HIT Seminar at LBL

Soft Physics Prospects at the LHC

1. Bulk matter physics: p_T range, hadro-production and collectivity
2. The usual suspects experiments and detectors at the LHC
3. Statistical observables: inclusive measurements
4. Baryon production: investigations in p+p
5. Multi-parton dynamics: expectations in p+p and recombination
6. Current status of ALICE: calibration, “first” and “next to first” physics
7. Conclusion and discussion: summary and first data in 2009 ?

Boris HIPPOLYTE (IPHC - Université de STRASBOURG)

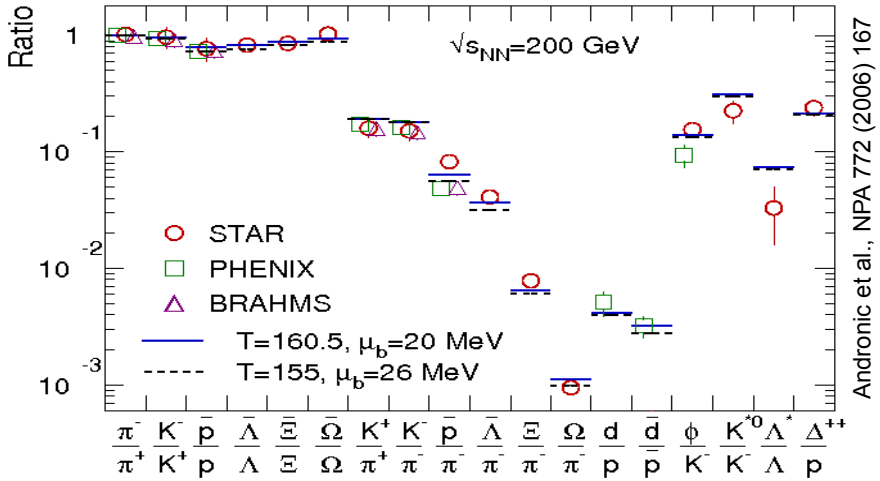
Bulk matter and properties in A+A ? … in p+p ?

Bulk matter: global properties describing the main characteristics of particle production/emission

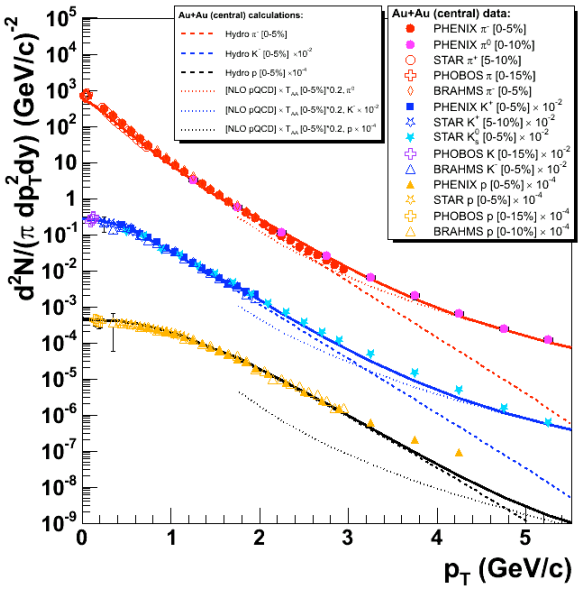
in A+A

1) most of the particles are in the soft physics region (precise range?);
2) statistical description and hydrodynamics (collective behaviour) works pretty well;
3) use differences to investigate new mechanisms (enhancement, suppression…);

$$\langle n_j \rangle = \frac{(2J_j+1)V}{(2\pi)^3} \int d^3p \left[e^{\sqrt{p^2+m_j^2}/T + \mu \cdot q_j/T} \pm 1 \right]^{-1}$$



Andronic et al., NPA 772 (2006) 167

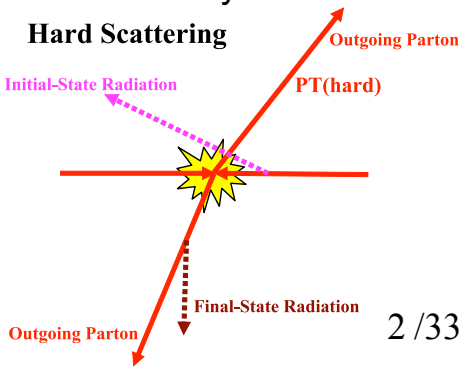


D'Enterria and Peressounko, Eur.Phys.J.C46:451, 2006.

for p+p

1) how to compare with A+A (R_{AA}) *and* any bulk property in p+p (first data at LHC)?
2) does multi-parton dynamics make sense in such a small system ?

reminder: we usually focus on the hard scattering in p+p...



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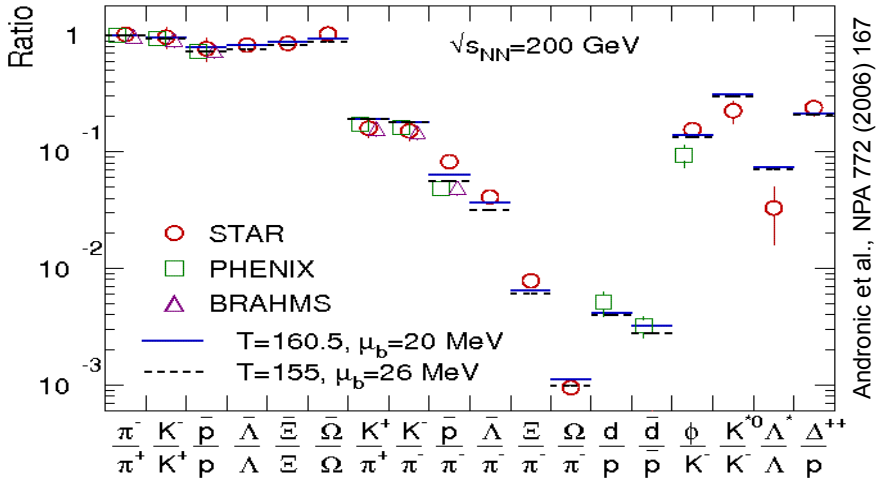

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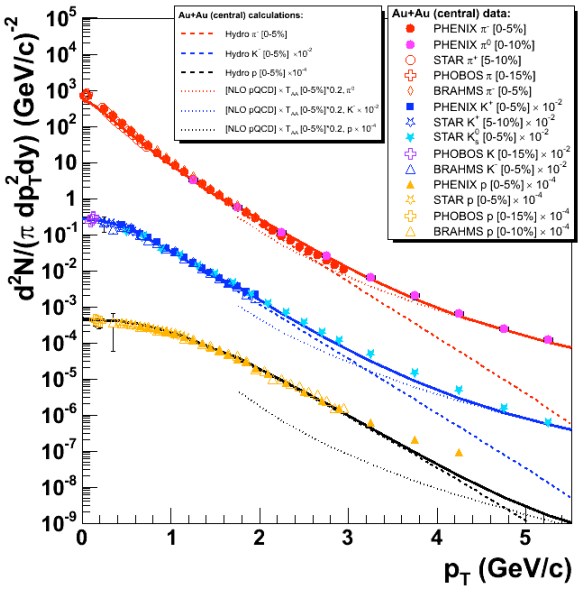

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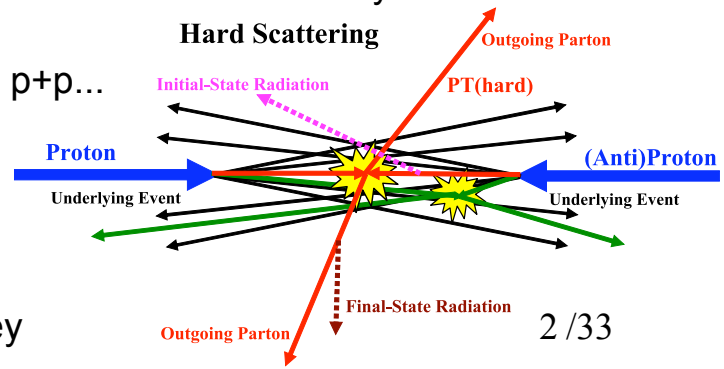
reminder: we usually focus on the hard scattering in p+p...

but we should not forget the underlying softer multi-parton dynamics

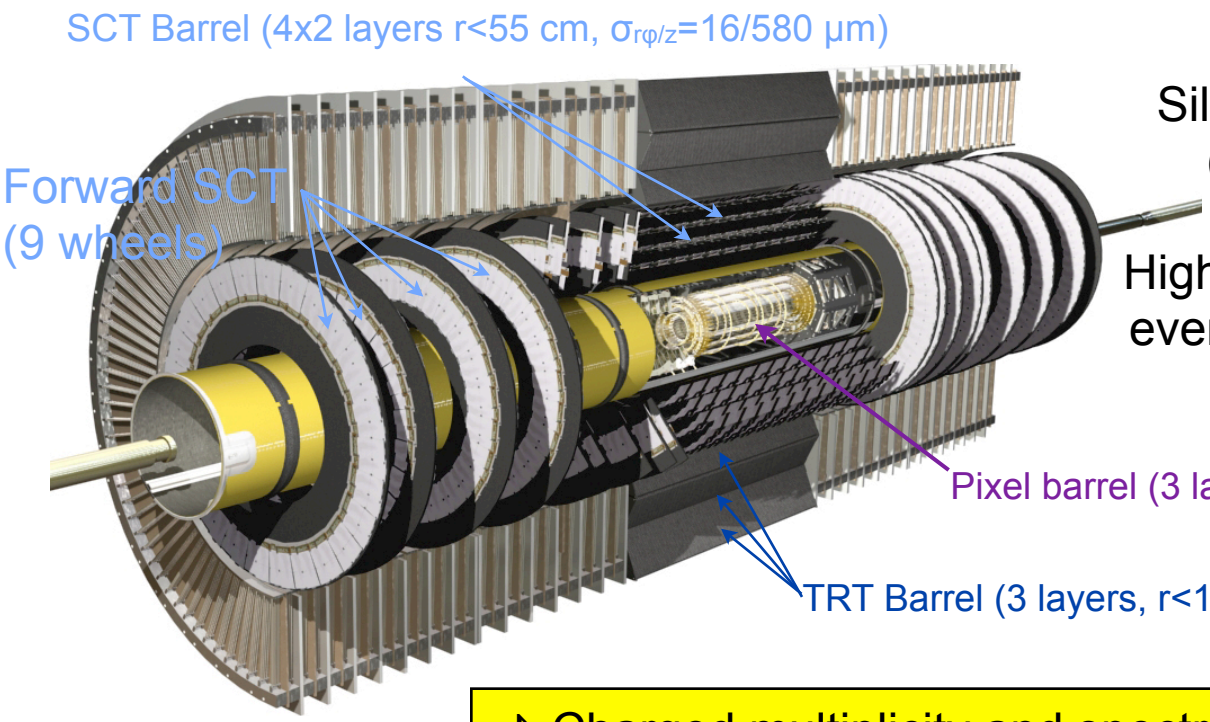


The LHC … so close to Geneva

	RHIC	LHC
radius / circumference	0.6 km / 3.8 km (2.4 miles)	4.2 km / 27 km (17 miles)
maximum energy: pp / AA	500 GeV / 200 GeV	14 TeV / 5.5 TeV
ring depth	3.65 m (12 feet)	50-175 m
magnets	1740	1232 dipoles + 392 quadrupoles

ATLAS Tracker

Barrel of **Pixel** sensors (3 layers) then **Semi-Conductor Tracker** strip detector (4x2 layers and $|\eta| \leq 2.6$), followed by the **Transition Radiation Tracker** (3 layers of straw-tubes interspersed with a radiator for e/π separation) inside a **2T magnetic field**.



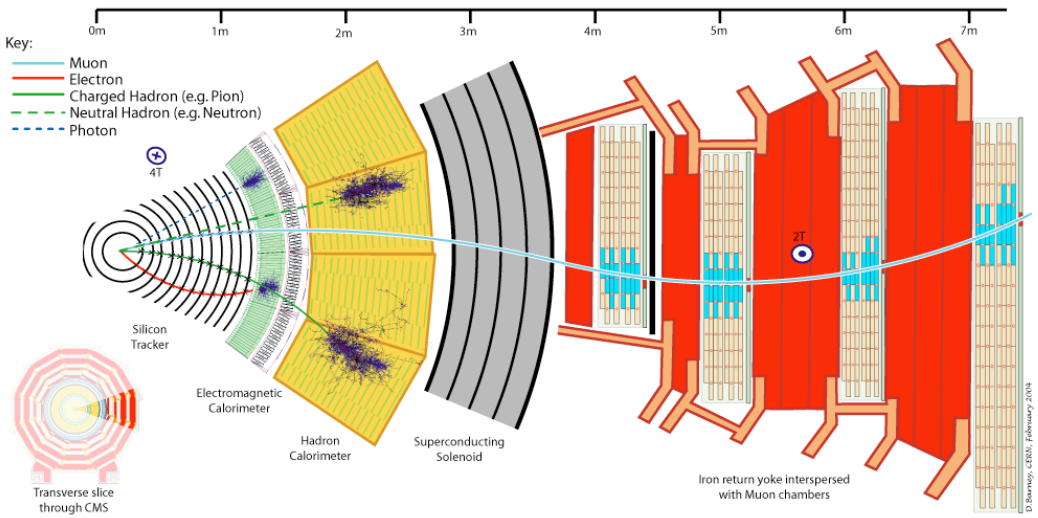
Silicon space points: 11 max
(3 for Pixel + 8 for SCT)

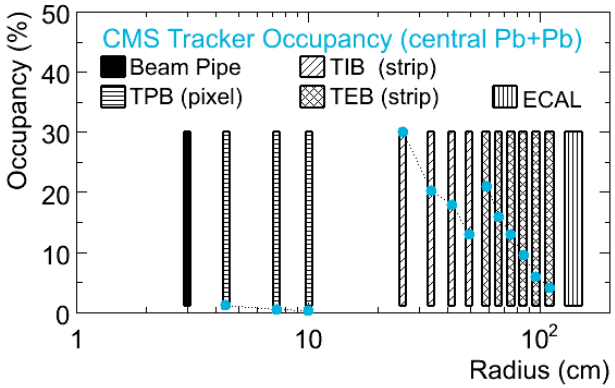
High occupancy for central TRT
even in p+p (~ 90% for Pb+Pb)

⇨ Charged multiplicity and spectra: fine
⇨ Very low p_T (B_T=2T) and PID with Tracker: challenging

CMS Elements and Tracker

Reconstruction and identification at low p_T with CMS: detectors involved in B=4T





High occupancy for strips in Pb+Pb

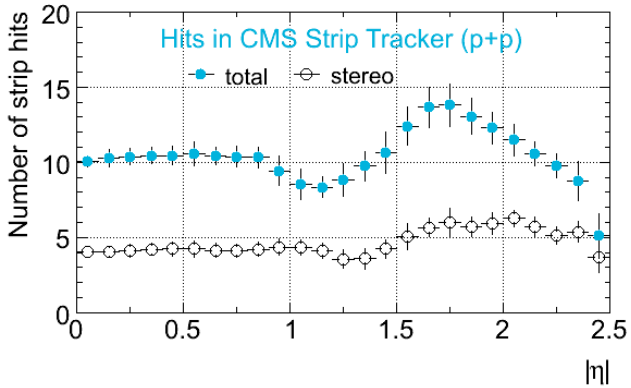
Barrel:

- Pixel (3 layers);
- Tracker Inner Barrel (TIB, 4 layers of strip);
- Tracker Outer Barrel (TOB, 6 layers of strip).

Forward:

- Tracker Inner Disks (TID, 5 layers: 2 pixel, 3 strip);
- Tracker End-Caps (TEC, 9 layers).

