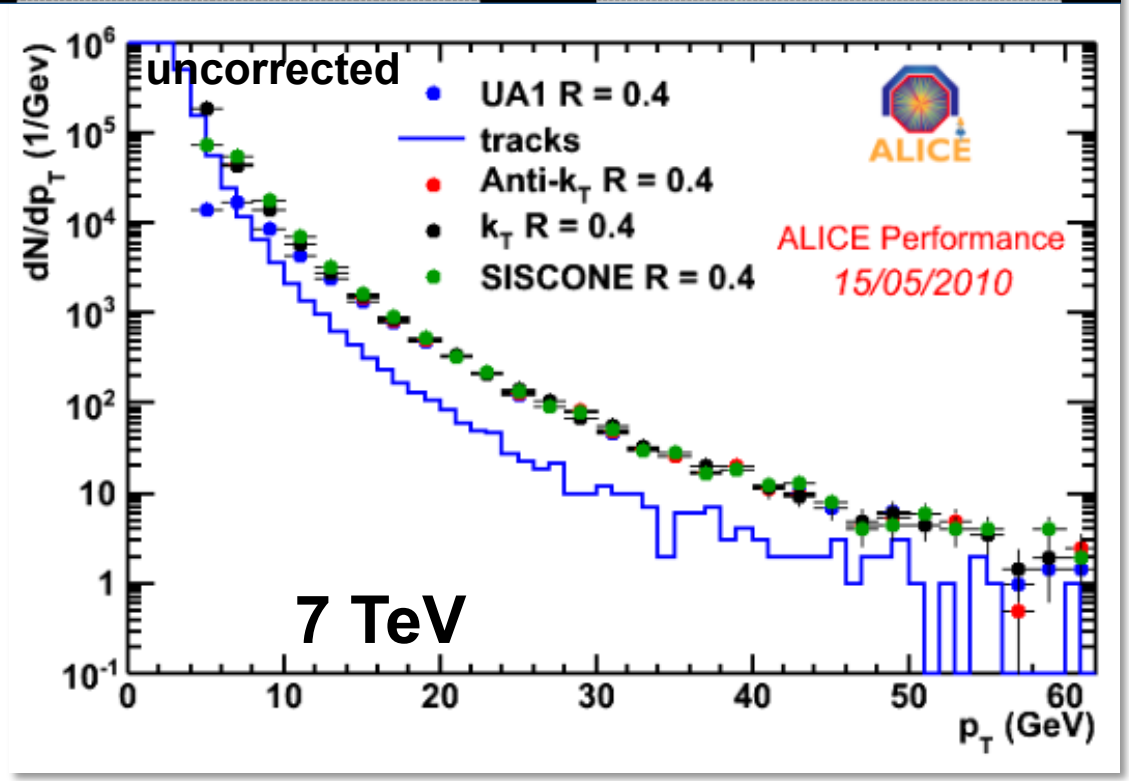


Jet reconstruction

- Charged-track jets raw spectra 0.9 and 7 TeV
  - $|\eta|<0.5$
  - Four jets algos compared
  - uncorrected







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  - $dN_{ch}/d\eta$ and dN/dN_{ch} measurements at 0.9, 2.36, and 7 TeV
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published

preliminary

in preparation

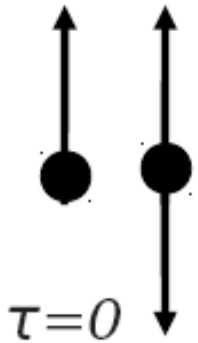
Event shape studies

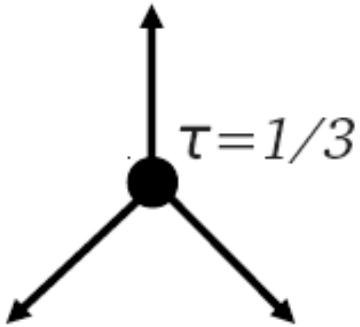
- Event shapes are sensitive to underlying event properties
  - multiple interactions mechanism
  - tuning of MC generators
- Can be used to classify events as “soft” or “hard”
- Look for unusual topologies
- Transverse thrust (hard scattering frame moves longitudinally)

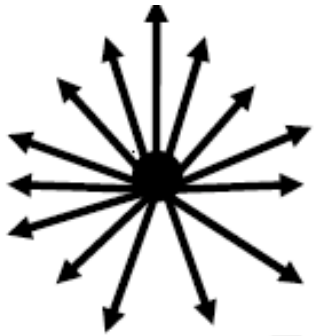
$$T \equiv \underbrace{max}_{\vec{n}_t} \frac{\sum_i |\vec{p}_{t,i} \cdot \vec{n}_t|}{\sum_i |\vec{p}_{t,i}|}$$

