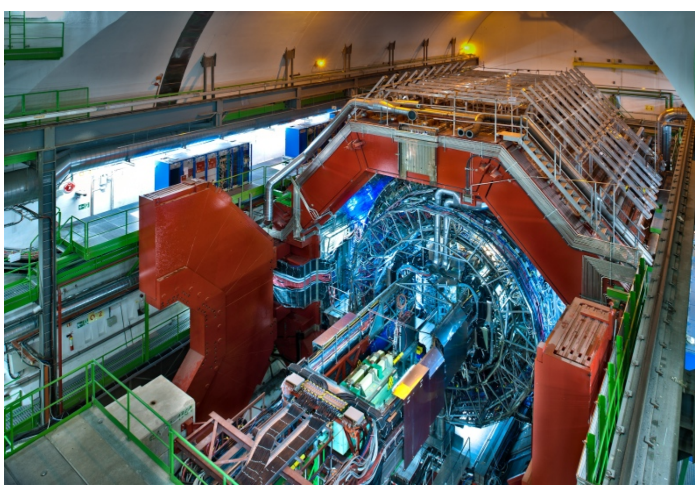
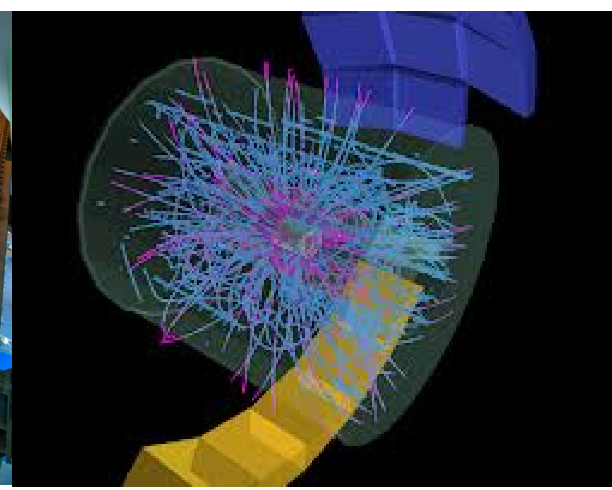
ALICE status report

Constantin Loizides (LBNL/EMMI)
on behalf of the ALICE collaboration

116th LHCC meeting
04 Dec 2013

Outline:
New physics results
LS1 activities
Upgrade plans for LS2


Recently submitted papers

- Measurement of charged jet suppression in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
  - arXiv:1311.0633 (submitted to JHEP)

- Centrality, rapidity and transverse momentum dependence of J/ψ suppression in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
  - arXiv:1311.0214 (submitted to PLB)

- Two- and three-pion quantum statistics correlations in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
  - arXiv:1310.7808 (submitted to PRC)

Recently published papers

1) K^0_s and Λ production in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV,
   PRL 111 (2013) 222301
2) Centrality dependence of the pseudorapidity density distribution for charged particles in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV, PLB 726 (2013) 610
3) Charmonium and e^+e^- pair photoproduction at mid-rapidity in ultraperipheral Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV, EPJC 73 (2013) 2617
4) Multiplicity dependence of the average transverse momentum in pp, p-Pb and Pb-Pb collisions at the LHC, PLB 727 (2013) 371
5) J/ψ elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV,
   PRL 111 (2013) 162301
6) Centrality determination of Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV with ALICE, PRC 88 (2013) 044909
7) Centrality dependence of π,K,p production in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV, PRC 88 (2013) 044910
8) Long range angular correlations of π,K,p in p-Pb collisions at $\sqrt{s_{NN}}$=5.02 TeV, PLB 726 (2013) 164
9) Performance of the ALICE VZERO system, JINST 8 (2013) 1001
10) ... plus 4 more accepted