M. Weber / Nuclear Physics B (Proc. Suppl.) 142 (2005) 430–433



Number of strips hits in p+p for PID

⇨ Excellent impact parameter and primary vertex determinations

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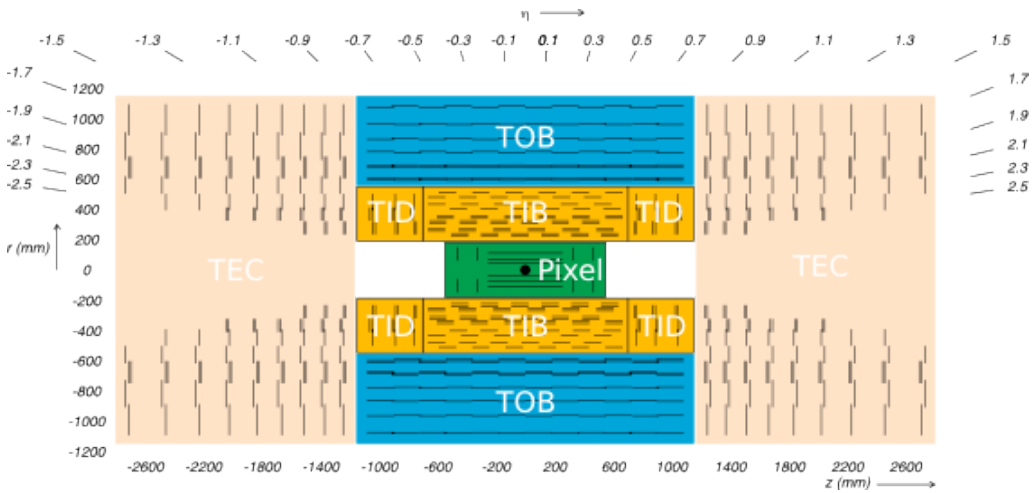

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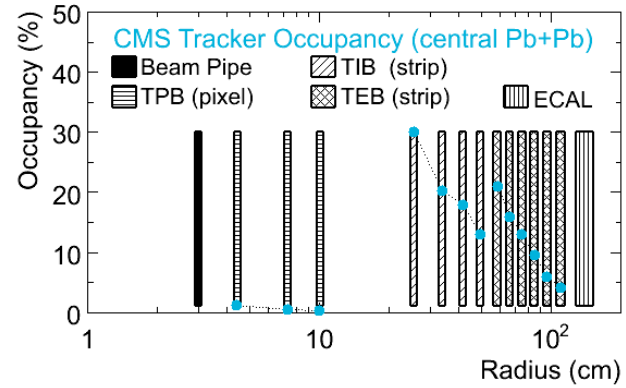

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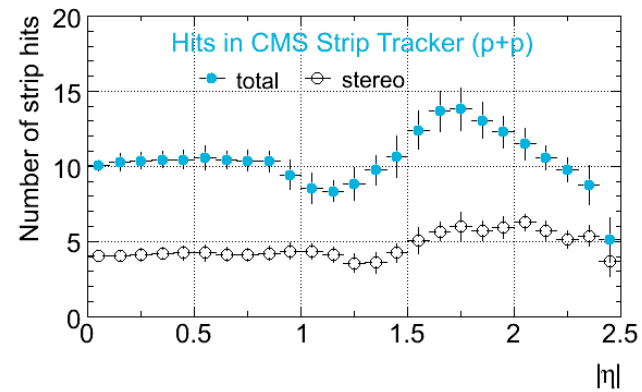

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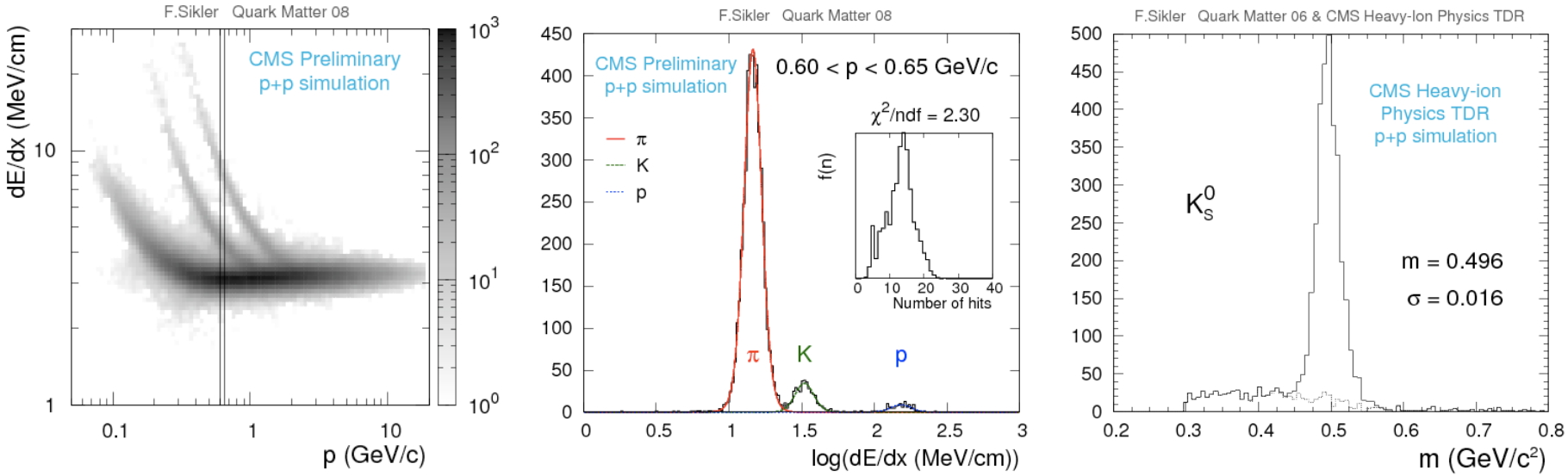
CMS PID

Modified algorithm for low-pT tracking in the pixel (3 hits): from straight line approximation to helix



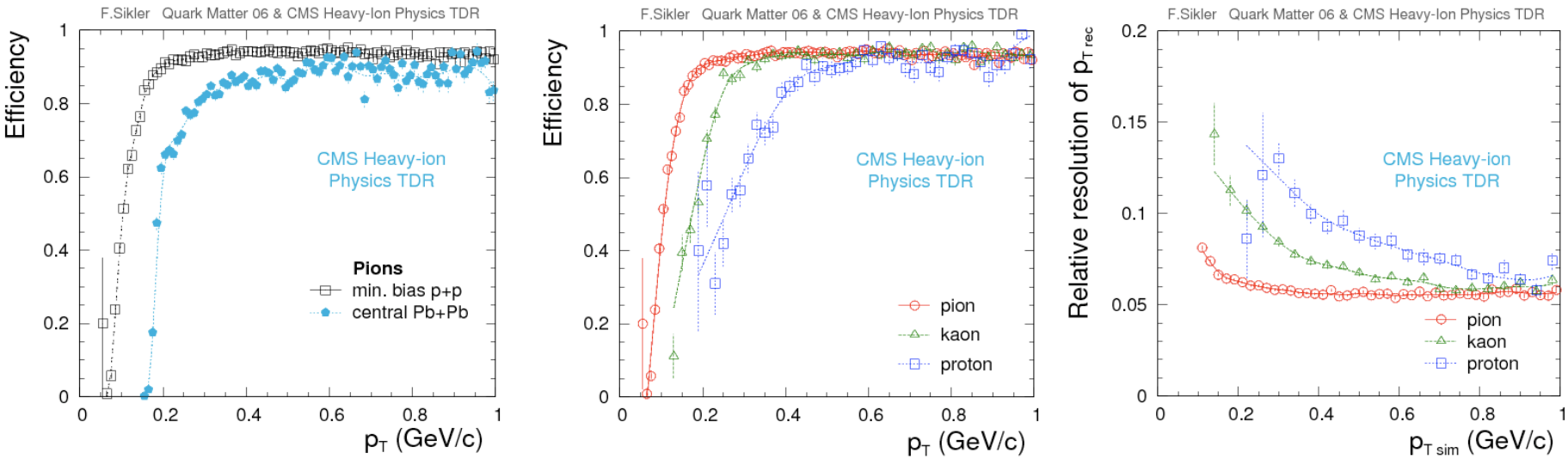
F. Sikler QM06: Int.J.Mod.Phys.E16:1819-1825,2007 and CMS-CR-2007-007;
F. Sikler QM08: arXiv:0805.0809 and CMS-AN-2006-101.

- dE/dx identification using both pixel and strip silicon detectors;
- topology identification: possibility for lambdas and gamma conversion too;
- optimization depending on luminosity conditions.

⇨ Identification at low p_T with CMS: dE/dx and invariant mass for neutral particles

CMS Efficiency

Efficiency calculations based on 25k p+p events and 25 central Pb+Pb

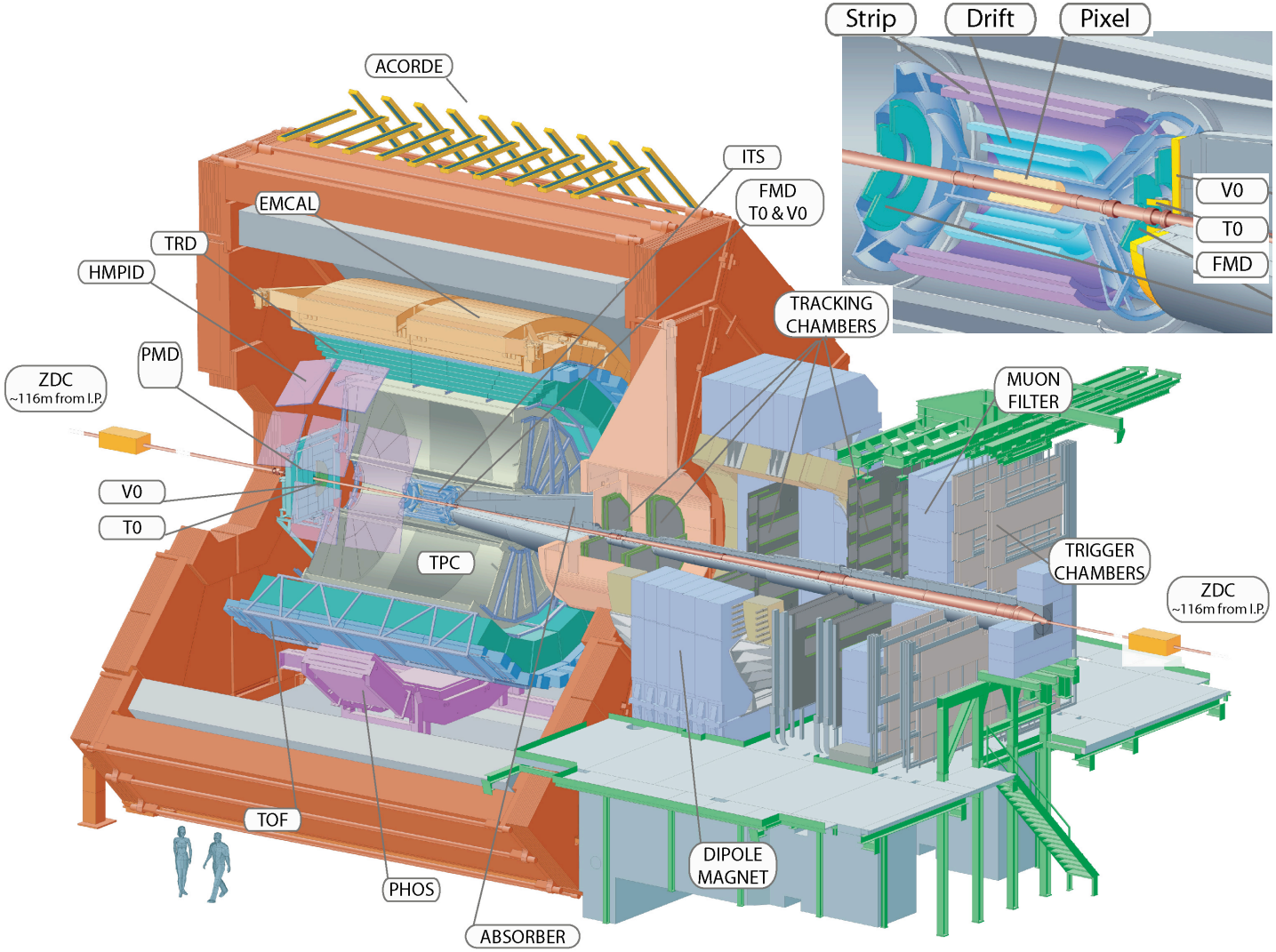


references: CMS-CR2007-007 and CMS-CR2007-054

- With $|\eta| < 1.5$, the average reconstruction efficiencies are 0.90/0.90/0.86 for pions/kaons/protons;
- Small bias (6%) at high p_T but quite significant at low p_T (10% correction for protons at 0.2 GeV/c).

⇨ Good efficiency and identification at low p_T in CMS

ALICE experiment and ~ 18 detectors



ALICE experiment and its central detectors

Transition-Radiation Detector

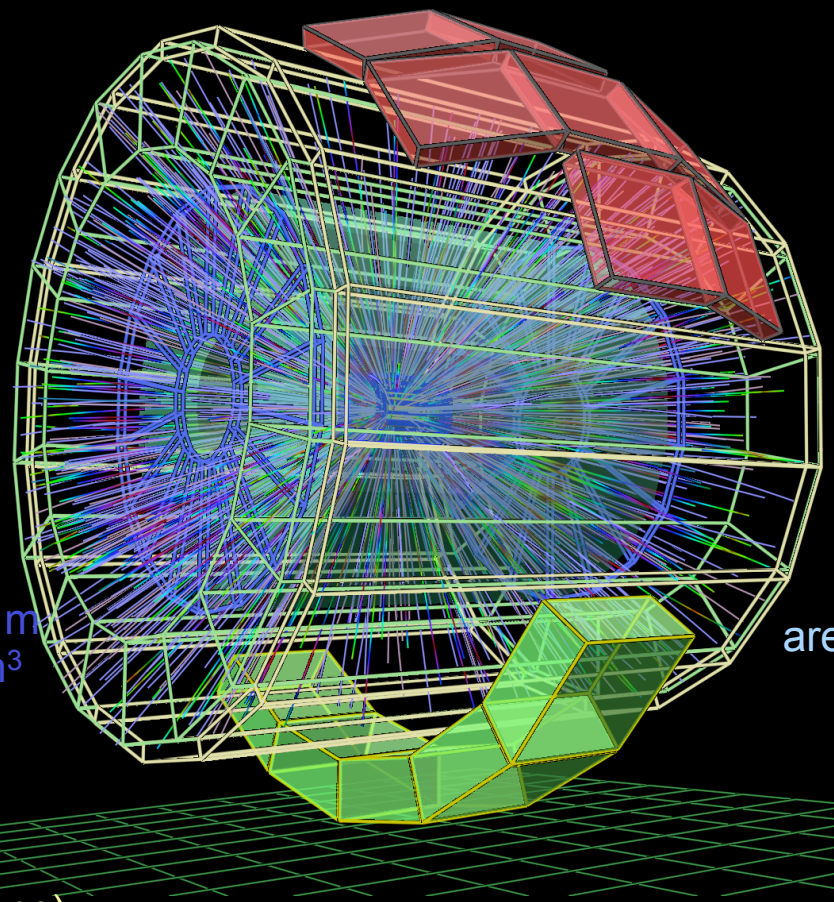
$-0.9 < \eta < 0.9$
azimuth 2π
length ~7 m
active area 736 m^2

Time Projection Chamber

$-0.9 < \eta < 0.9$
azimuth 2π
length 5 m
diameter 5.6 m
inner/outerR: 1/2.5 m
active volume 88 m^3

Time Of Flight

$-0.9 < \eta < 0.9$
azimuth 2π
length 7.45 m (100 ps)
active area 141 m^2



High-Momentum Particle Identification Detector

$-0.6 < \eta < 0.6$
azimuth 57.61°
active area 10 m^2

Inner Tracking System

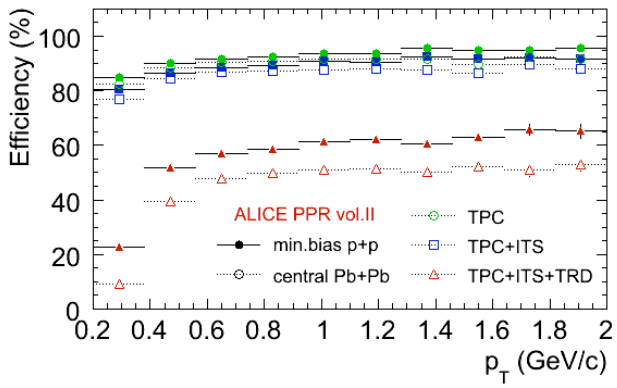
$-0.9 < \eta < 0.9$
silicon layers 6
pixel/drift/strip 2/2/2
cells(M) 9.84/23/2.6
area 0.21/1.31/4.77 m^3