$$\tau \equiv 1 - T$$

→ ***measures the transverse sphericity of the event***





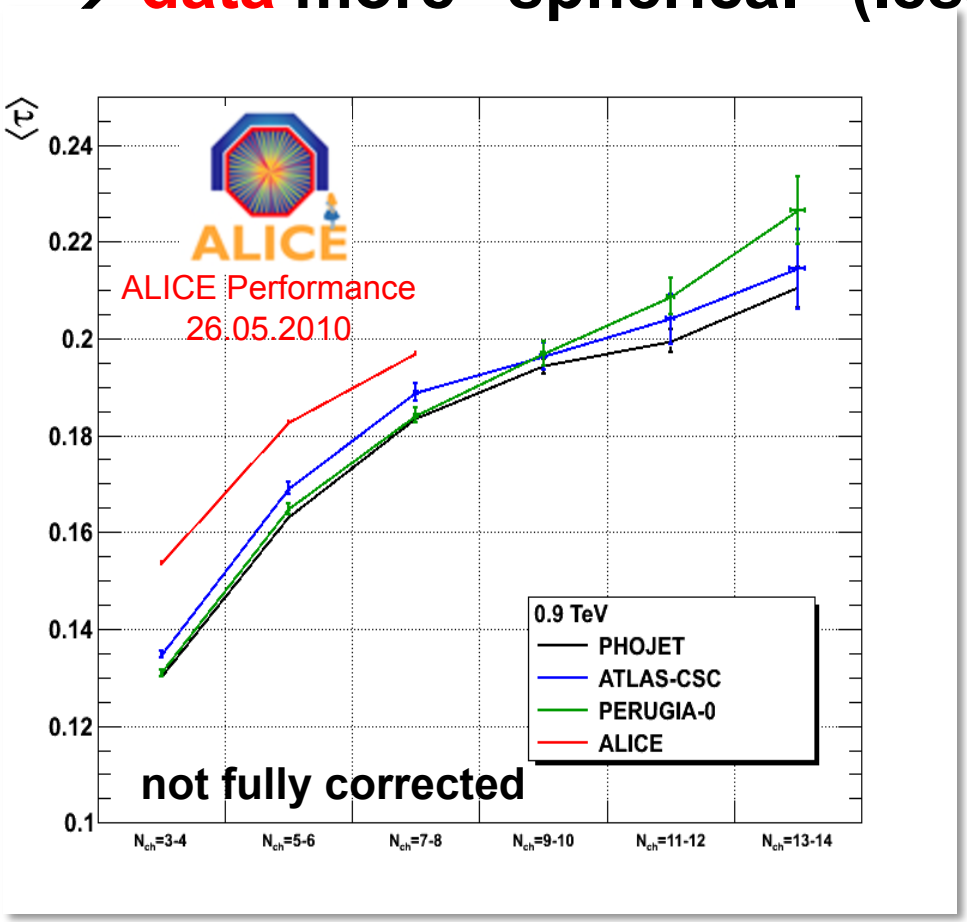


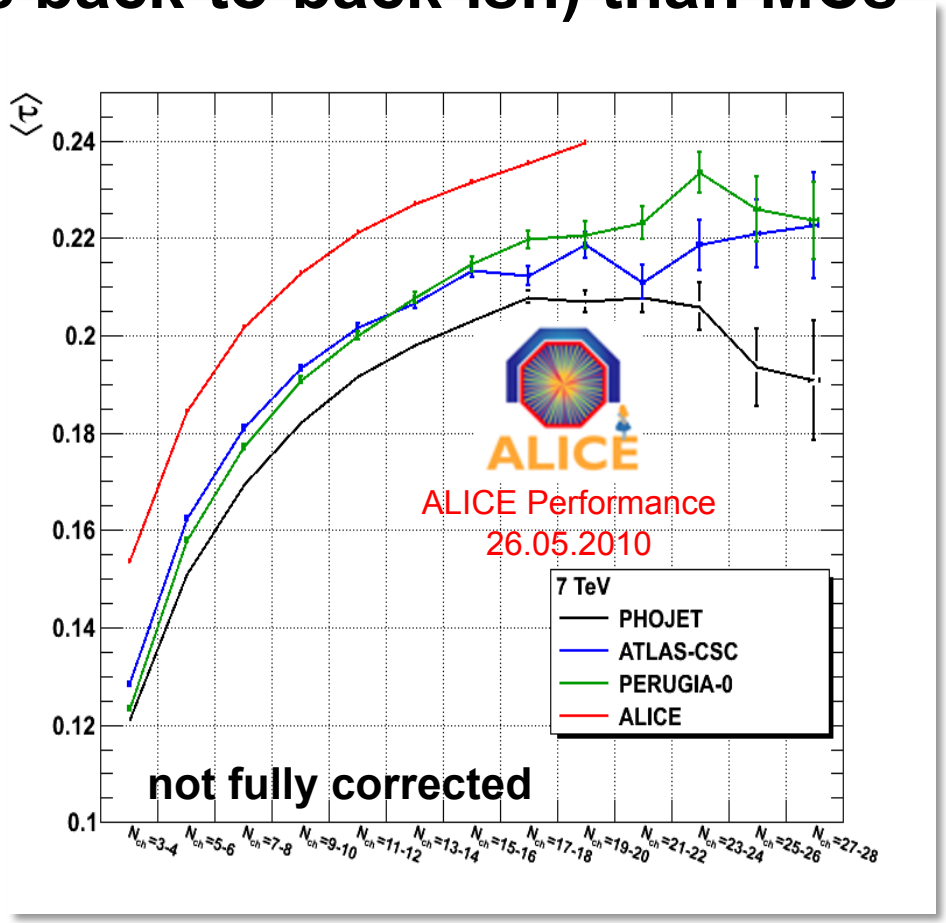
$\tau = 0.3633 = 1\text{-}2/\pi$

Event shape: Thrust

- $\langle\tau\rangle$ (= <1-T>) vs. multiplicity at 0.9 and 7 TeV
- Thrust spectrum is unfolded based on MC (χ^2 minimization)

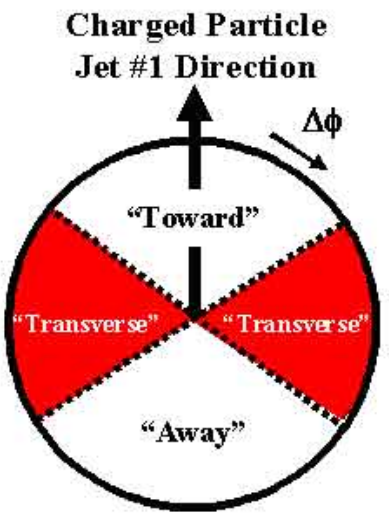
→ **data more "spherical" (less back-to-back-ish) than MCs**