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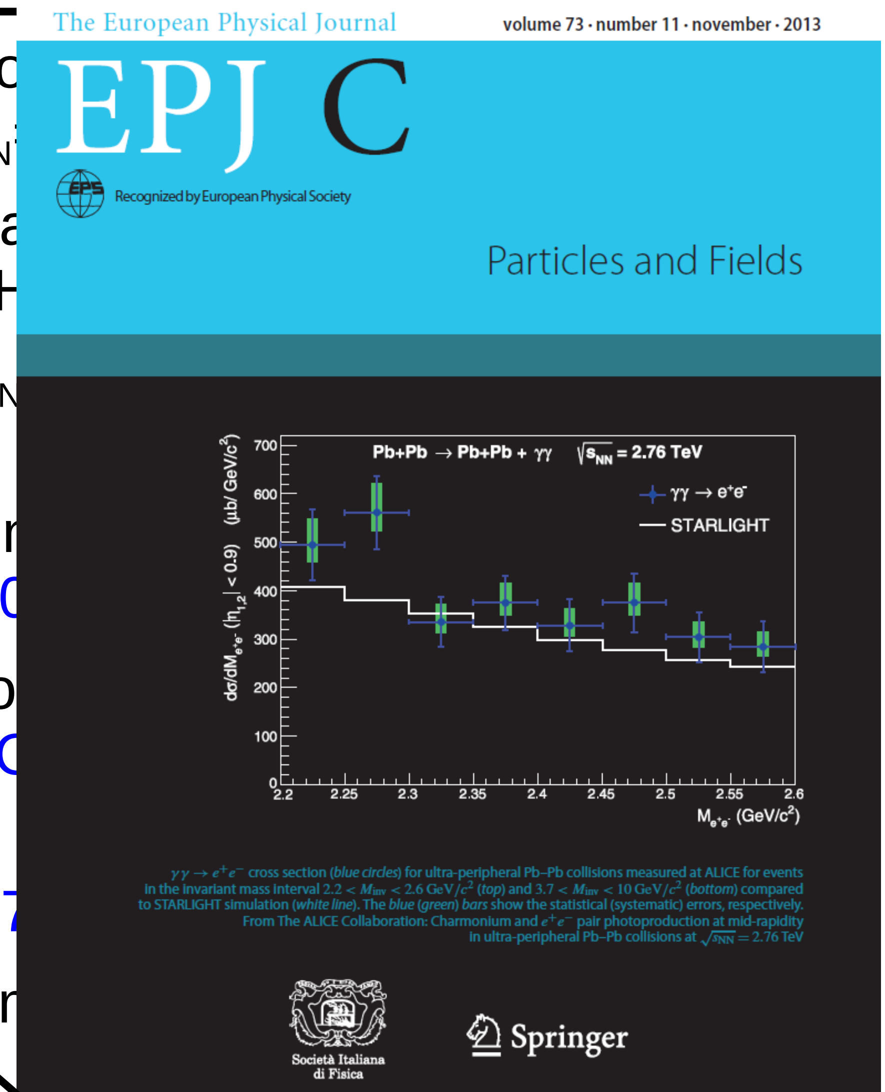