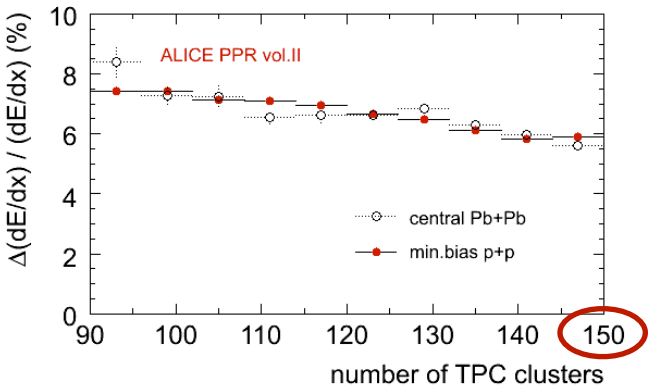
PHOton Spectrometer

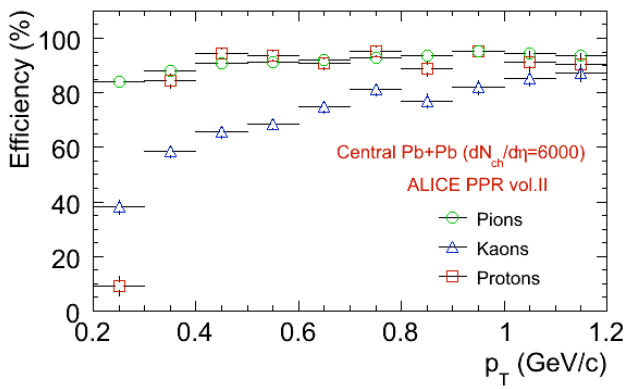
$-0.12 < \eta < 0.12$
azimuth 100°
active area 8 m^2

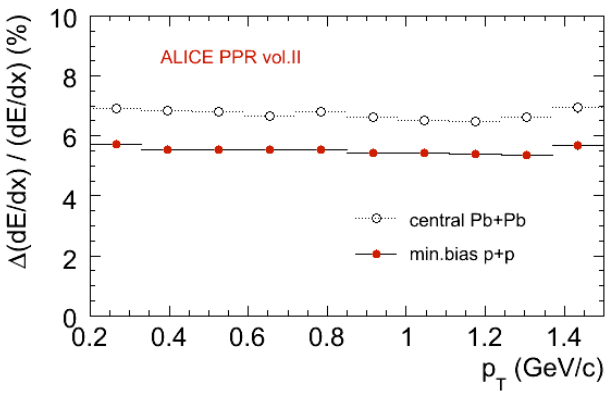
ALICE performances

Efficiencies vs. p_T: i) p+p and Pb+Pb comparison; ii) species dependence
dE/dx resolution for PID: i) dE/dx vs. # of TPC cluster; ii) dE/dx vs. p_T





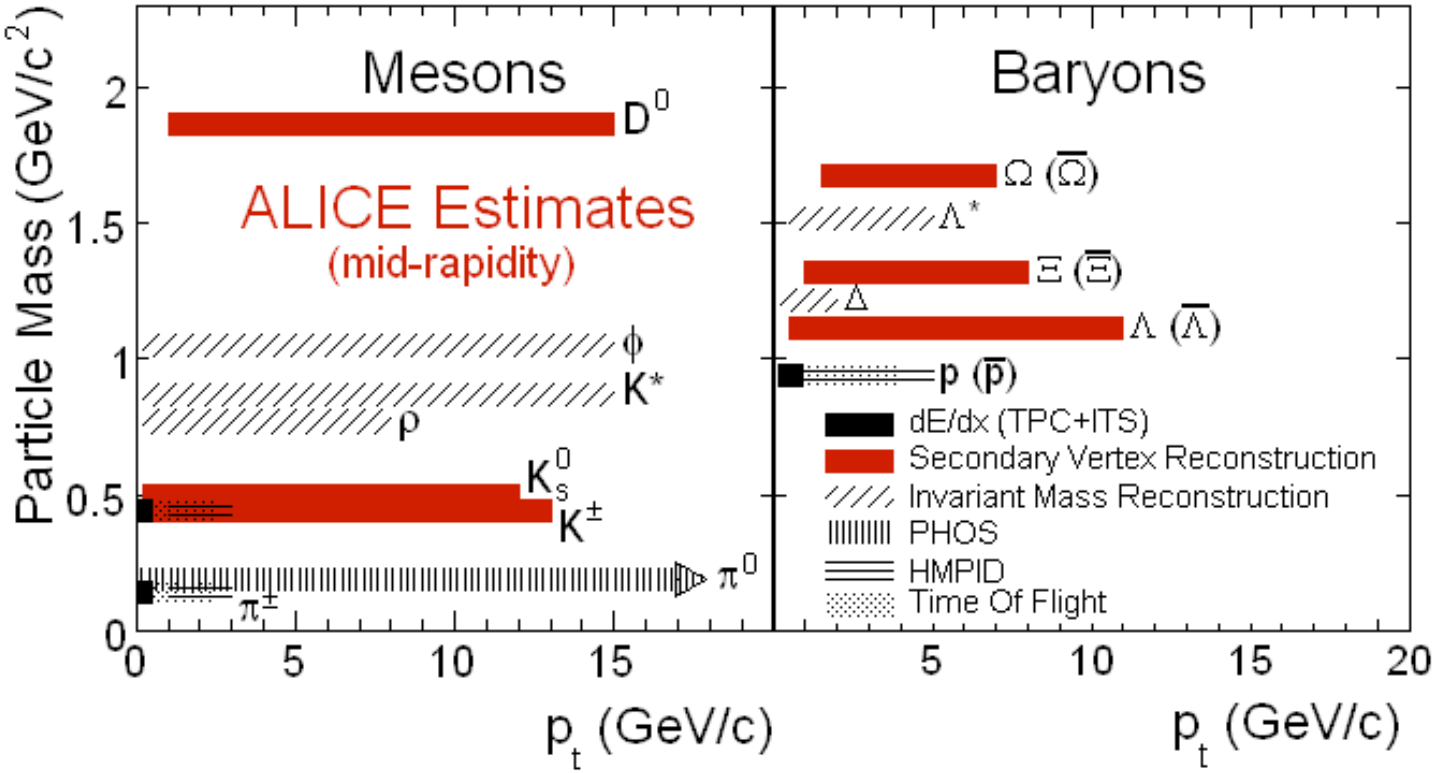




- ⇨ Alice is designed for high multiplicity: excellent efficiency and resolution at low p_T;
- ⇨ Charm and strange weak decay identification via topology reconstruction (not shown);
- ⇨ Lower magnetic field w-r-t Atlas and CMS but also lower luminosity conditions required.

Particle identification vs p_T

Estimated p_T ranges for 10 M central Pb-Pb events (PPR vol. II).
Ranges for first year p-p events can be close if one month of data taking.



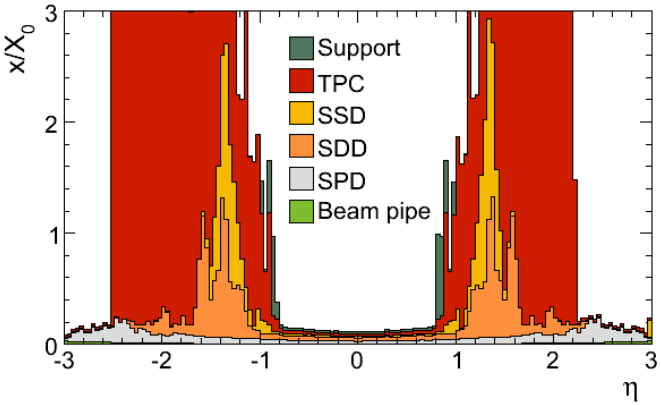
⇨ low p_T : thermal emission and hydrodynamics;

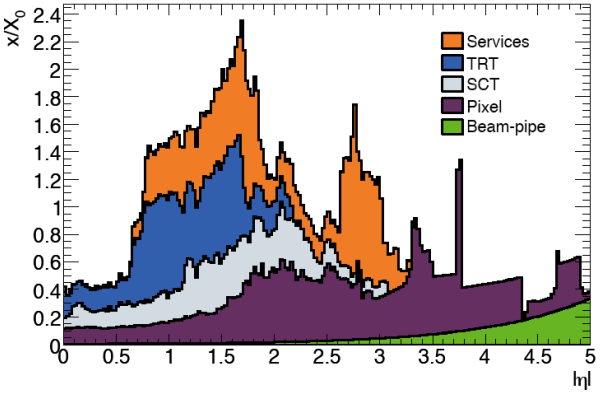
⇨ intermediate to high p_T : hadronization mechanisms, tomography.

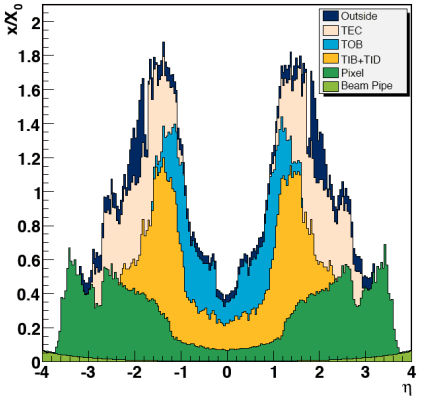
Material budget

Cumulative mid-rapidity material budget for ALICE, ATLAS and CMS

ALICE	x/X_0 (%)	ATLAS	x/X_0 (%)	CMS	x/X_0 (%)
Beam pipe	0.26	Beam pipe	0.45	Beam pipe	0.23
Pixels (7.6 cm)	2.73	Pixels (12 cm)	4.45	Pixels (10.2 cm)	7.23
ITS (50 cm)	7.43	SCT (52 cm)	14.45	TIB (50 cm)	22.23
TPC (2.6 m)	13	TRT (1.07 m)	32.45	TOB (1.1 m)	35.23







⇨ Ideal Reconstruction and identification low p_T : lowest material budget

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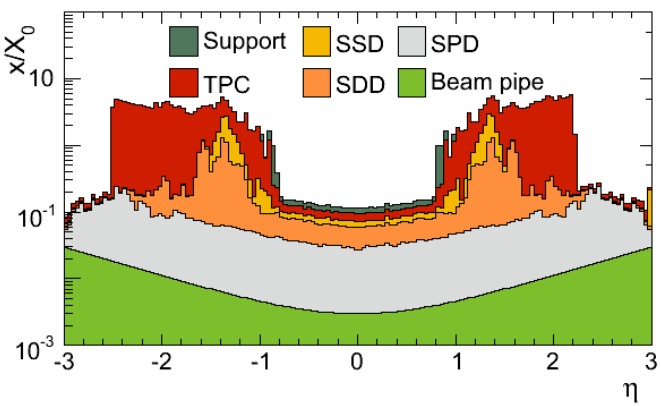

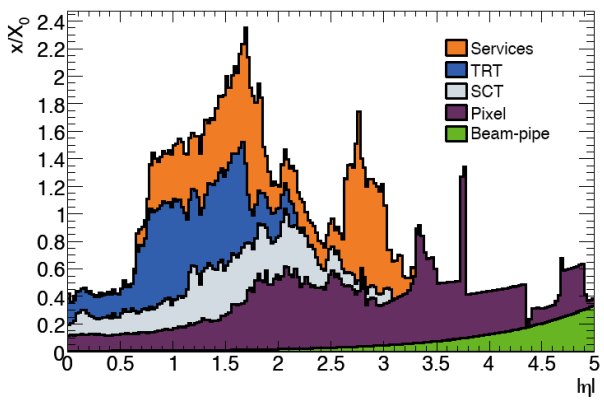

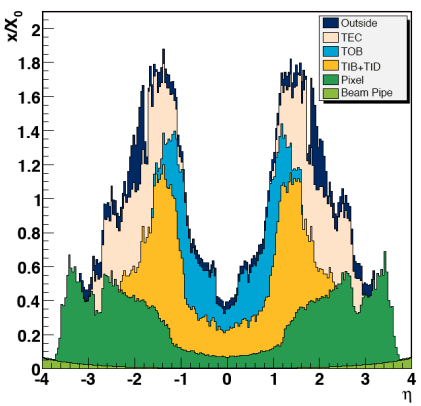

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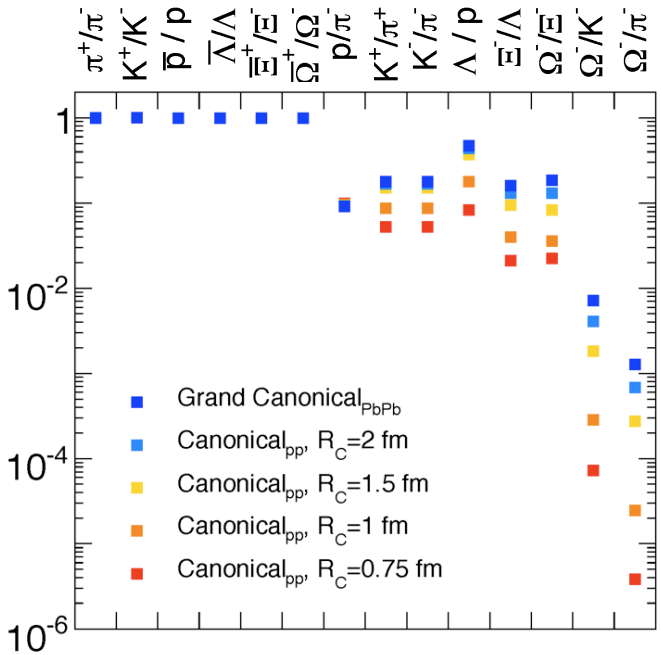
Hadro-production: equilibrium vs. non equilibrium

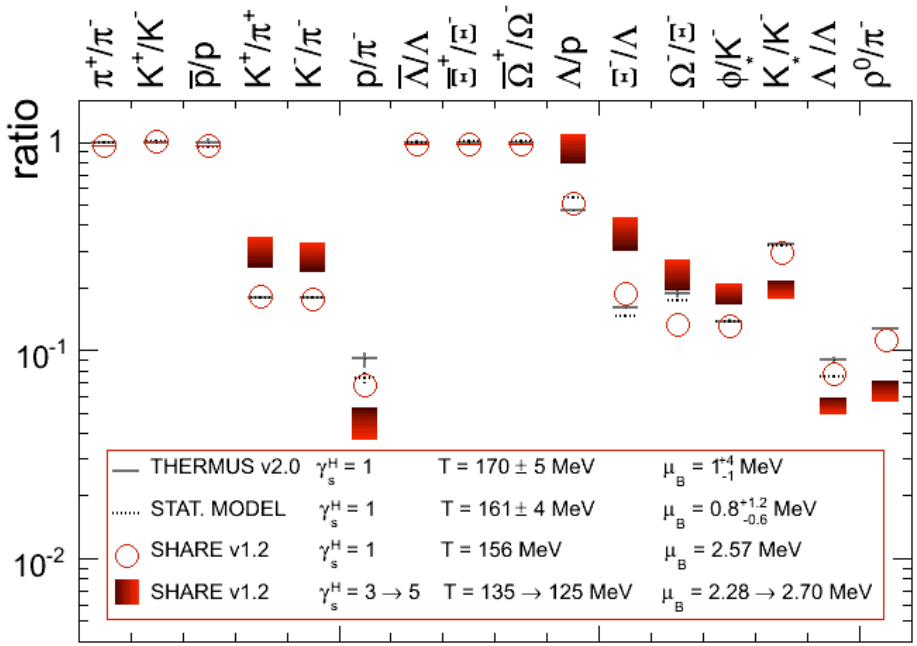
Statistical thermal models describe mid-rapidity p_T-integrated production of baryons and mesons over a large energy range.