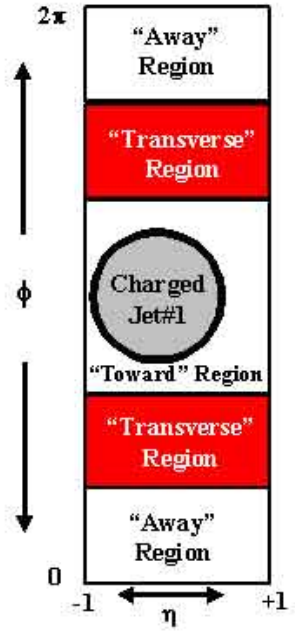


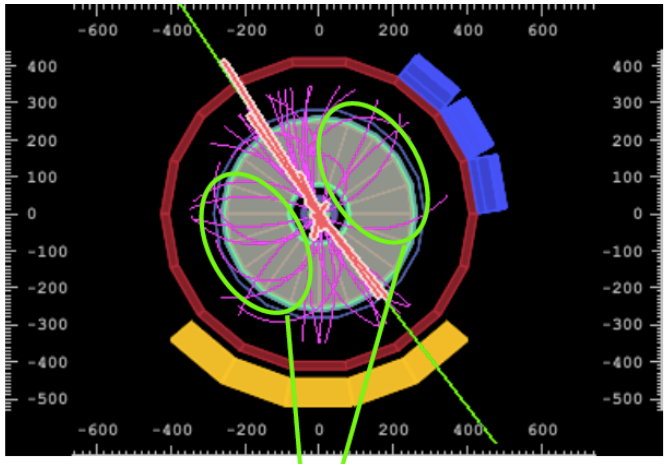


Event structure: Underlying Event

- Event-by-event analysis:
  - identify leading hadron
  - define transverse regions
  - Σp_t in the two regions
- Region with larger energy (MAX) → sensitive to QCD final-state radiation
- Region wth smaller energy (MIN) → sensitive to soft component (multiple interactions)



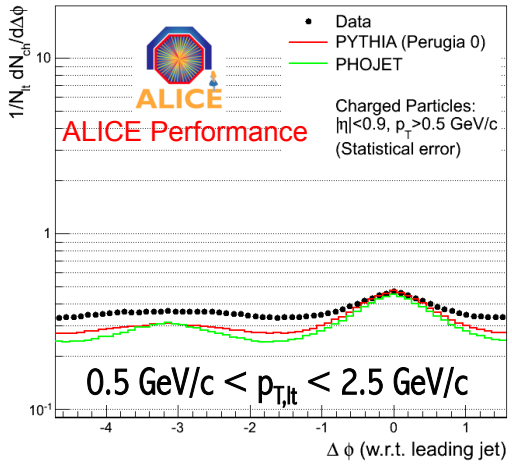


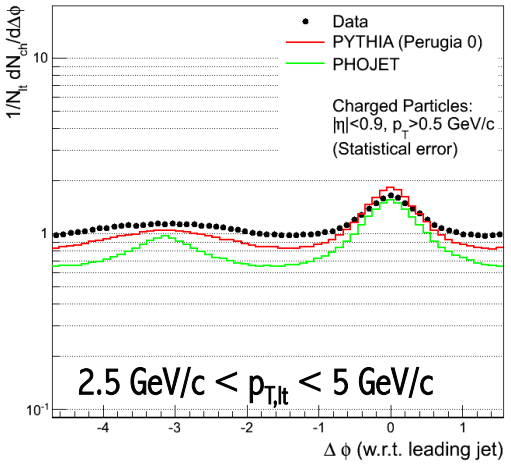


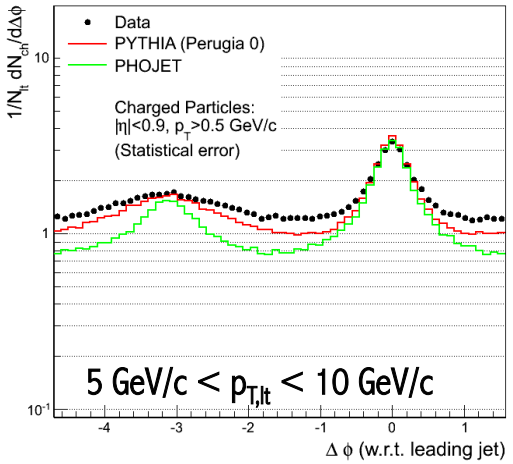
TRANSVERSE REGIONS: here we measure the UE!

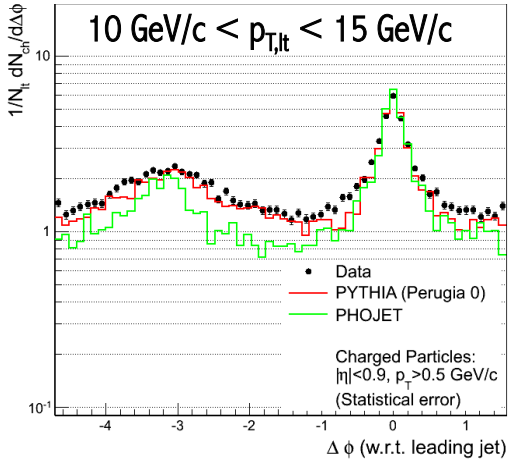
Underlying Event 7 TeV: first look at Δφ

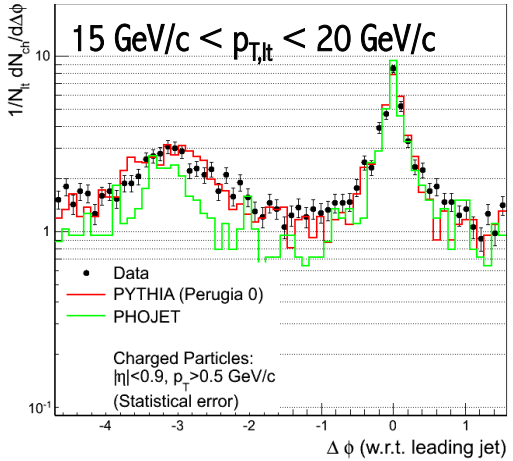
- Start by looking at inclusive Δφ correlations wrt leading track
- Data not corrected, compared to MCs (geant + recon)
- Leading p_t<10 GeV/c → **data** less back-to-back-ish than **MC**s