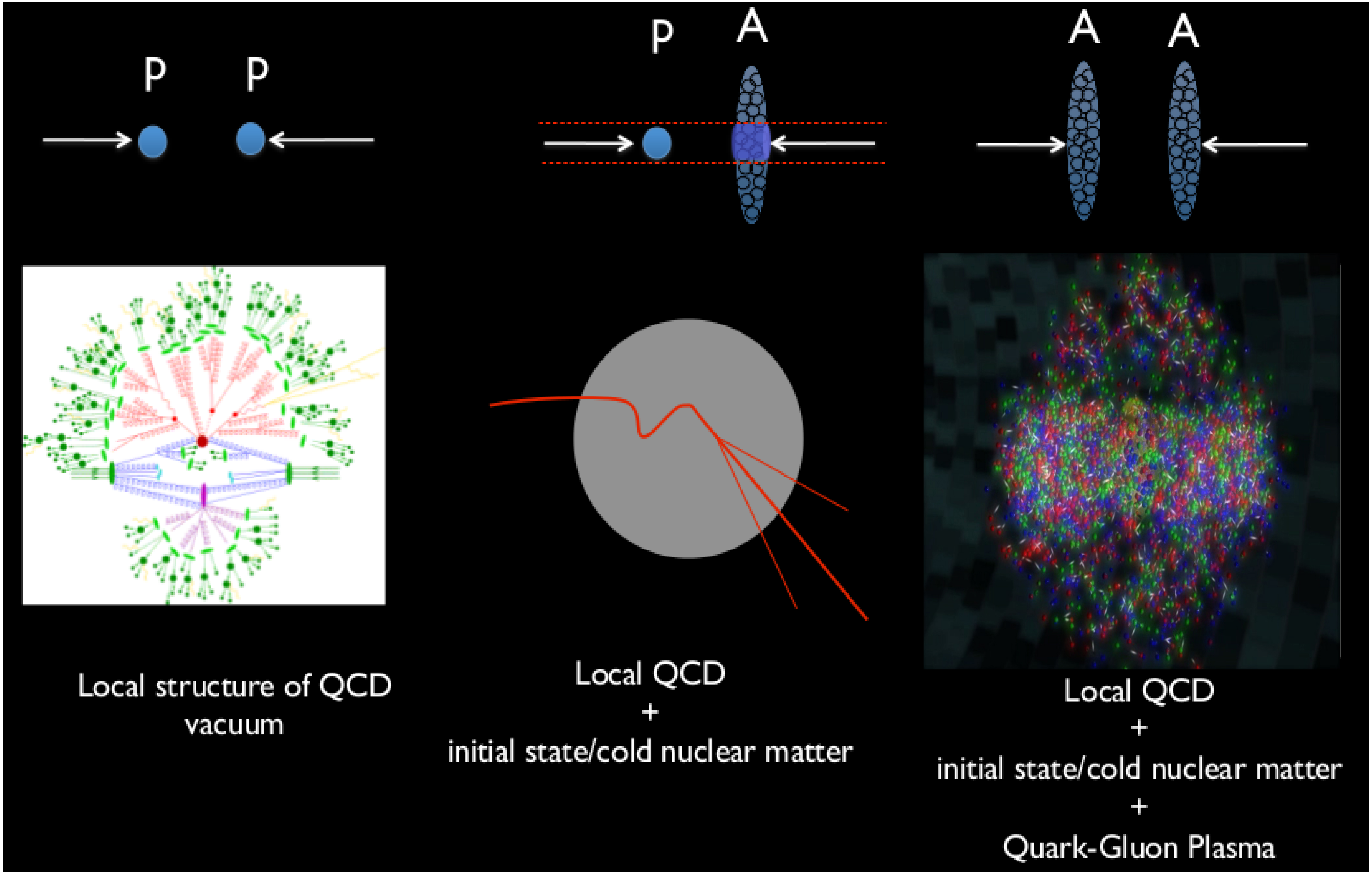
New preliminary results

1) K* in pp at 2.76 TeV (*)
2) D-meson-hadron angular correlations in pp at 7 TeV (*)
3) v2{SP, $|\Delta\eta>0.8|$} for π,k,p in pp at 7 TeV (*)
4) D-meson rapidity distributions in p-Pb (*)
5) HFE-hadron angular correlations in p-Pb
6) π,K,p at high pT in p-Pb
7) Two-particle angular correlation (mini-jets analysis) in p-Pb
8) Balance function in p-Pb
9) $J/\psi\rightarrow\mu\mu$ (forward) vs pT and <pT> of $J/\psi\rightarrow\mu\mu$ (forward) vs multiplicity (*)
10) $J/\psi(2S)\rightarrow\mu\mu$ (forward) in p-Pb
11) $J/\psi\rightarrow ee$ in p-Pb and $J/\psi\rightarrow ee$ vs pT in Pb-Pb
12) $\Phi\rightarrow\mu\mu$ in p-Pb (*)
13) Dijet kT in p-Pb
14) Exclusive J/ψ photoproduction in ultraperipheral p-Pb
15) Azimuthal sensitive HBT in Pb-Pb
16) Hadron-jet coincidence measurements in Pb-Pb