Baryo-chemical potential μ_B and Chemical freeze-out Temperature T_{ch}

I.Kraus et al., in arXiv0711.0974 [hep-ph]



ALICE Estimates : Equilibrium vs Non Eq. particle ratios



⇨ Expectations at LHC: T_{ch} =161±4 MeV
μ_B =0.8+1.2-0.6 MeV

Eq. [I.Kraus *et al.*, J.Phys.G32 (2006) S495]
[A.Andronic *et al.*, Nucl. Phys. A772 (2006) 167]
Non Eq. [J.Rafelski *et al.*, Eur. J. Phys. C45 (2006) 61]

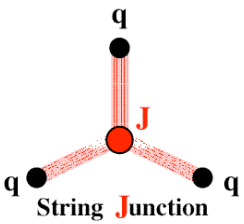
Note: Anti-particle/particle ~ unity will be difficult to constrain but can be used for addressing baryon transport

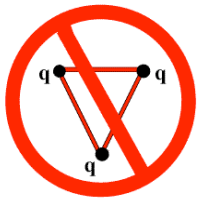
Baryon number transport

P. Christakoglou: HEP2008, Athenes

Studying the baryon number (BN) transport and carrier:

- gluonic field: B.Z. Kopeliovich and B. Zakharov, Z. Phys. C43 (1989) 241.
  probability to transport BN is constant with rapidity
- valence quark: G.C. Rossi and G. Veneziano, Nucl. Phys B123 (1977) 507.
  probability to transport BN is exponentially suppressed

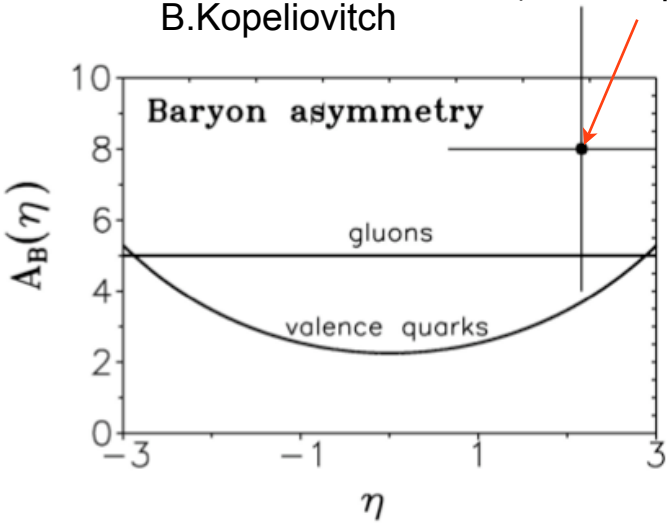




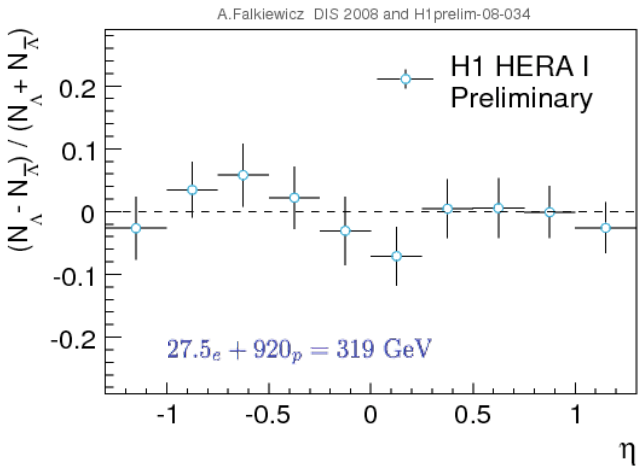
Baryon asymmetry vs. y or η: $A_B = (2\times)\frac{N_B - N_{\bar{B}}}{N_B + N_{\bar{B}}}$

B.Kopeliovitch

H1 (Hera, Δη=7)



A. Falkiewicz: DIS2008, London



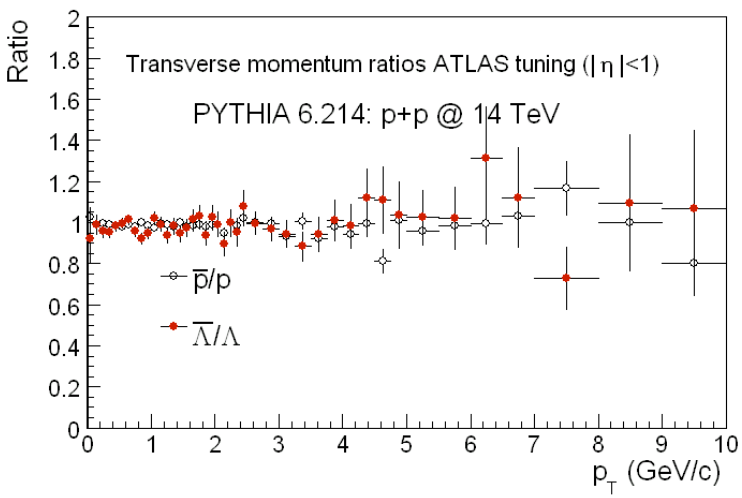
⇨ Current measurements are compatible with no asymmetry within uncertainties

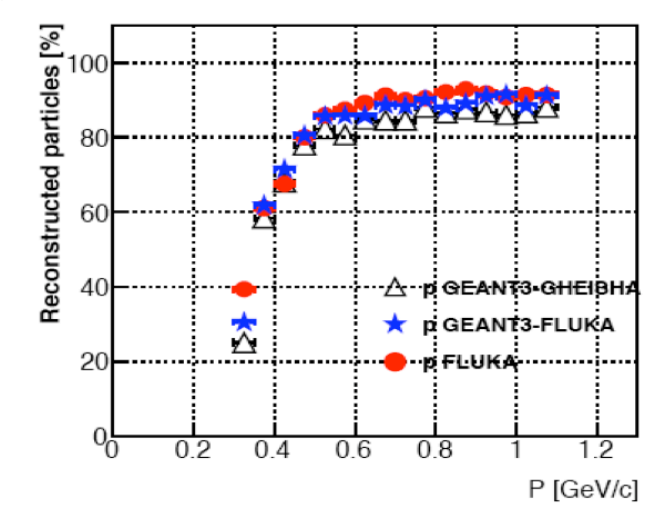
Baryon number transport

P. Christakoglou: HEP2008, Athenes

Specific to LHC conditions: high energy so $\bar{B}/B$~1 and large rapidity gap (y_p±9.6)

- QGSM: asymmetry ~0% (~no transported baryons from y_p to y_0 via fragmentation);
- Kopeliovitch: asymmetry ~5% for protons and ~8% for Λs;
- Veneziano: smaller but non-zero asymmetry.





Try to perform this measurement at LHC energies

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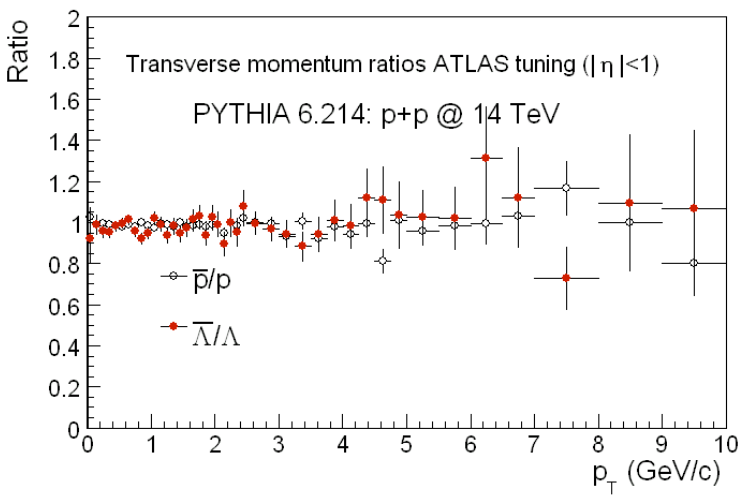
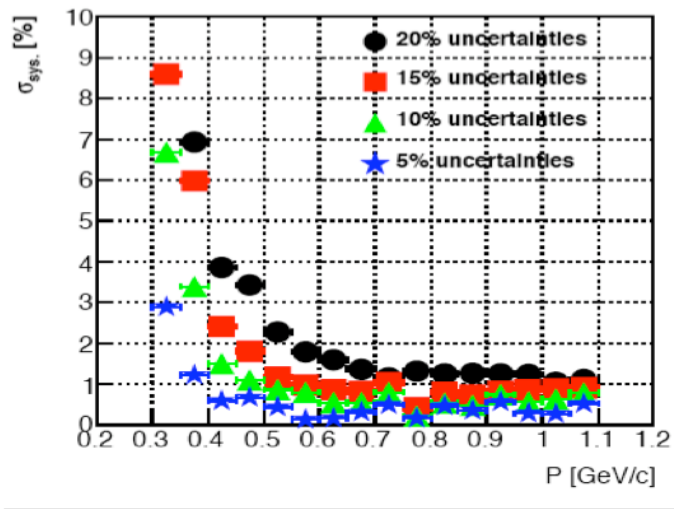


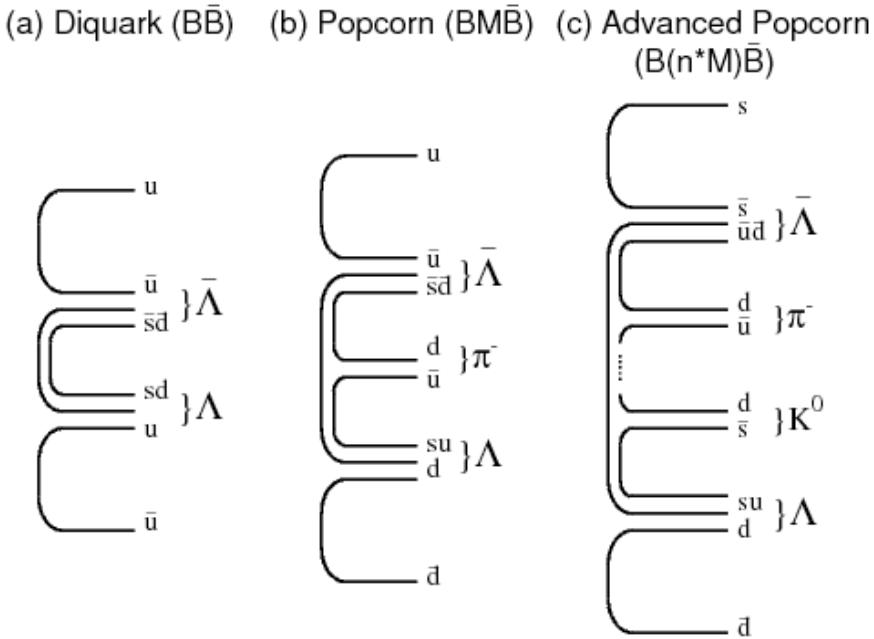


The systematic uncertainties on both the ratio and the asymmetry are below 1% for a material uncertainty of 15% (p > 0.5 GeV/c).

Try to perform this measurement at LHC energies

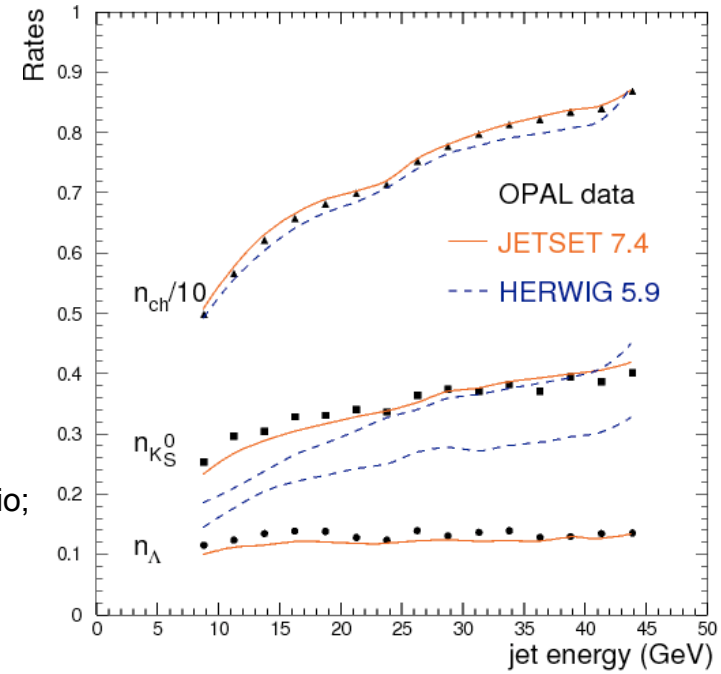
Baryon-production from fragmentation (LUND / PYTHIA)

Modified "popcorn" scenario from the diquark model for baryon production



Studied at LEP e.g. OPAL:

1. baryon yields vs. jet energy
2. baryon correlations vs. η gap between the baryon pair



Distinguishing between different scenario for fragmentation

- JETSET (now PYTHIA): anisotropic string decay
- MOPS : (now advanced/Popcorn in PYTHIA) MOdified Popcorn Scenario;
- HERWIG: isotropic clustering

Revisit baryon production at LHC energies

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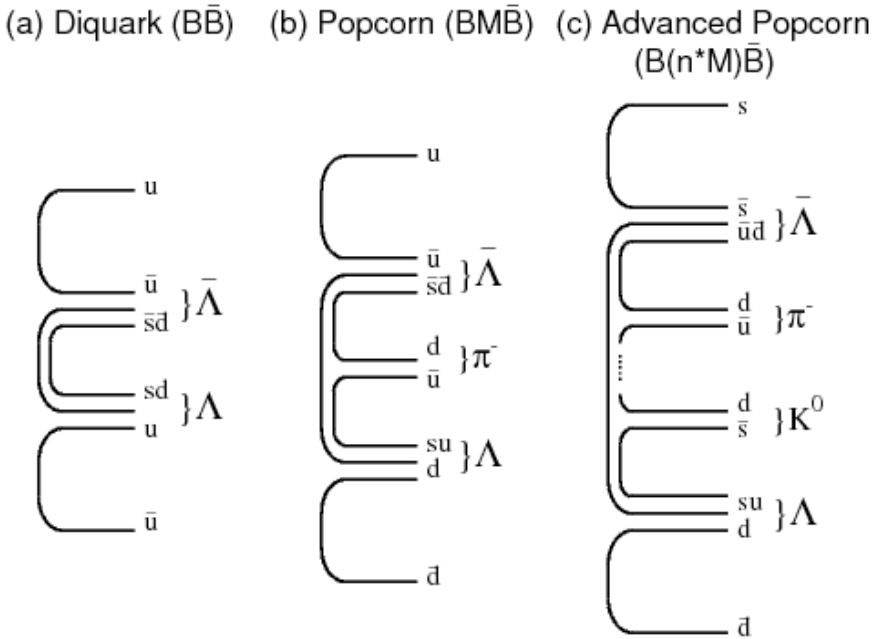

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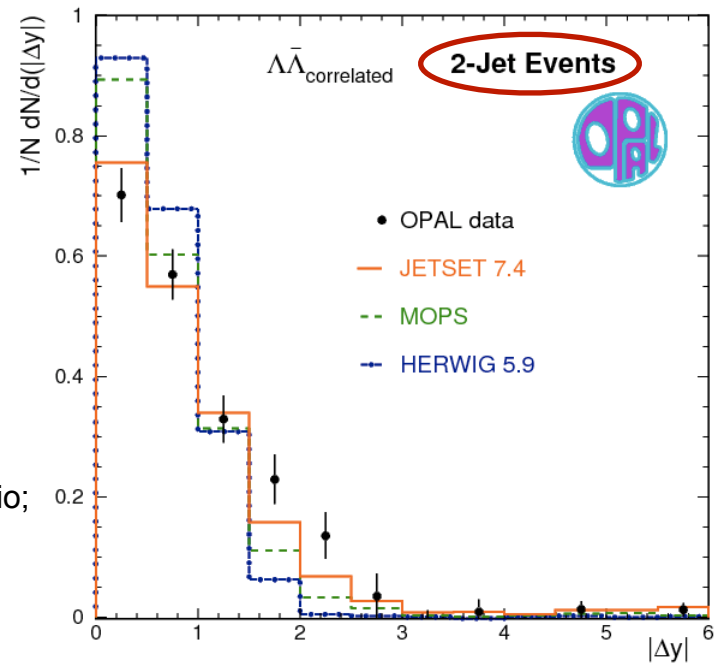

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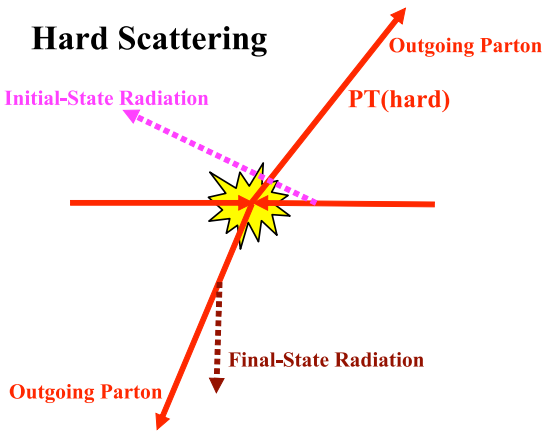
Multi-parton dynamics in p+p at LHC energies

Soft component in p+p collision: multiple parton interactions

Hard parton scattering is one part of the story



Significant differences for production rates and ratios between “min. bias” and “u.e.”;
⇨ important for e.g. understanding baryon/meson ratio, deconvoluting R_{AA}...
⇨ angular studies may include leading charged particle and/or full jet reconstruction.