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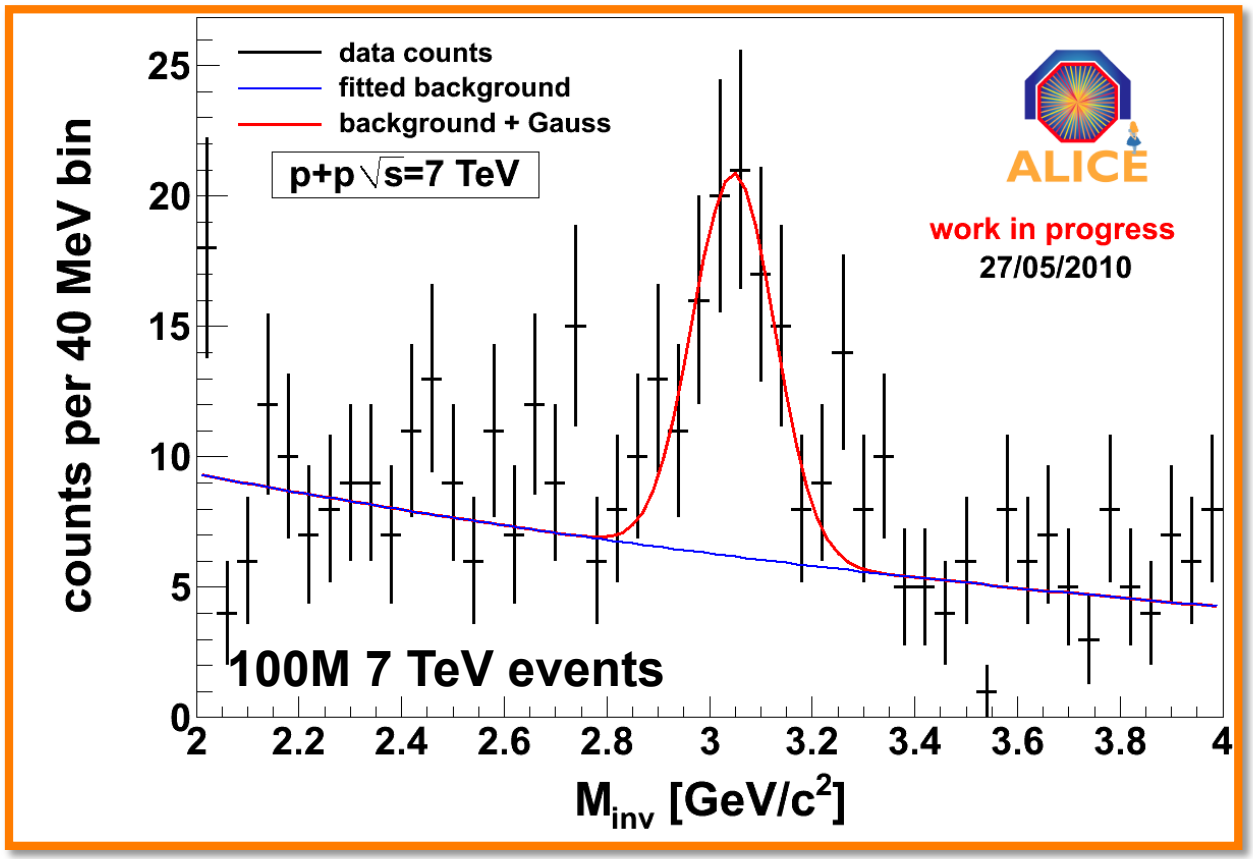
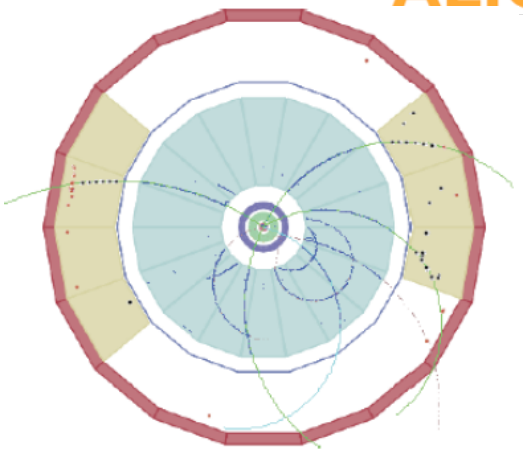
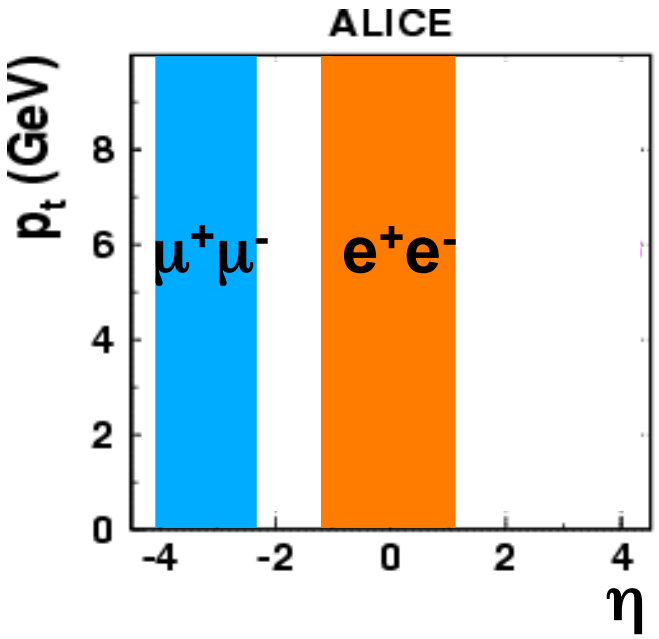
J/ψ→ee, |η|<0.9