(*) not discussed in the talk

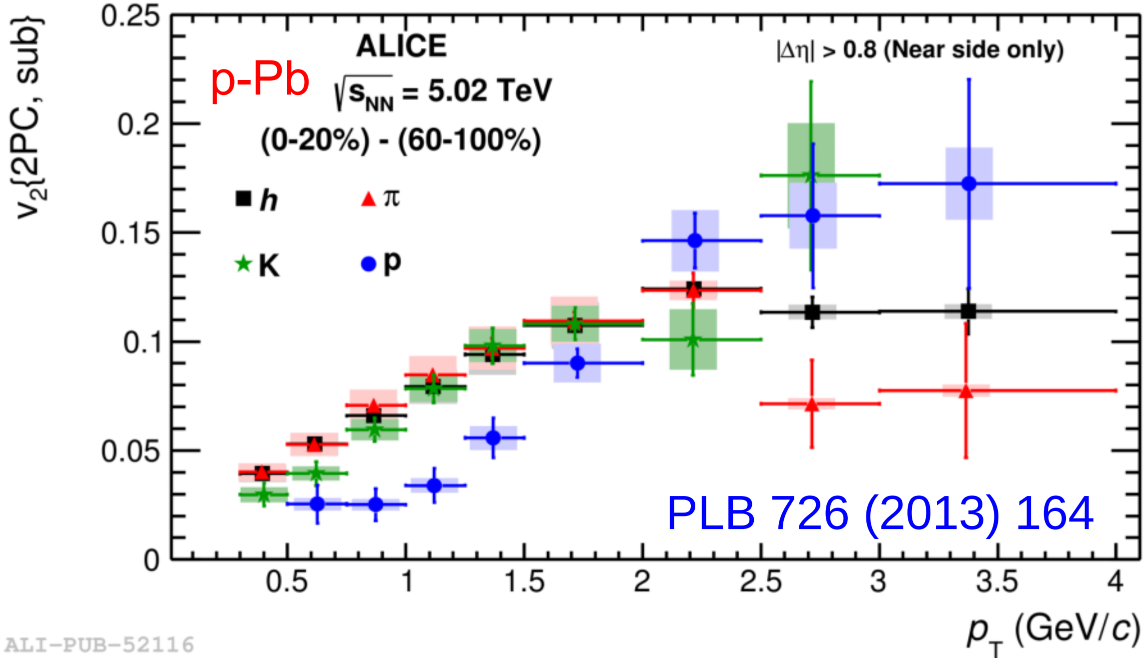
New physics results

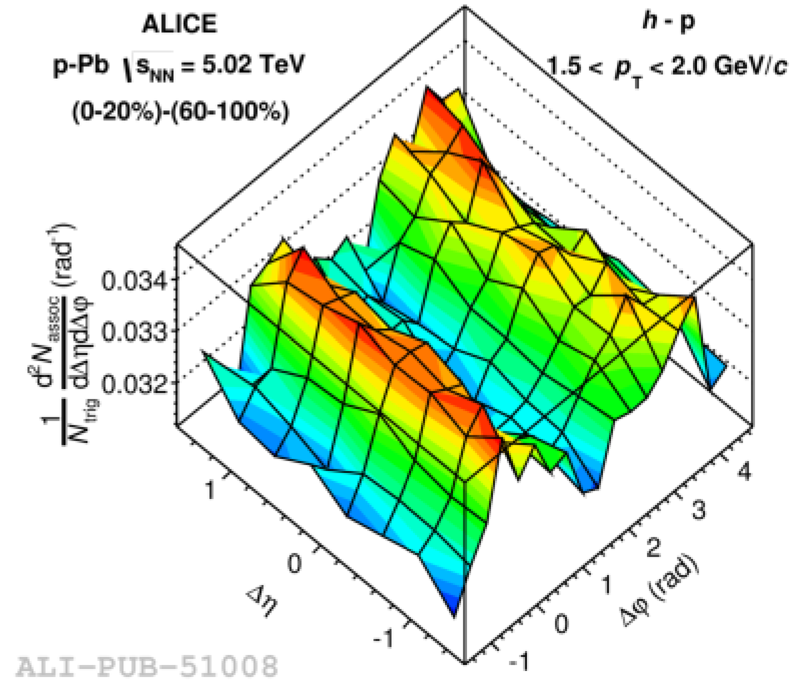
Reminder

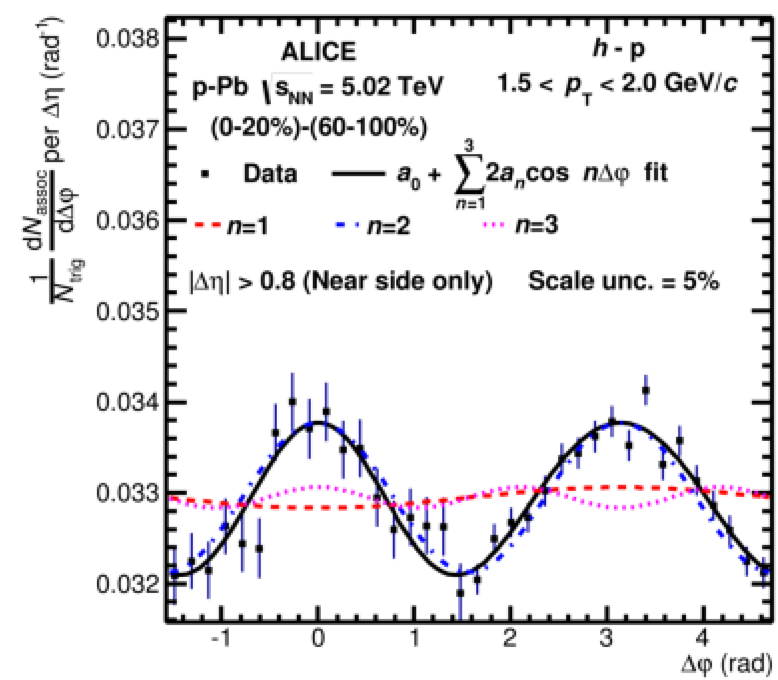

p
p
p
A
A
A
Local structure of QCD
vacuum
Local QCD
+
initial state/cold nuclear matter
Local QCD
+
initial state/cold nuclear matter
+
Quark-Gluon Plasma