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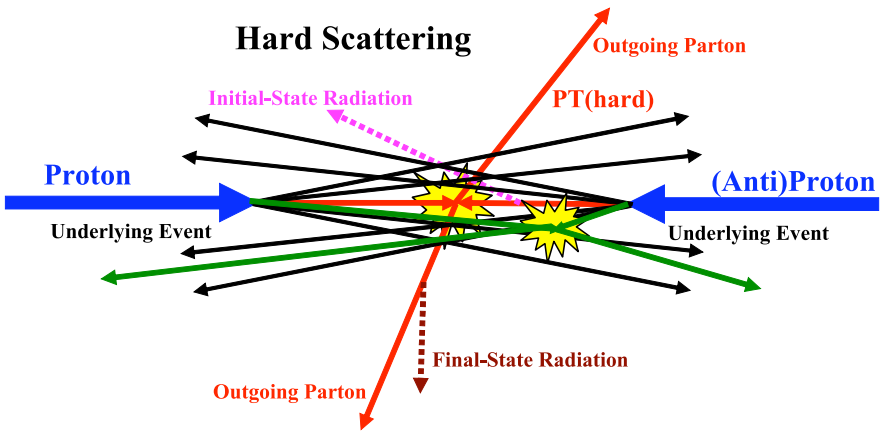

R.Field: «The "underlying event" consists of the "beam-beam remnants" and from particles arising from soft or semi-soft multiple parton interactions (MPI).»

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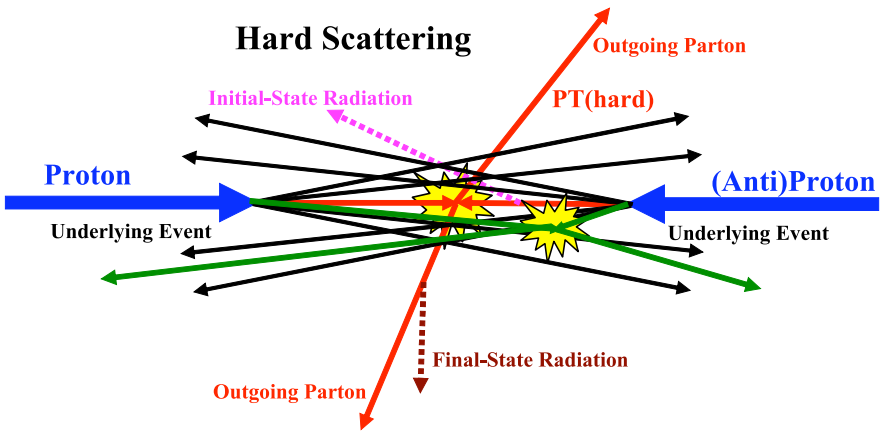

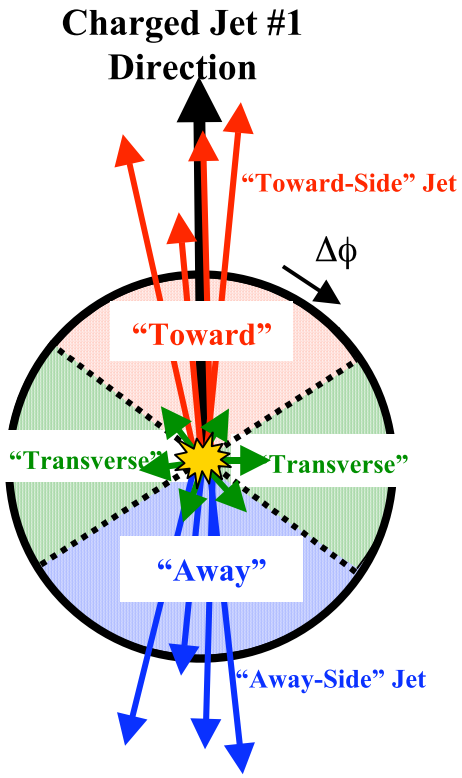

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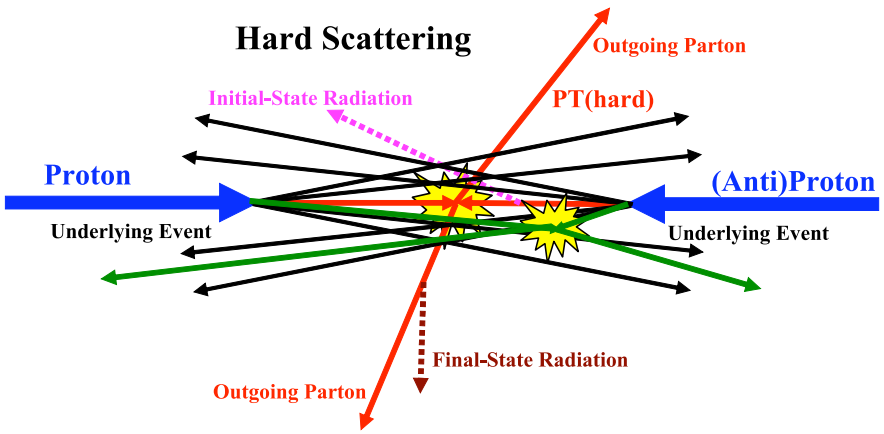

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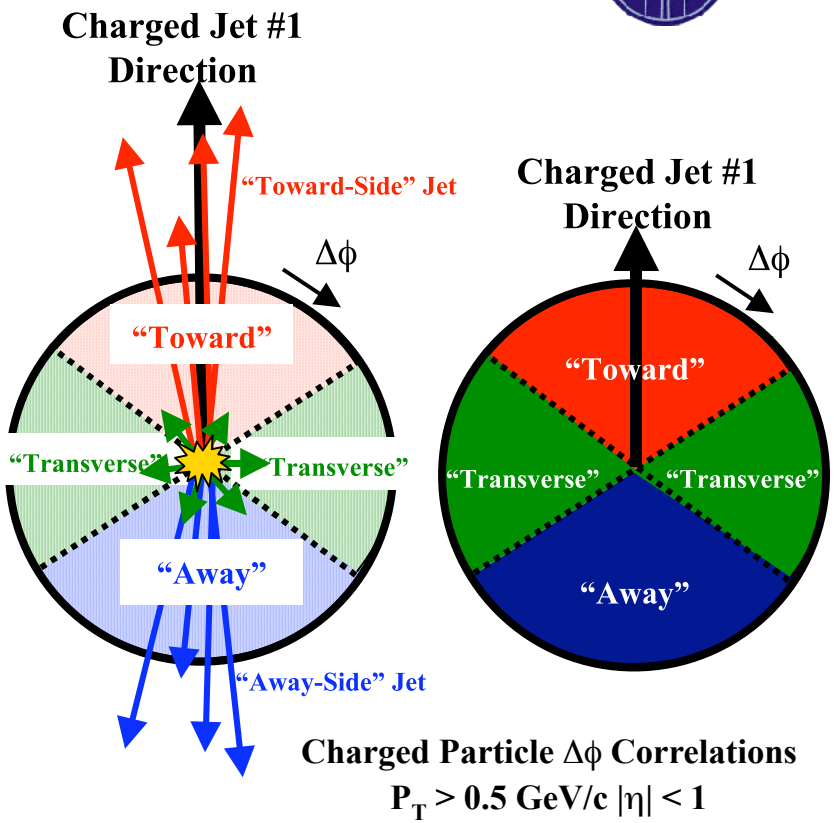

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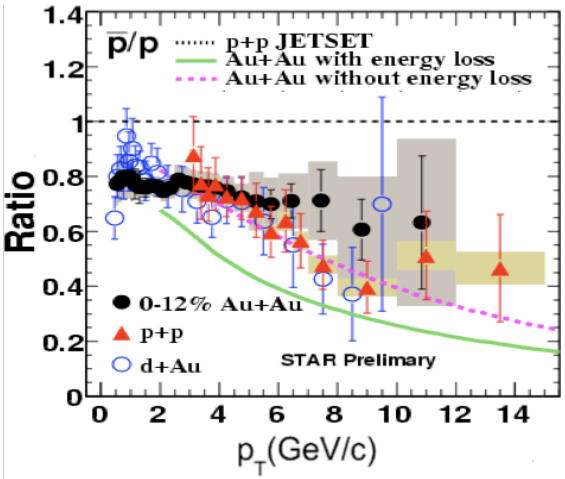
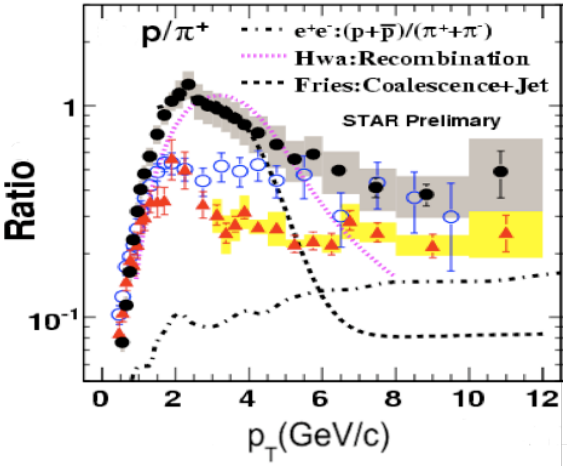
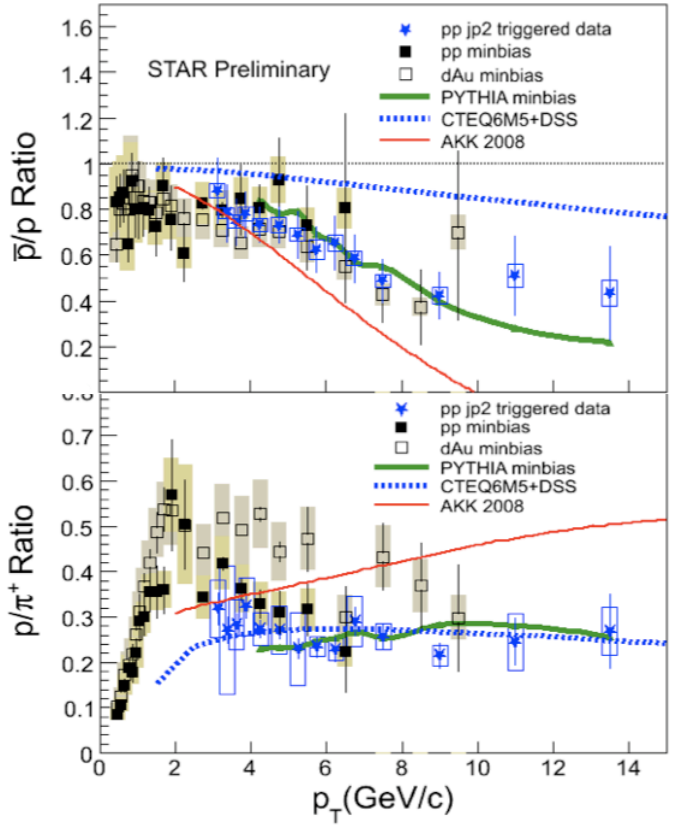
Baryon / Meson ratios at RHIC and HERA

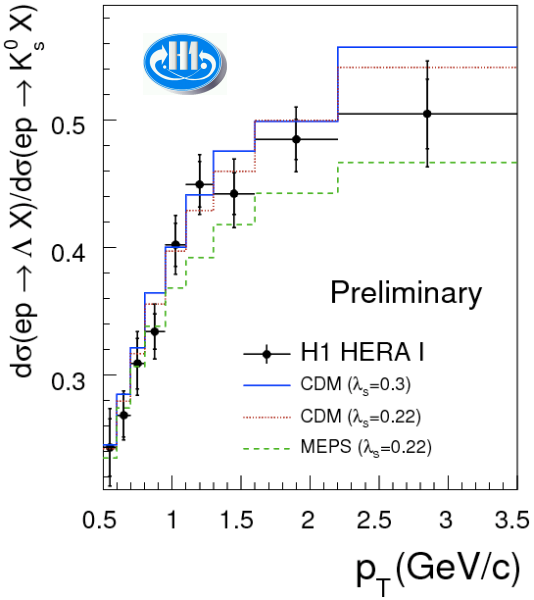
Probing baryon/meson differences at LHC energies implies PID over a large p_T range.





Studying p+p and e+p production for understanding the specificities of A+A



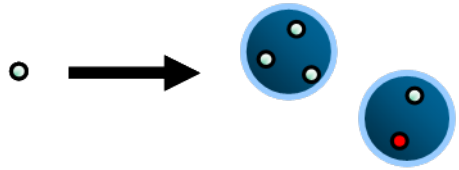


Yichun Xu (STAR) HQ08: nucl-ex arXiv:0901.0692

As studied at RHIC, first step for investigating recombination and coalescence mechanisms

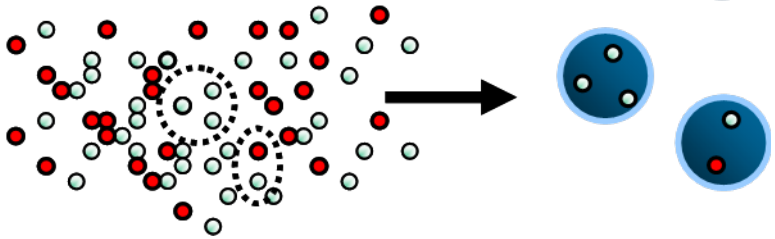
Recombination / Coalescence vs. Fragmentation

Hadronization of 1 parton: fragmentation



Dilute parton system
High virtualities

If phase space is filled with partons: hadronization via recombination/coalescence

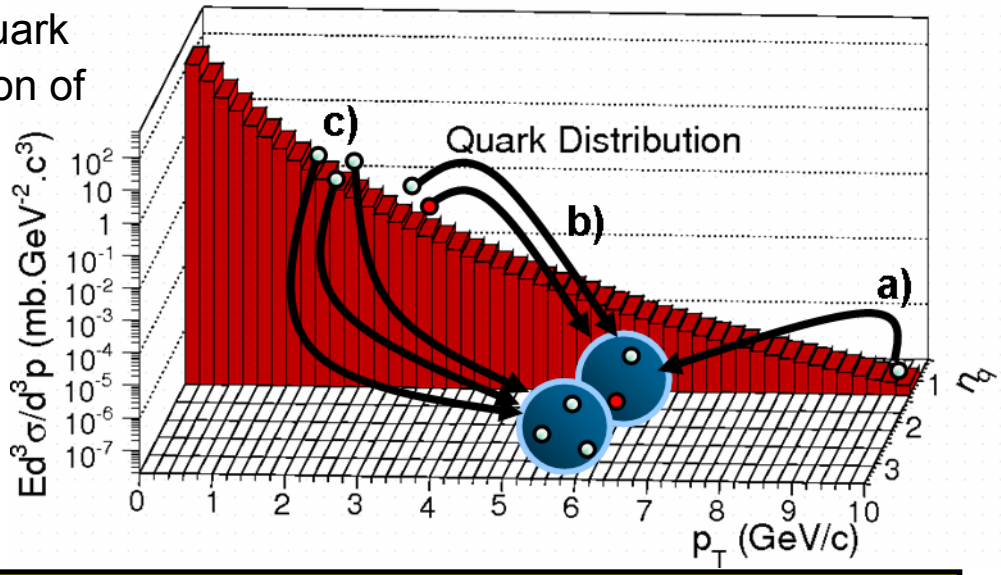


Dense parton system
Low virtualities

The in vacuo fragmentation of a high p_T quark competes with the in medium recombination of lower momentum quarks

a) 6 GeV/c pion from 1x 10 GeV/c quark fragmentation
b) 6 GeV/c pion from 2x 3 GeV/c quark recombination
c) 6 GeV/c proton from 3x 2GeV/c quark recombination

Baryon/Meson ratios
Constituent Quark Scaling (e.g. v_2)
Correlations via Soft+Hard contributions