- e PID from TPC
  - TRD and EMCAL calib. ongoing



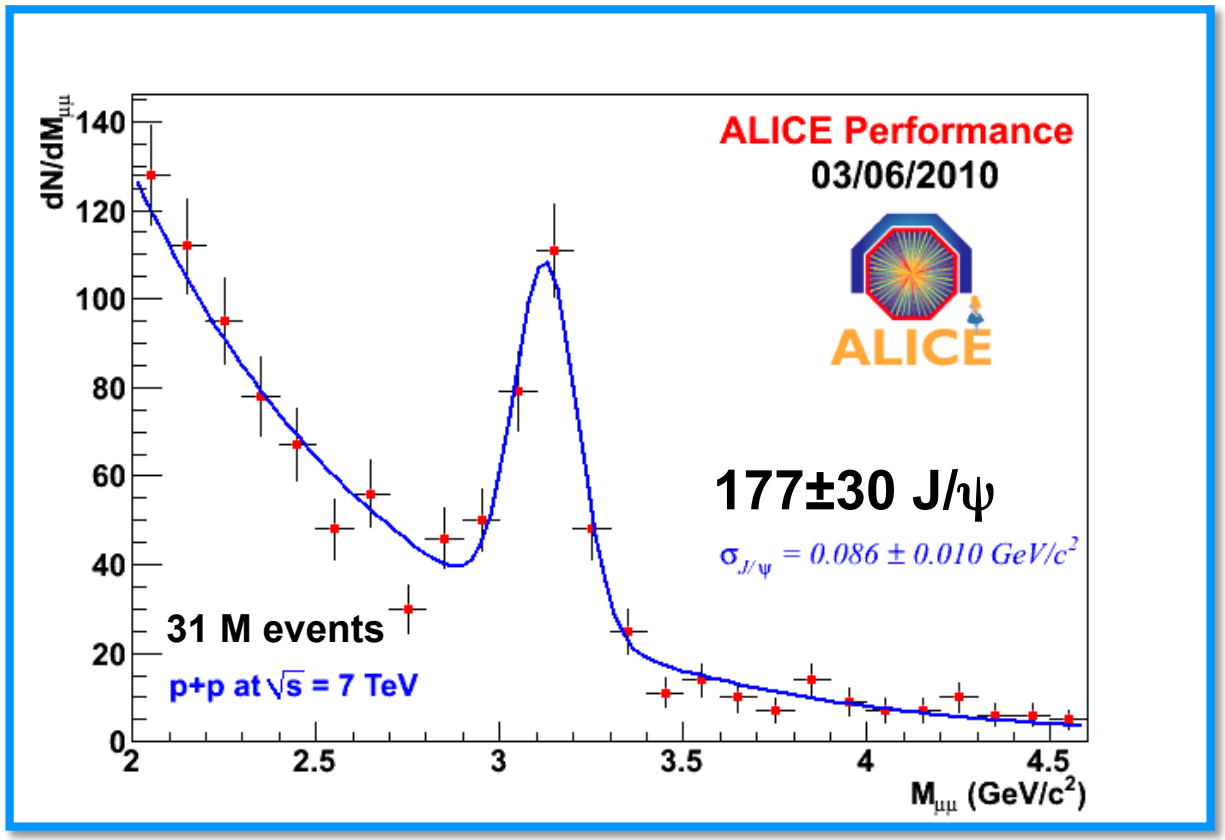


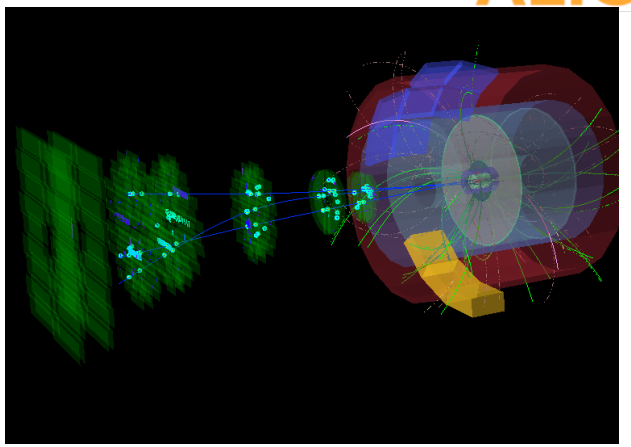
acceptance to p_t=0



Forward J/ψ→μμ

- J/ψ→μμ, -4<η<-2.5





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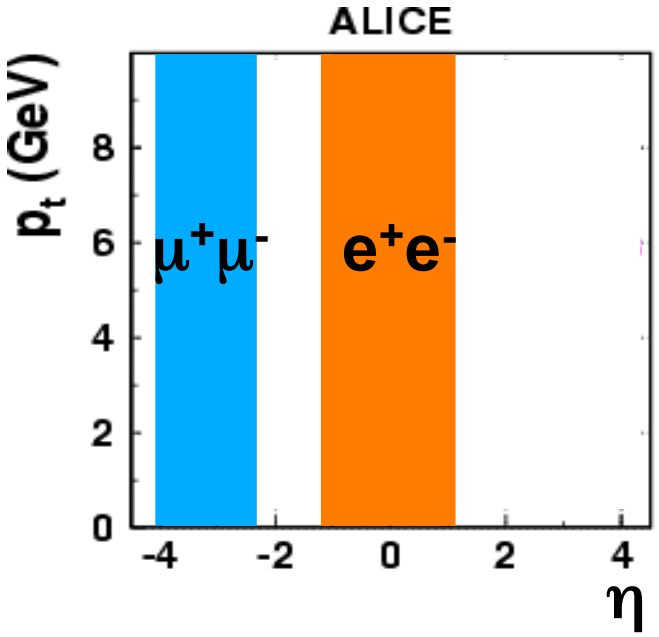
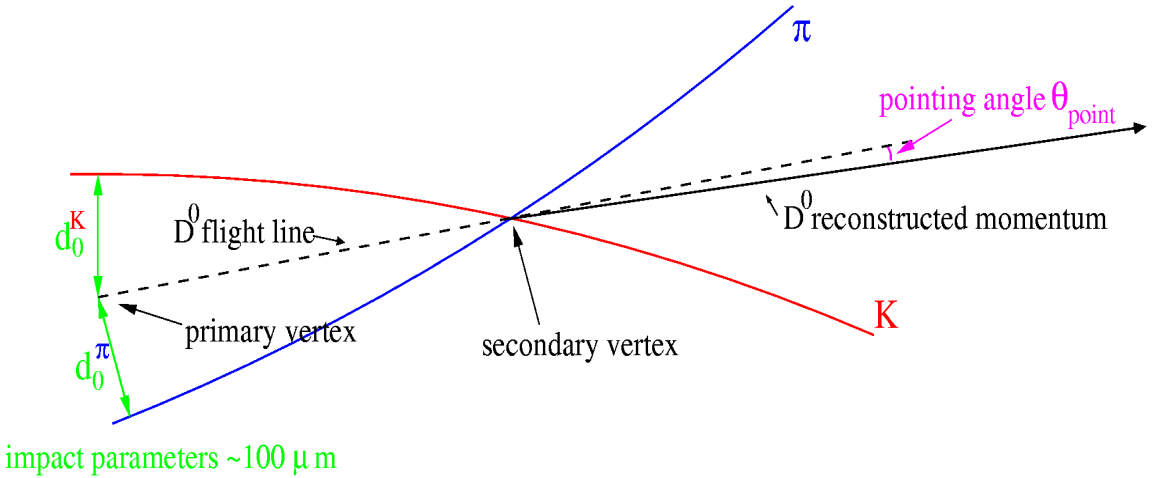
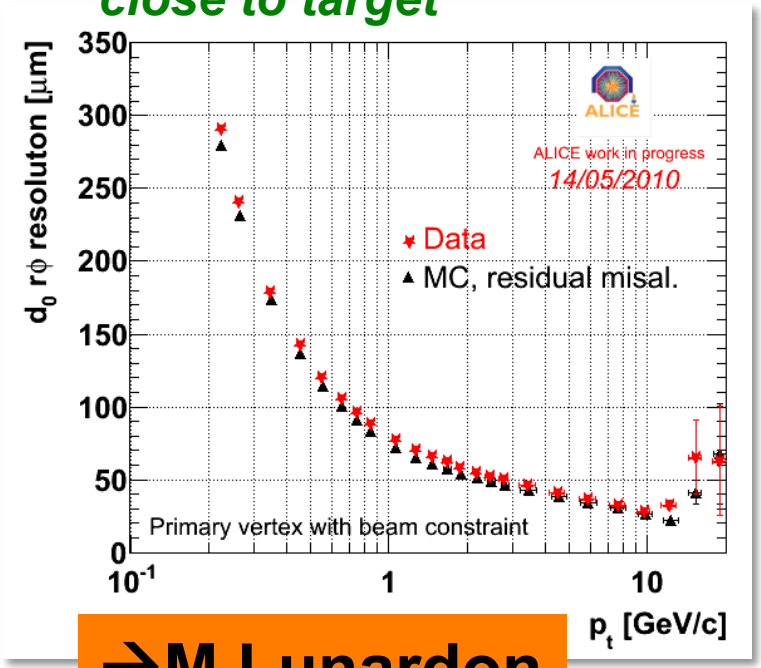