Bulk observables in p-Pb

Identified particle ridge v_2 and spectra



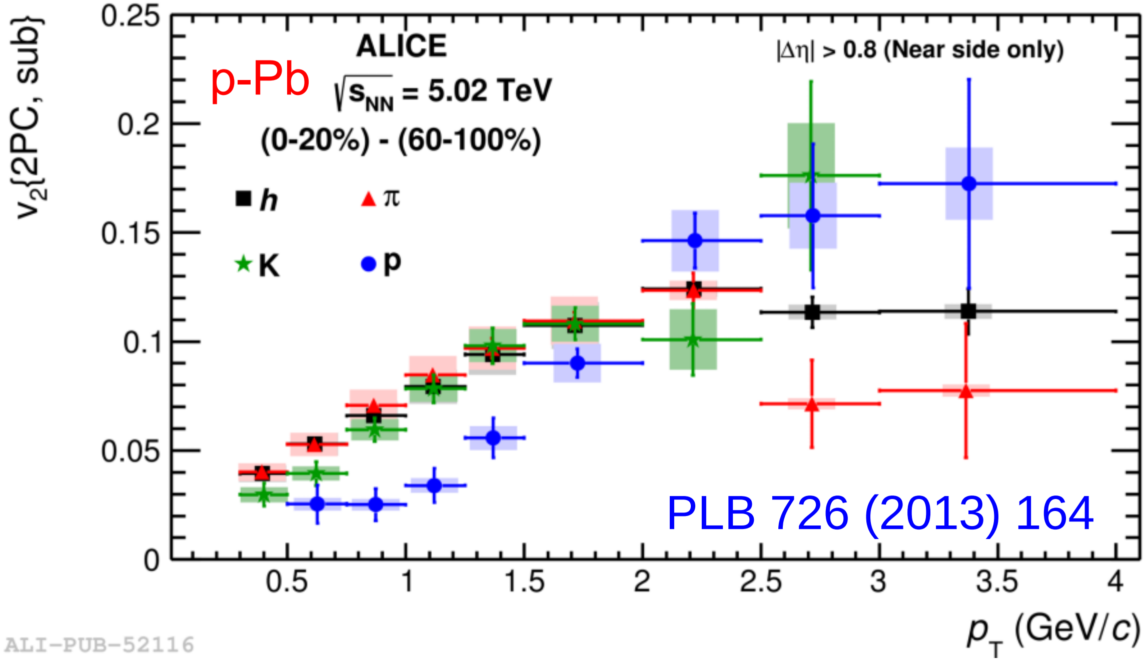




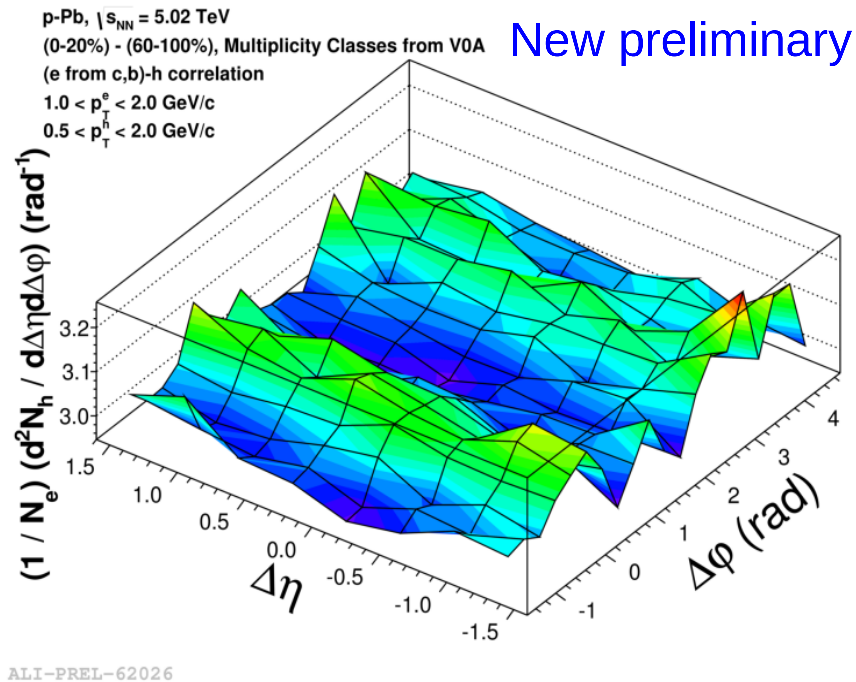
- Double ridge in high-multiplicity p-Pb