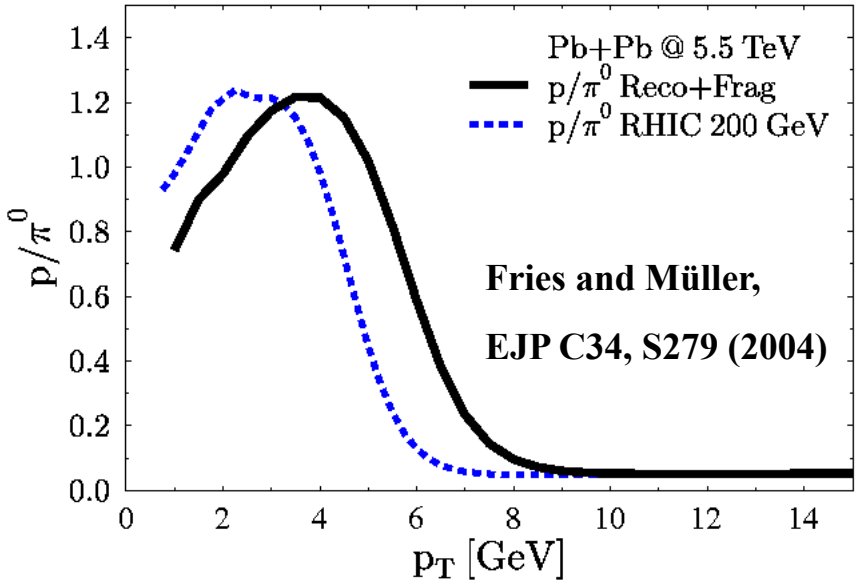


"...requires the assumption of a thermalized parton phase... (which) may be appropriately called a quark-gluon plasma." Fries *et al.*, PRC 68, 044902 (2003)

Baryon / Meson ratios at LHC energies

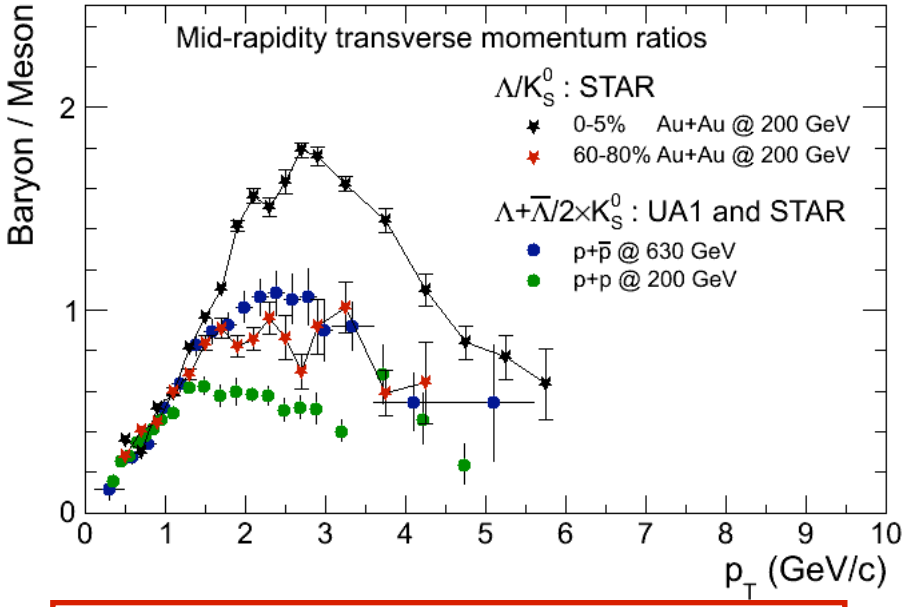
Probing baryon/meson differences at LHC energies implies PID over a large p_T range.

Calculation implies assumption on transverse radial flow extrapolation



But first LHC data will be elementary collisions
⇨ check magnitude of this behaviour then invoke coalescence mechanisms if needed.

60-80% from STAR ~ p+pbar from UA1



Amplitude for mixed ratio predicted to be the same at LHC than for RHIC but the turnover and limit are shifted to higher p_T

What should we expect for p+p collisions at the LHC ?

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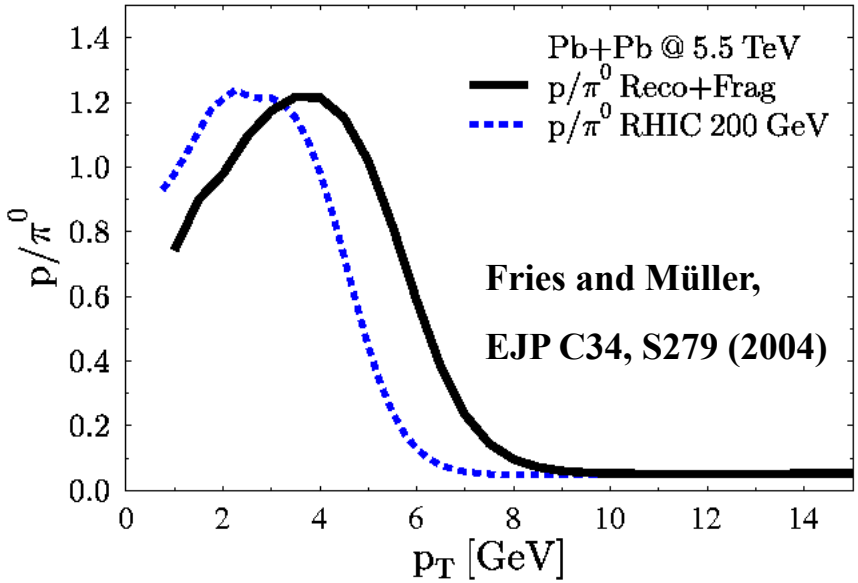
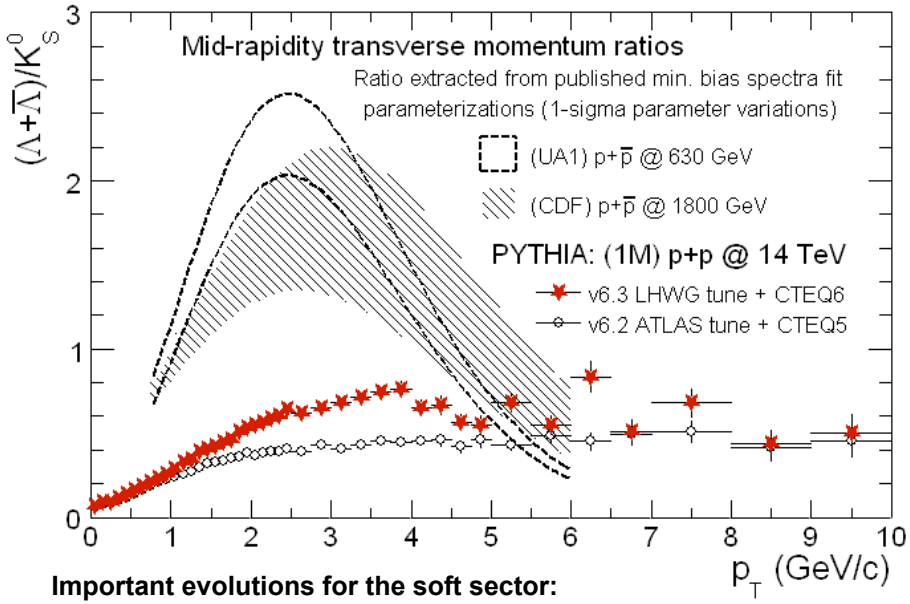


PYTHIA Configuration from preprint hep-ph/0604120



Amplitude for mixed ratio predicted to be the same at LHC than for RHIC but the turnover and limit are shifted to higher p_T

Important evolutions for the soft sector:

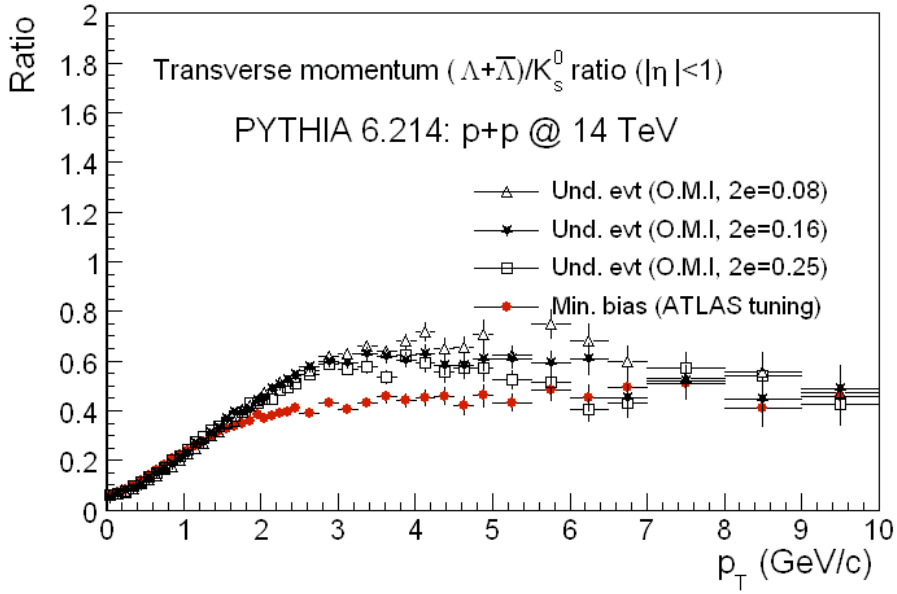
PYTHIA: **v6.2 ⇨ v6.3** New multiple interaction (N.M.I) treatment (part.-part. interactions and i/fsr)

PDF: **CTEQ5 ⇨ CTEQ6** Gluon distribution function (visible at low Q^2)

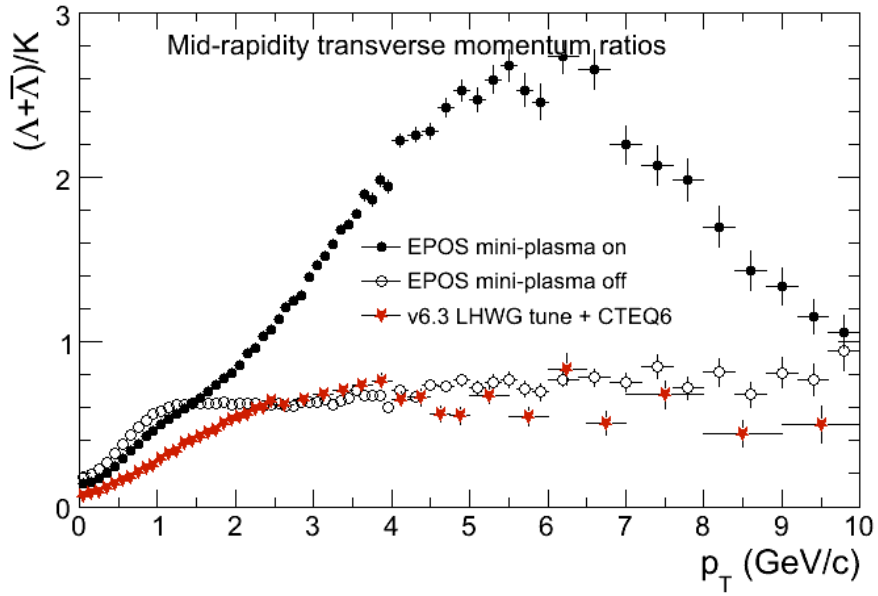
Missing a factor of ~2 wrt RHIC ⇨ UA1 ⇨ CDF extrapolations
⇨ investigation of NLO contribution, baryon creation mechanisms (diquark to popcorn scenario or gluonic baryon junctions).

Predictions for B/M p_T ratio: p+p @ 14 TeV

Ratios and differences between min. bias and underlying event description



Checking uncertainty for parameters energy dependence:
PYTHIA authors' suggestions : **2ε~0.08 ⇨ 0.25**



B.H. HQ08: arXiv:0901.3176

Comparison between standard LHC extrapolation and underlying event description

Little **light/strange** flavor dependence in this region

Underlying event description **needed/enough** for production of hadrons in intermediate p_T region ?

Predictions from EPOS based on pomeron exchanges can lead to much higher ratios

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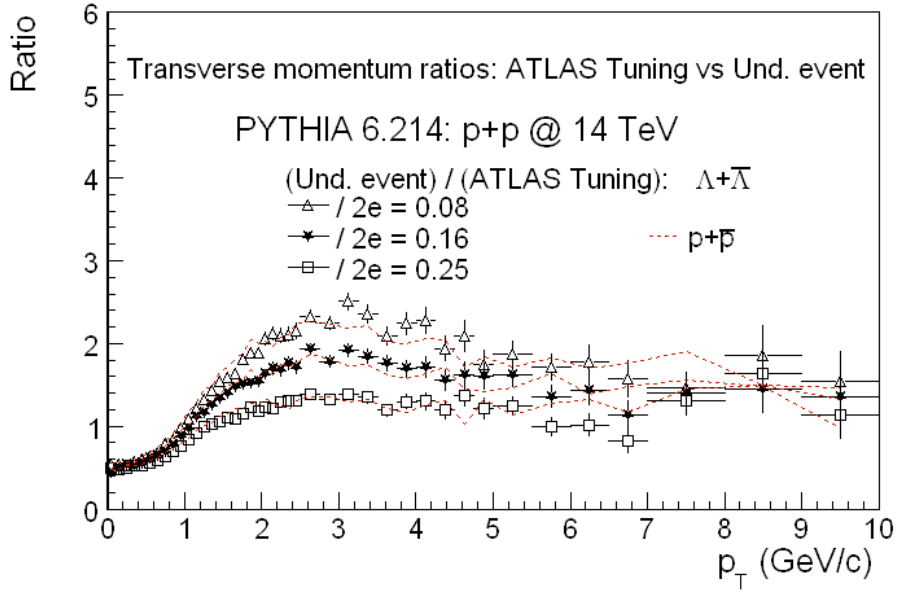

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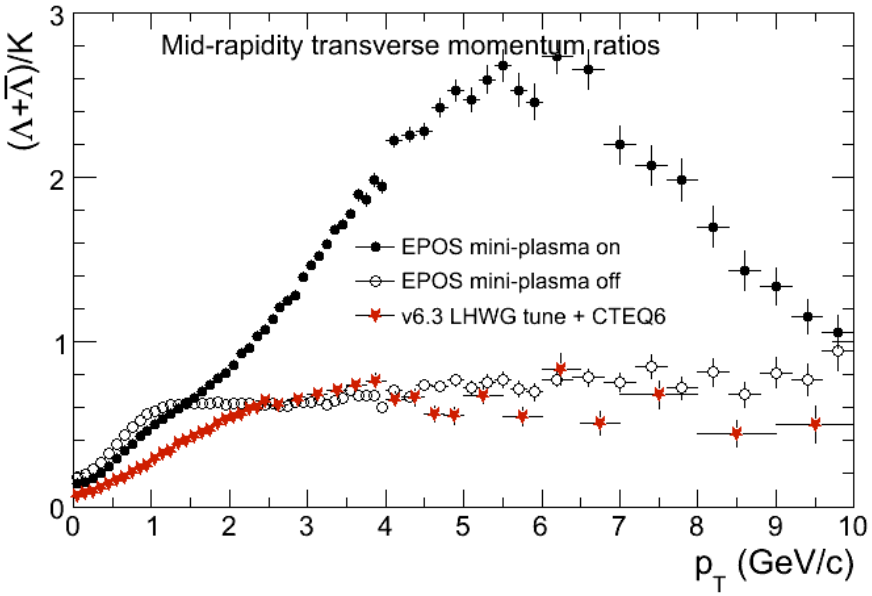

B.H. HQ08: arXiv:0901.3176

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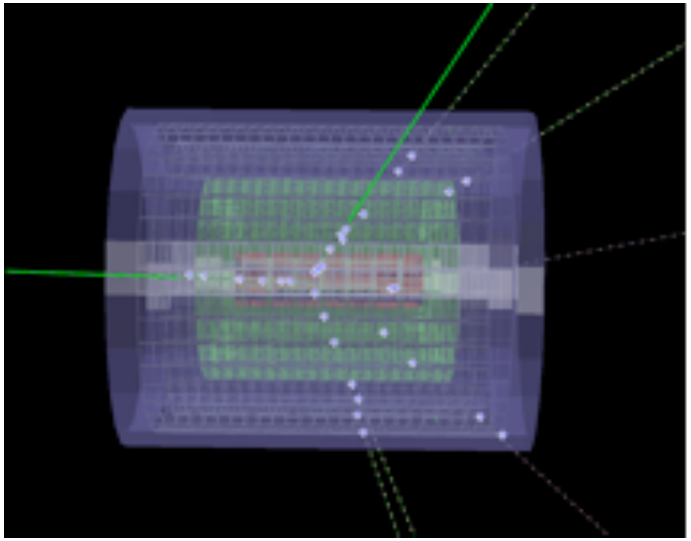
Predictions from EPOS based on pomeron exchanges can lead to much higher ratios