Charm: D meson reconstruction

- Main selection: displaced-vertex topology
- Example: $D^0 \rightarrow K^- \pi^+$
  - good pointing of reconstructed D momentum to the primary vertex
  - ppair of opposite-charge tracks with large impact parameters
- K ID in TPC+TOF helps rejecting background at low p.



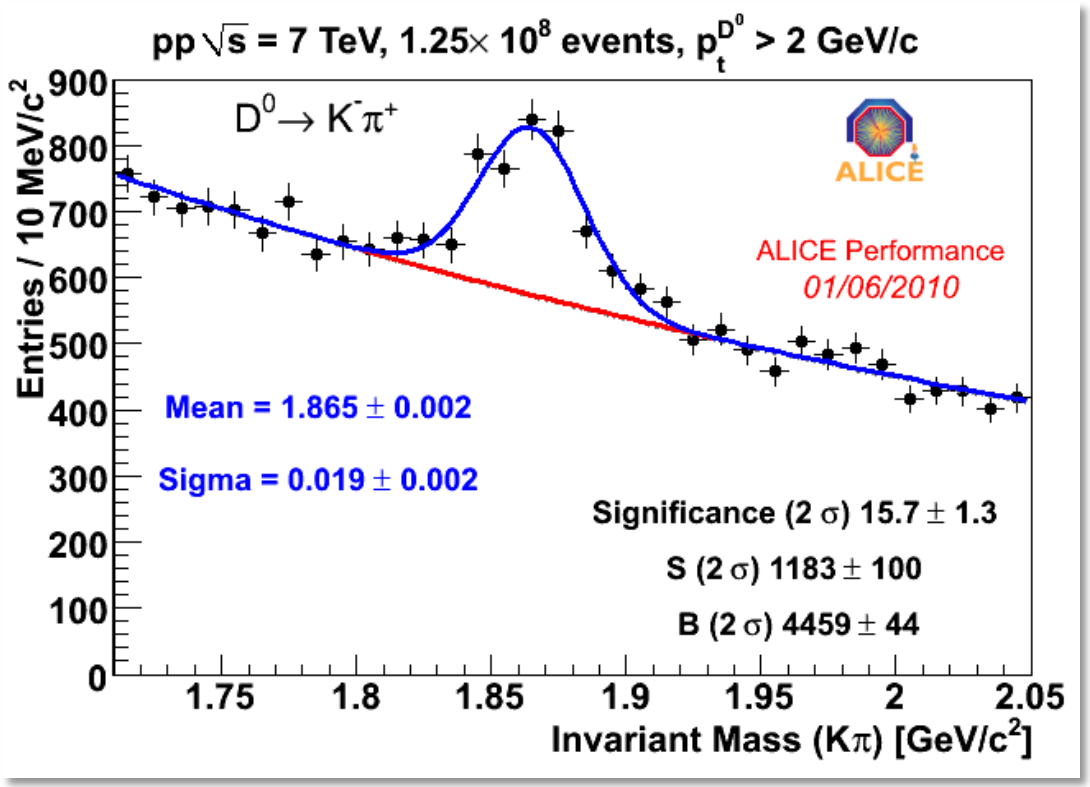
Impact parameter resolution close to target