  - Particle type dependent v_2 vs p_T

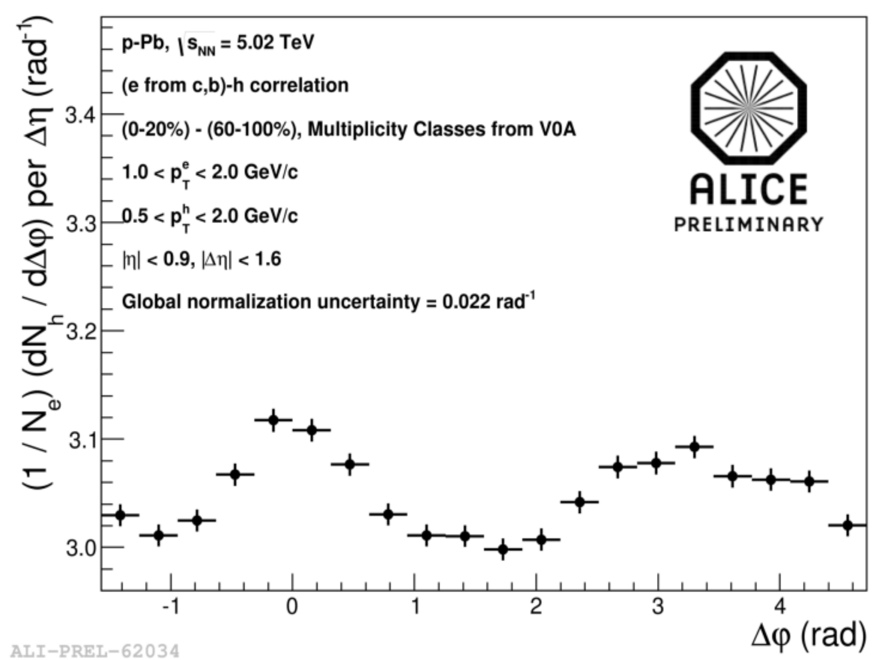
$$v_n^i\{2PC\} = V_{n\Delta}^{h-i} / \sqrt{V_{n\Delta}^{h-h}} \text{ with } V_{n\Delta}^{h-i}\{2PC\} = a_n^{h-i} / a_0^{h-i}$$