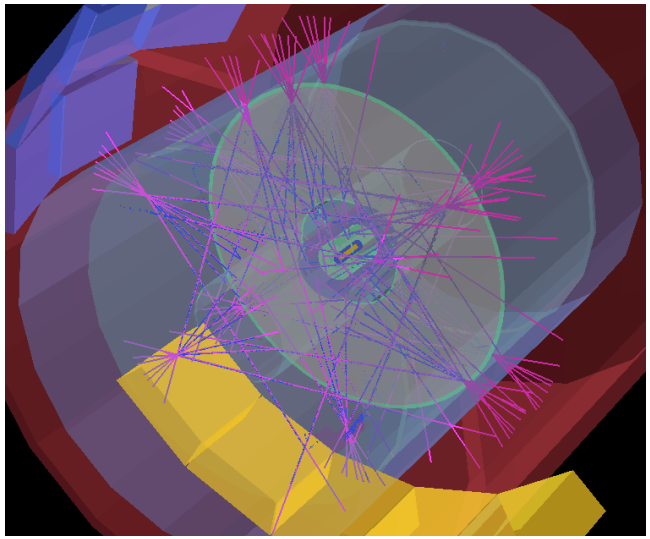
Current status of the main central detectors

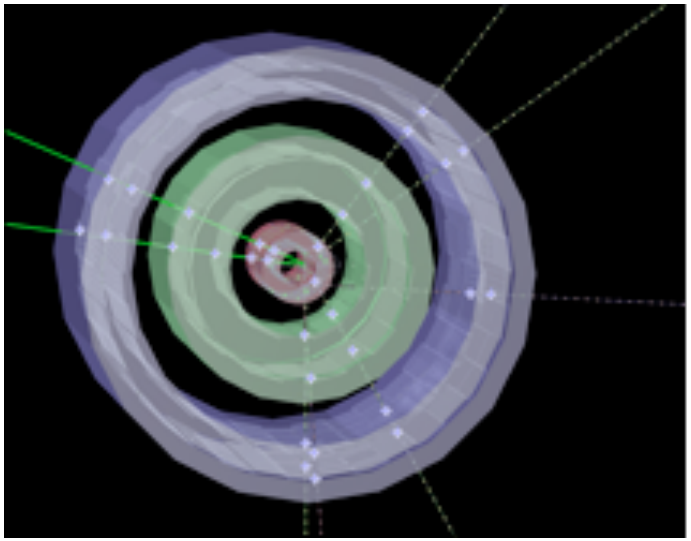
For central detector calibrations and in-situ studies, **laser beam events, (a few) beam-gas events** and **many cosmics events** were used since end of 2007

Beam-gas collisions recorded with the ITS



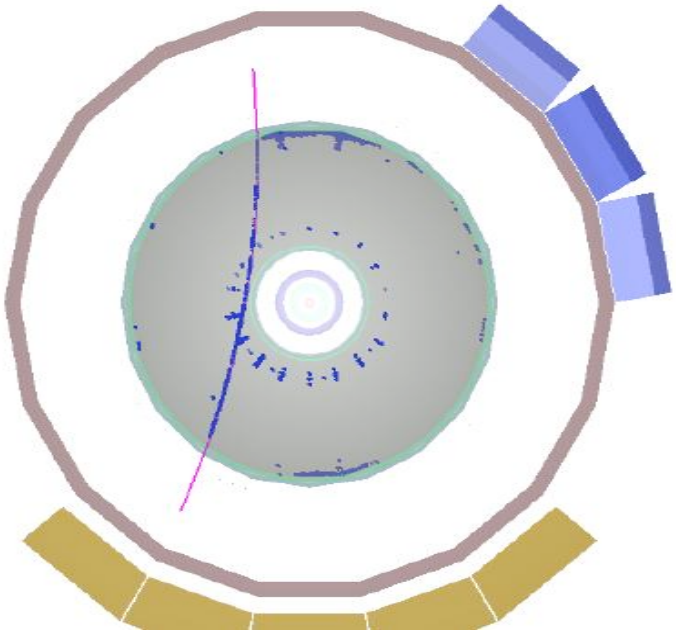
TPC calibration with laser beams

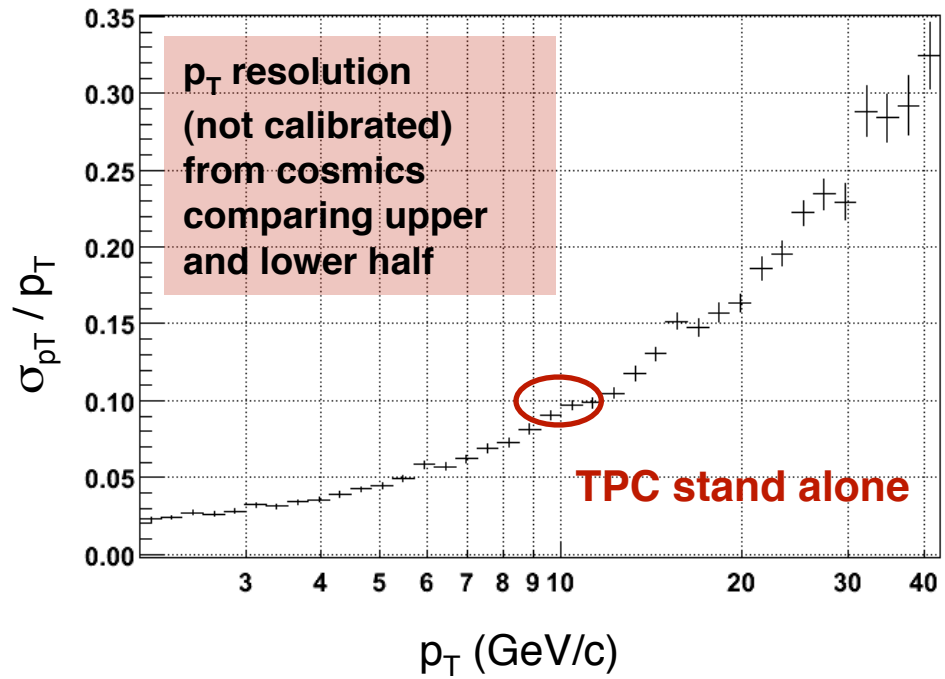




Calibration and preliminary p_T resolution in the TPC

Marian IVANOV





TPC tracking

- p_T resolution ~ 10% @ 10 GeV/c (without calibration)
- Calibration with laser tracks + cosmics
- Alignment ongoing
- PPR goal: ~ 5% @ 10 GeV/c

p_T reach

- p_T up to ~ 20 GeV/c quickly accessible with ~150 k events

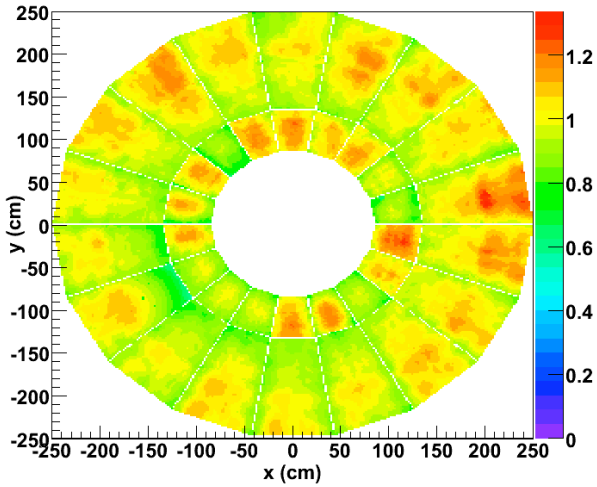
First physics

- p_T < 3 GeV/c with ~20 k events

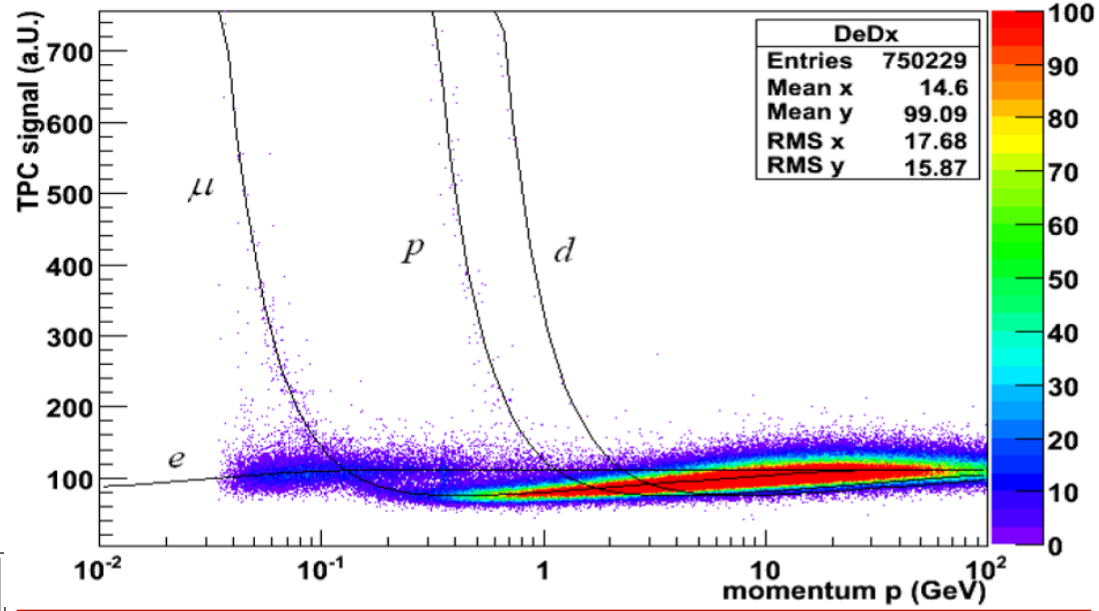
Preliminary particle identification with the TPC

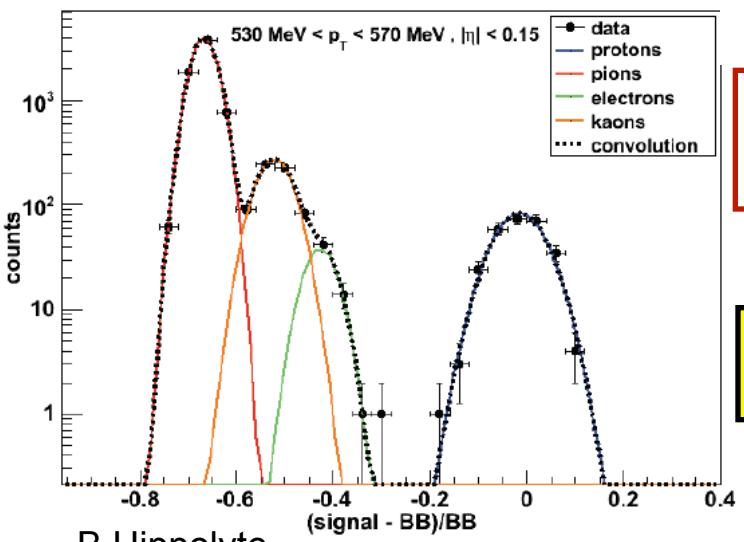
Alexander KALWEIT

- TPC gain calibration with radioactive Kr (before correction)



5,000,000 cosmic events from June 2008, simple Kr calibration





- TPC calibrated for PID with krypton and laser applied to cosmics data
- dE/dx resolution σ~5.7% (gain calibration with krypton)
- PID good at p_T< 1 GeV/c (20 k sufficient in this region)

Deconvolution of specific energy loss via Bethe-Bloch parameterization for all the different species

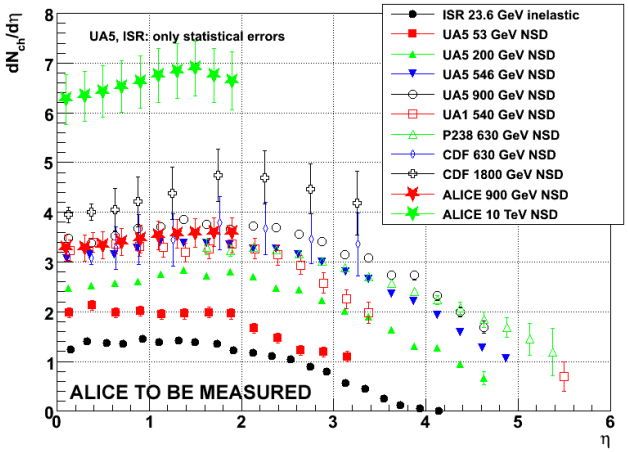
“First Physics” analyses in ALICE

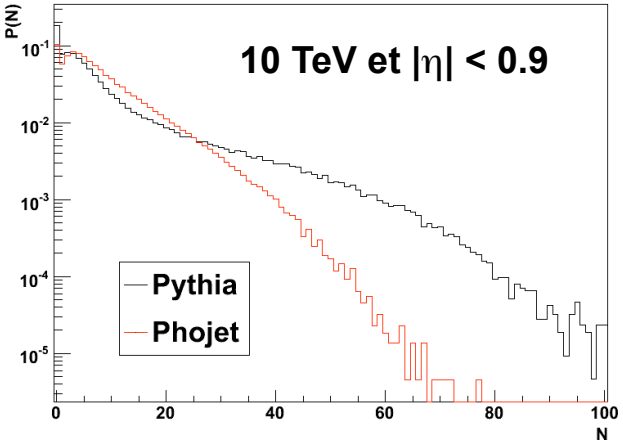
The “First Physics” analyses anticipated by the Collaboration have 3 main objectives.

Comment: first data are likely to be for pp collisions at 900 GeV (already recorded by UA5)...

then moving quickly to 10 TeV !

1. Measuring charged particle density vs. pseudorapidity: **$dN_{ch}/d\eta$ vs. η**
2. Multiplicity distribution: **dN/dM**
3. Cross section as a function of transverse momentum: **dσ/dpt**



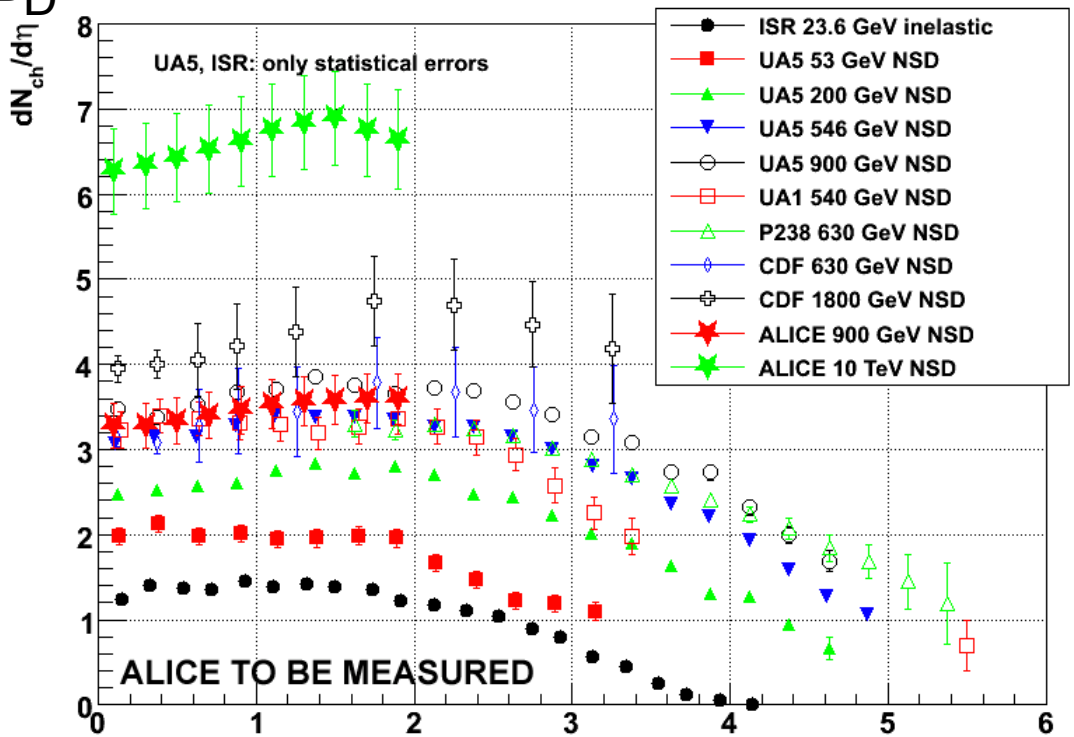


First Physics with ALICE

Jan Fiete OETRINGHAUS

Pseudorapidity density: $dN_{ch}/d\eta$ vs. η

Mesurement performed with the SPD
cf: ALICE-INT-2007-005



SPD+V0 (MB1) trigger
SPD tracklet data
40 K evts @ 900 GeV
150 K evts @ 10 TeV
|vtx-z| < 10 cm

Of course, stat. will depend on the LHC schedule...