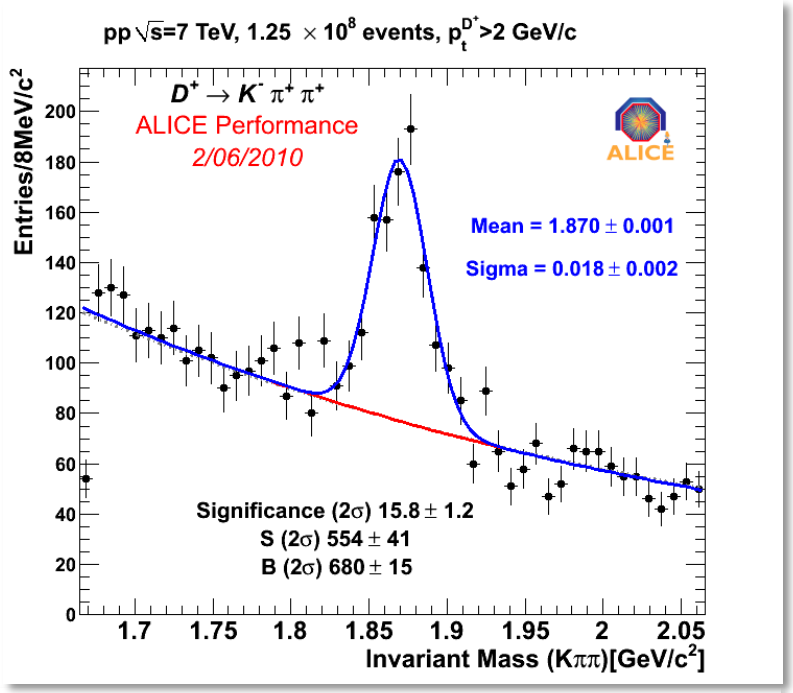


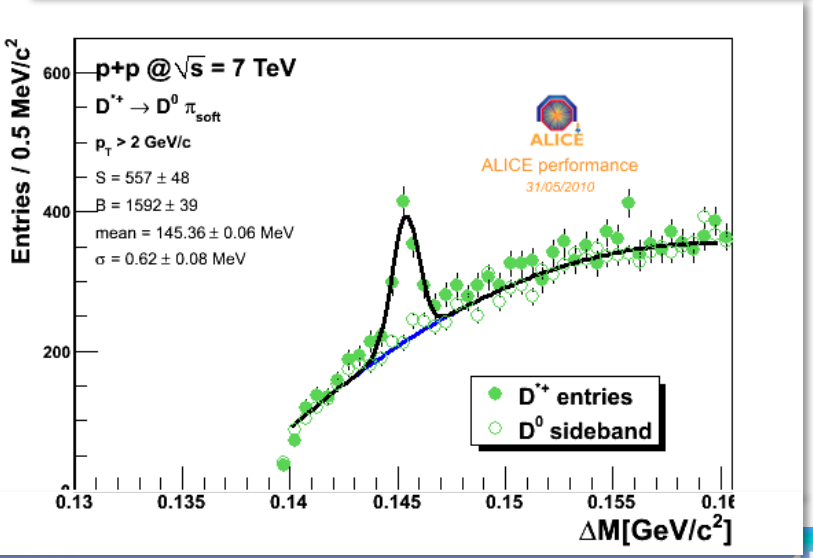
→M.Lunardon

Charm: D^0, D^+, D^{*+}

- 1.25×10^8 pp at 7 TeV
- Signals in 4 p_t bins in 2-10 GeV/c
  - expect to cover 0.5-15 GeV/c with 10^9
  - compare to pQCD (FONLL) at 7 TeV