Identified particle ridge v_2 and spectra



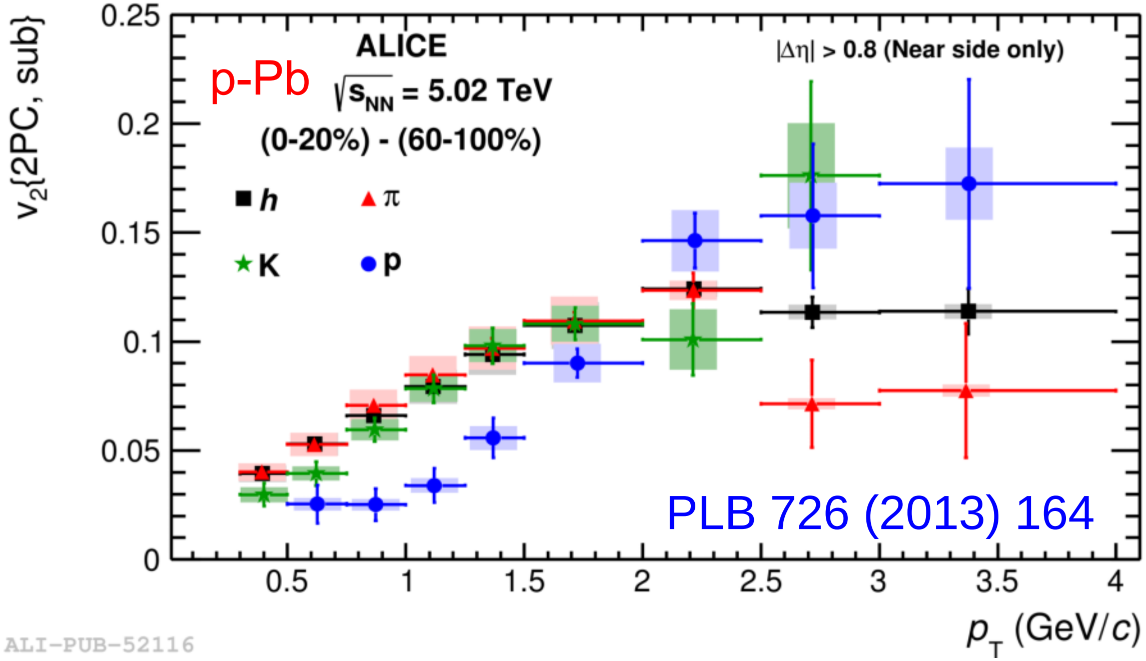
New preliminary

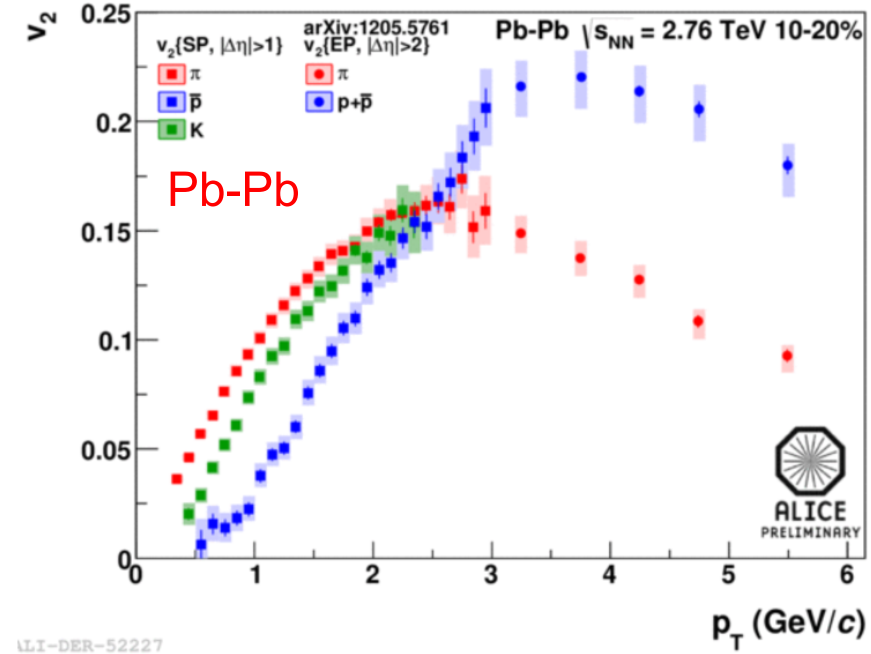




- Double ridge in high-multiplicity p-Pb
  - Particle type dependent v_2 vs p_T
  - Similar effect also for HF electrons
    - Suggestive of same origin