First Physics with ALICE

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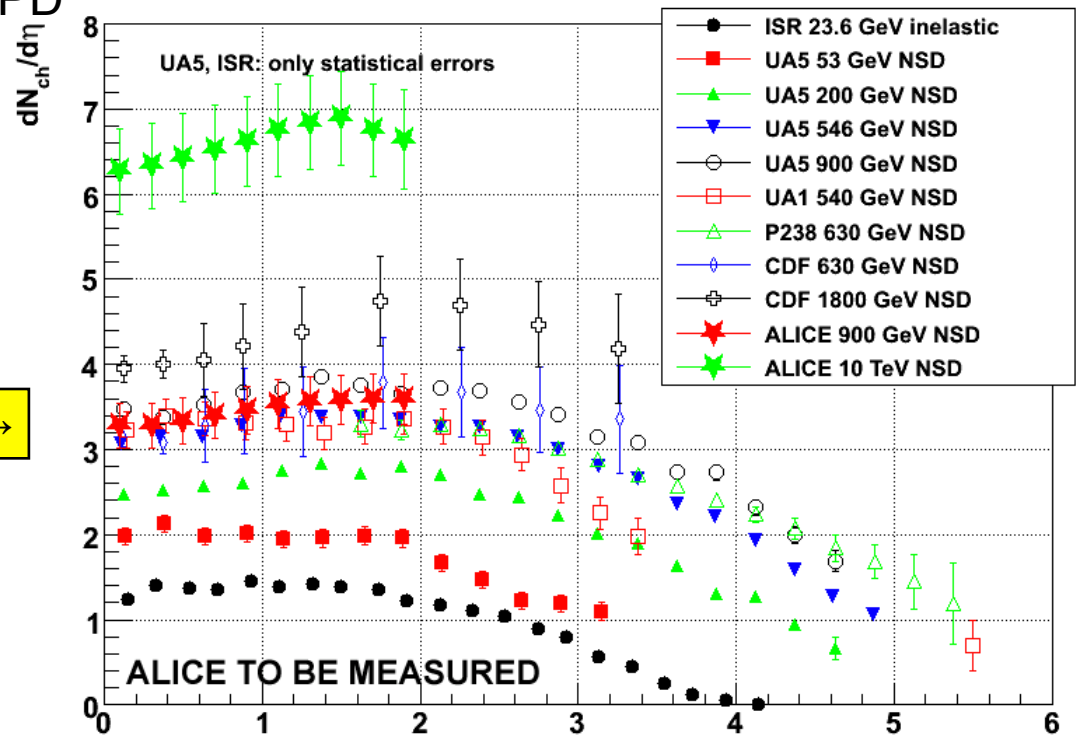

in 1-2 weeks… →

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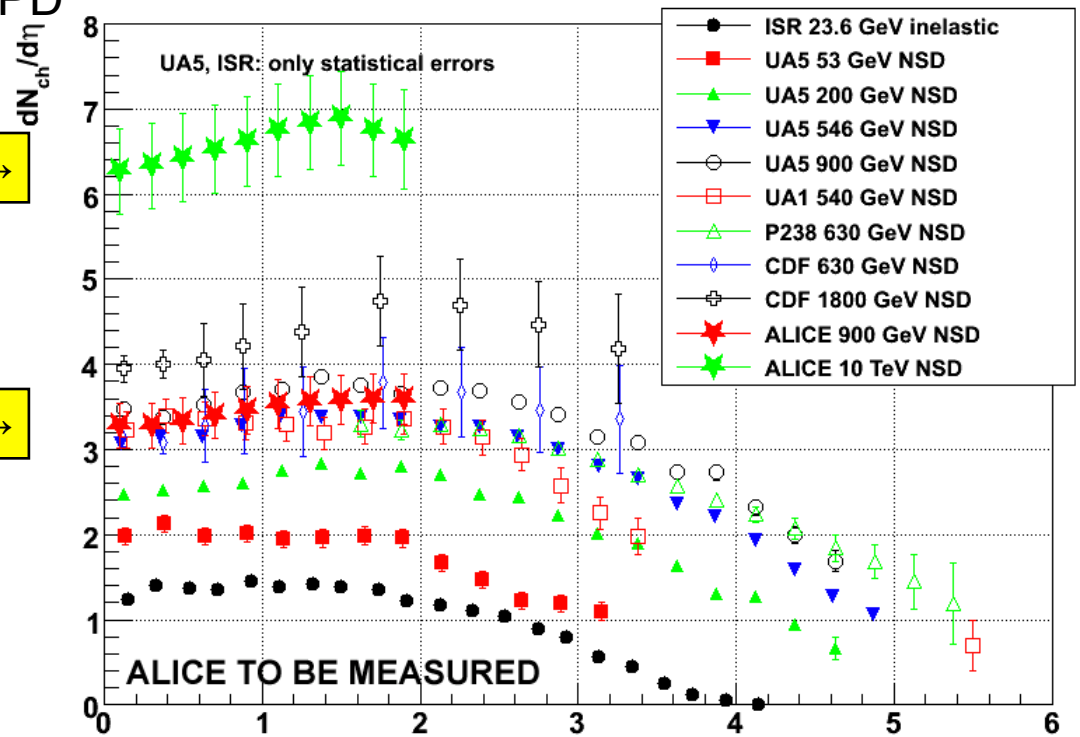
cf: ALICE-INT-2007-005

in 3-9 weeks… →

in 1-2 weeks… →



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Prospects from the PWGs 2→4

Several proposals for “next-to-first” physics analyses: different constraints and strategies

Obviously, depending on data quality and the available stat., items will be addressed differently. Any “proposal” must be submitted to the ALICE Physics Board and defended before being validated:

- PWG2: first envisaged topics
  Baryonic chemical potential and chemical freeze-out temperature (very basic);
  Baryon production Asymmetry (specific to the LHC and ALICE);
  Baryon/meson ratio (difficult to extrapolate with RHIC and TEVATRON data).

- PWG3: many possibilities
  Open charm with displaced vertex: $D^0 \rightarrow K+\pi$;
  J/Psi via di-μ mode and open HF via single μ ;
  $B \rightarrow D \rightarrow e+X$ (single electron).

- PWG4: depending on statistics in the case of min.bias trigger events
  Extension of the $dN(h^+ + h^-)/dpt$ range;
  Inclusif jet spectrum (± underlying event studies) ;
  Photo conversion.

The following slide is currently just proposals and estimates: nothing really validated yet but can be discussed here of course...

PWG2: Analysis proposals and expected publications

PAPER I: First day baryon ratio paper – Protons/Λs	
Study	Ratio of \bar{p}/p and \bar{Λ}/Λ
Statistics	~100K events
Detectors	TPC
PID	• Use the not final calibrated dE/dx (p) • Topological cuts for Λs
Acceptance	$0.5 < p_T < 0.9$ GeV/c $\|y\| < 0.5$
Corrections	Include the corrections that don't cancel out in the ratio

3 to 4 possibilities depending on stat.

PWG2: Analysis proposals and expected publications

PAPER I: First day baryon ratio paper – Protons/Λs	
Study	Ratio of \bar{p}/p and \bar{Λ}/Λ
Stat	
Det	
PID	
Acc	
Cor	

PAPER II: First days identified charged hadron spectra paper	
Study	• Spectra of $p^{\pm}$, $K^{\pm}$ and $\pi^{\pm}$ • Ratio of anti-particle/particle and spectra
Statistics	~200-300K events
Detectors	ITS+TPC+TOF
PID	• Use the close to final calibrated dE/dx (TPC-ITS) and the TOF
Acceptance	$0.5 < p_T < 1$ GeV/c $\|y\| < 1.0$
Corrections	Include the entire set of corrections

3 to 4 possibilities depending on stat.

PWG2: Analysis proposals and expected publications

PAPER I: First day baryon ratio paper – Protons/Λs	
Study	Ratio of \bar{p}/p and \bar{Λ}/Λ

PAPER II: First days identified charged hadron spectra paper	
Study	• Spectra of $p^{\pm}$, $K^{\pm}$ and $\pi^{\pm}$ • Ratio of anti-particle/particle and spectra

PAPER III: First year baryon spectra paper – Protons/Λs	
Study	• Spectra of p , \bar{p}, Λ and \bar{Λ} • Ratio of \bar{p}/p, \bar{Λ}/Λ
Statistics	>1M events
Detectors	ITS+TPC+TOF
PID	• Use the close to final calibrated dE/dx (TPC-ITS) and the TOF • Use topological cuts for Λs
Acceptance	$0.5 < p_T < 5$ GeV/c $\|y\| < 1.0$
Corrections	Include the entire set of corrections

3 to 4 possibilities depending on stat.

PWG2: Analysis proposals and expected publications

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PAPER IV: First year baryon/meson production mechanisms (Λ+Λbar+K^0_s)	
Study	Λ+Λbar + K^0_s spectra and ratio
Statistics	>3M events
Detectors used	TPC+ITS+TOF
PID	Use final dE/dx calibration
Acceptance	K^0_s and Λ: $0.3 < p_T < 8.0$ GeV/c K^0_s and Λ: $\|y\| < 0.75$
Corrections	all corrections and feed-down studies

The LHC story… in 2008...

Scenario anticipated beginning of September

What really happened...

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- ⇨ 10th Sep 15:00: LHC circulated the second beam

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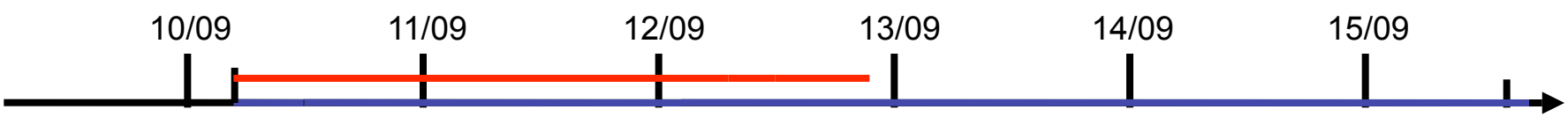

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Serious electrical problem p8.
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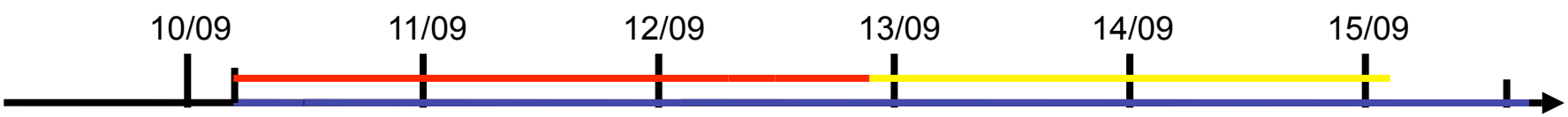

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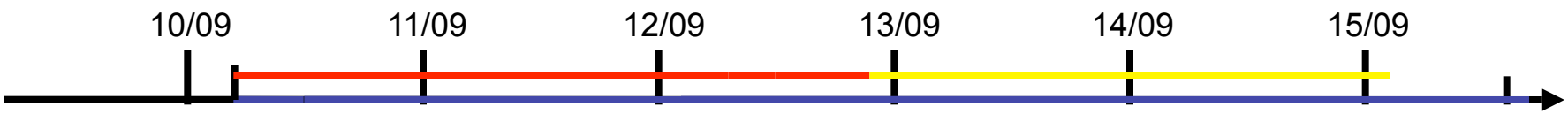
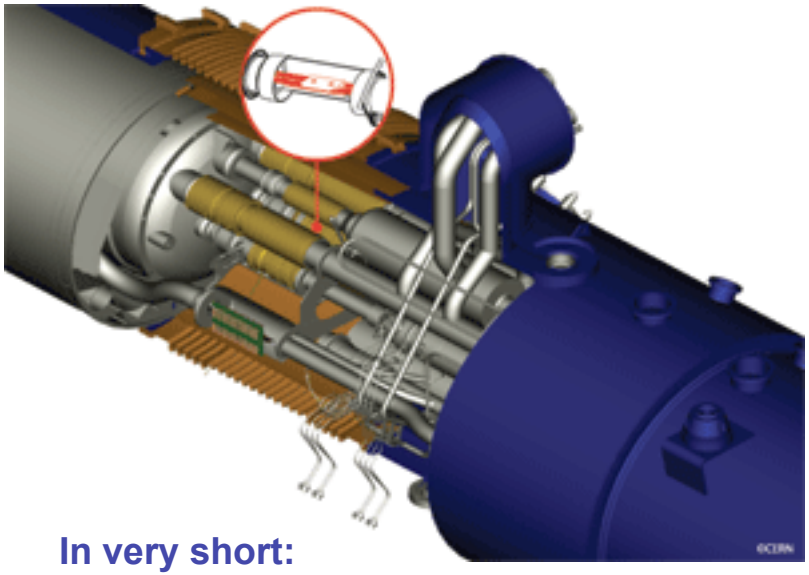
- ⇨ 18th Sep: LHC operations restarted after replacement
- ⇨ 19th Sep 15:00: major incident in sector 3-4...



The LHC status… end 2008 to 2009...



In very short:

- Incident: while ramping up to 10 TeV (dipole current increasing at the rate of 10 A/s), a resistive zone developed and led to a resistive voltage of 1V at 9kA. “Power supply tripped off and the energy discharge switch opened inserted dump resistors in the circuit to produce a fast current decrease”. During the discharge and “within one second, an electrical arc developed, puncturing the helium enclosure and leading to a release of helium into the insulation vacuum of the cryostat”.

- Consequences: the number of magnets to be repaired is at most 5 quadrupoles and 24 dipoles (i.e. ~400 m) of sector 3-4 (9 to 10:30 pm) but 53 magnets, 39 dipoles and 14 “short straight sections” will be removed from the tunnel and inspected. Replacement of all needed magnets before end of march 2009. Interconnection work should be finished end of mai 2009.

Reminder: short term prospects

Scenario for first data taking at 900 GeV

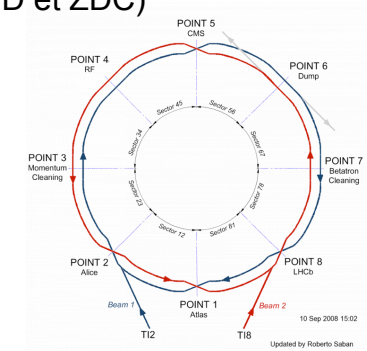
Hopefully during before october !

- 900 GeV: fully part of the LHC commissioning
  First goal for ALICE: “measurement of multiplicity density in pp at 900 GeV”
  Duration of data taking: depends on efficiency / stability of the collider but probably a couple of shifts and hopefully more than last year ;-)

Reminder: 3 h à 10 Hz = 108 K evts

- First runs: acquisition of 10 to 20 K events
  Triggering: bunch-crossing as a start;
  Magnetic field: without then with field (safer for the stability of the LHC);
  Detectors: priority for First Paper analysis (last year: SPD, SSD, TPC, V0, FMD et ZDC)

- Further runs: acquisition of as many events as possible
  Triggering: minimum bias interaction trigger;
  Magnetic field: with nominal field;
  Detectors: as many as possible (if ready and decent dead time).



Comments

- Reconstruction: the first events corresponding to one beam circulating last year were reconstructed with standard AliRoot (v4-15-Rev-01): 58334, 58338, 58343, 58376, 58378 in less than 24 hours. Transfered to Cern Analysis Facility 12 hours later.

- LHC Phase A (2008): 43 bunches per beam with an intensity of 2×10^9 protons per bunch. Normal time (2008) between first beam circulating and first collisions: 9 days then 2 days of data taking with solenoids up and running.

Summary and Conclusion

First physics in the soft region will be exciting at the LHC

- most measurements will complement the RHIC ones;
- many will help understanding further particle production and defining the bulk properties of the created matter.

Many LHC experiments have a soft physics program

- in p+p, there is a lot of physics at low p_T to investigate and not only as a Pb+Pb reference !
- I hope that many of you will participate to the LHC studies...
- cool if my slides lead to many discussions.