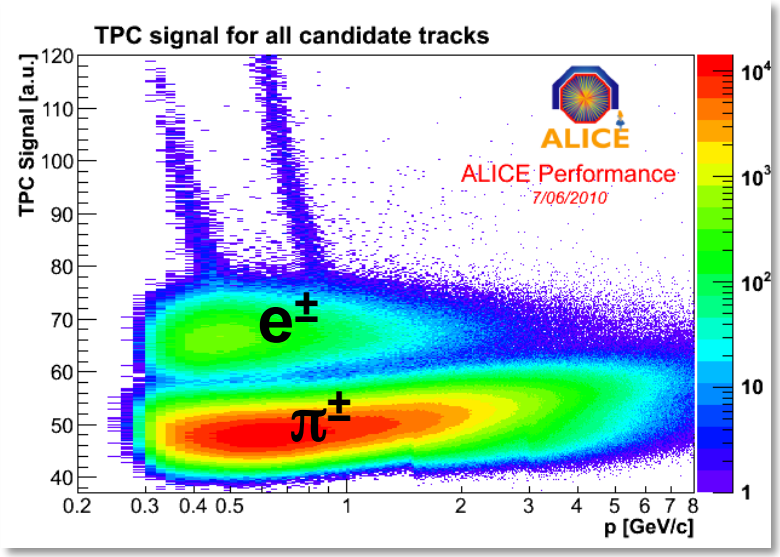


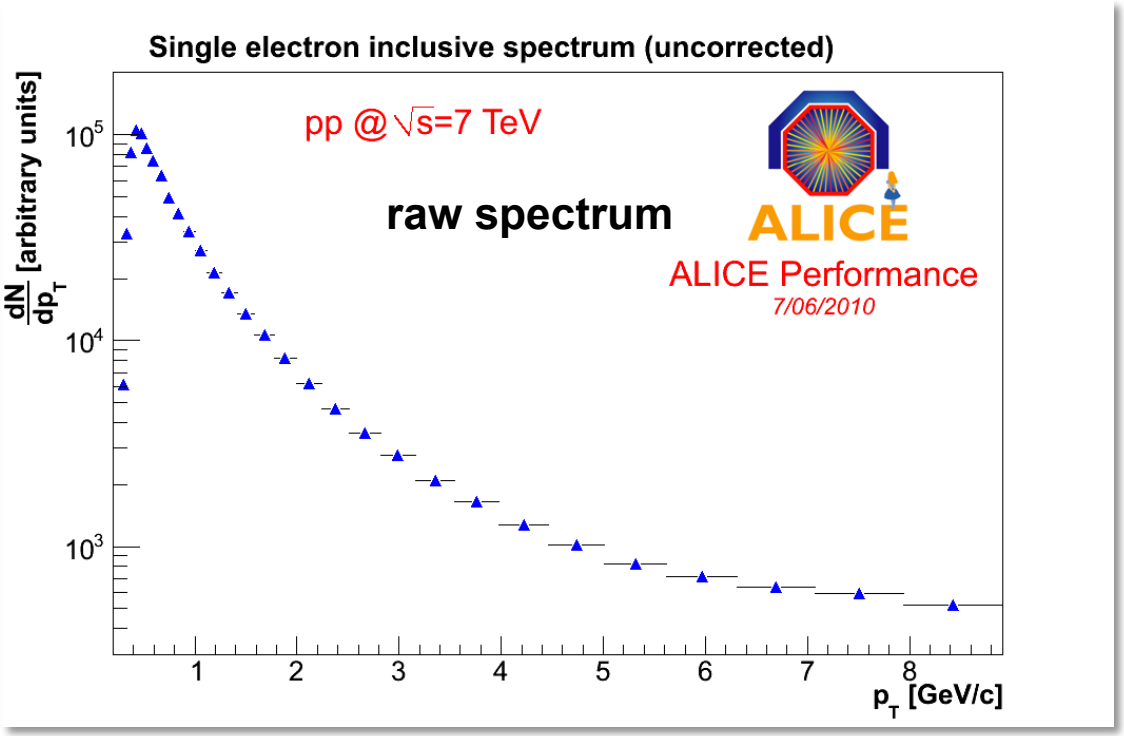


Heavy flavour from single leptons

- c and b production in semi-leptonic channels in preparation

Electrons $|\eta|<0.9$:
TPC dE/dx after K and p rejection with TOF. TRD and EMCAL will join soon



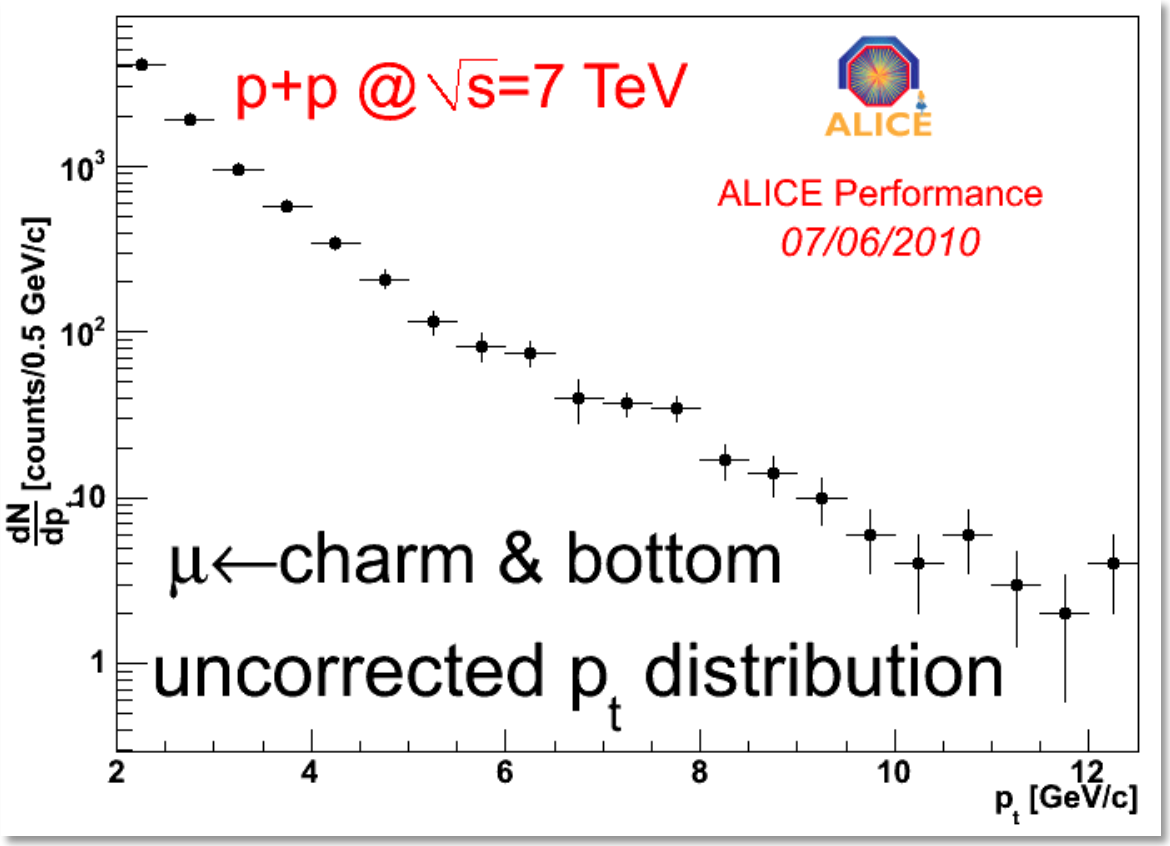


+ displacement selection → beauty

Heavy flavour from single leptons

- c and b production in semi-leptonic channels in preparation

Muons $-4<\eta<-2.5$:
Light quark contribution subtracted with PYTHIA (normalized to data at low p_t).
Not corrected.



→ c (low p_t) & b to be separated by fitting based on pQCD shapes,
in progress ...

First Physics Results from ALICE

- Particle multiplicity
  - *increase from 0.9 to 7 TeV significantly larger (>20%) than predicted*
- Momentum spectra
  - *$\langle p_t \rangle$ VS N_{ch} not described by any of the MCs*
- Anti-proton/proton ratio at midrapidity
  - *$\overline{p}/p$ goes to 1 at 7 TeV → baryon number transfer suppressed over large Δy*
- Femtoscopic measurement at 0.9 TeV
  - *particle emitting source "size" increases with multiplicity*
- Event topology
  - *lower "jettiness" than expected in LHC collisions*
- Promising performance for ID spectra, strangeness, charm, charmonium
  - ***ALICE is ready to deliver many more Physics Results***

Outlook

Papers in the pipeline:

- Charged particle p_t distribution
- Baryon-antibaryon asymmetry
- Bose-Einstein correlations
- Strangeness production (K^0, Λ, Ξ, Φ)
- Identified particles p_T (π, K, p)

Analyses in progress:

- dN/dp_t at 7 TeV
- π^0, η
- c and b production
- J/ψ production
- high multiplicity
- jet correlations
- event shape
- underlying events
- reconstructed jets
- b-tagged jets
- …

November 2010: Pb-Pb collisions in ALICE!

→H.Torii