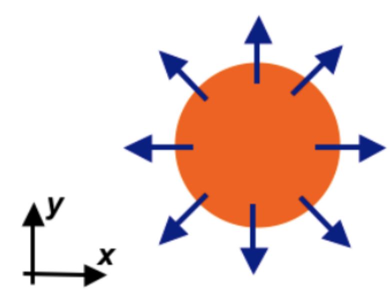
Identified particle ridge v_2 and spectra





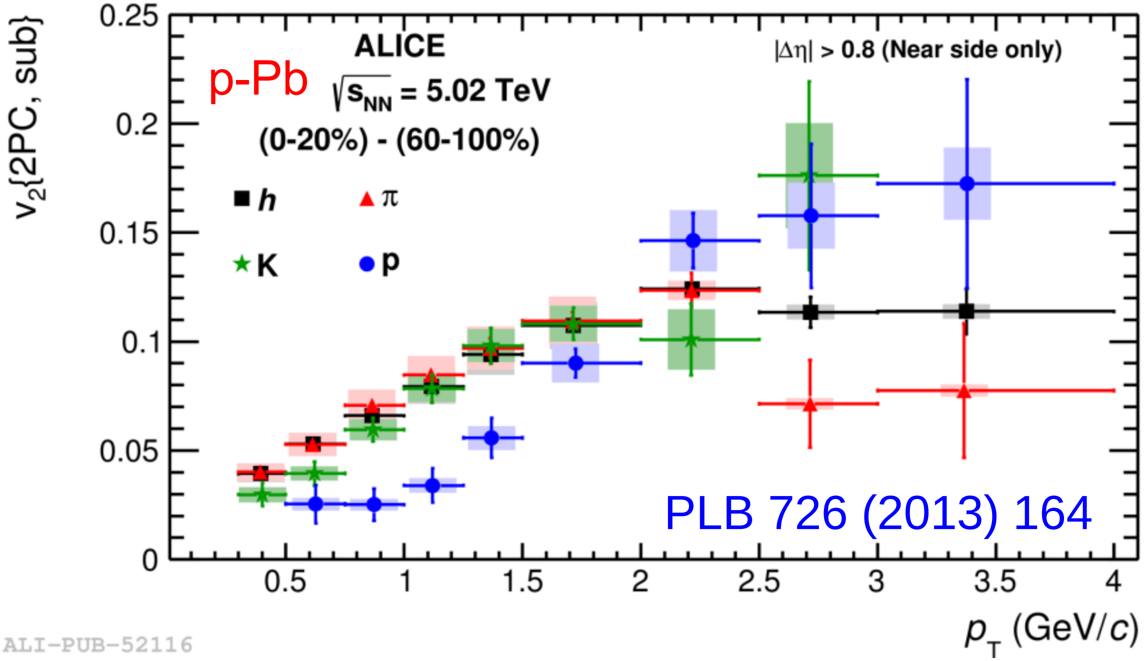
- Double ridge in high-multiplicity p-Pb
  - Particle type dependent v_2 vs p_T
  - Characteristic mass splitting and similar p-π crossing as in Pb-Pb
    - In hydro-dynamical models, suggestive of radial flow

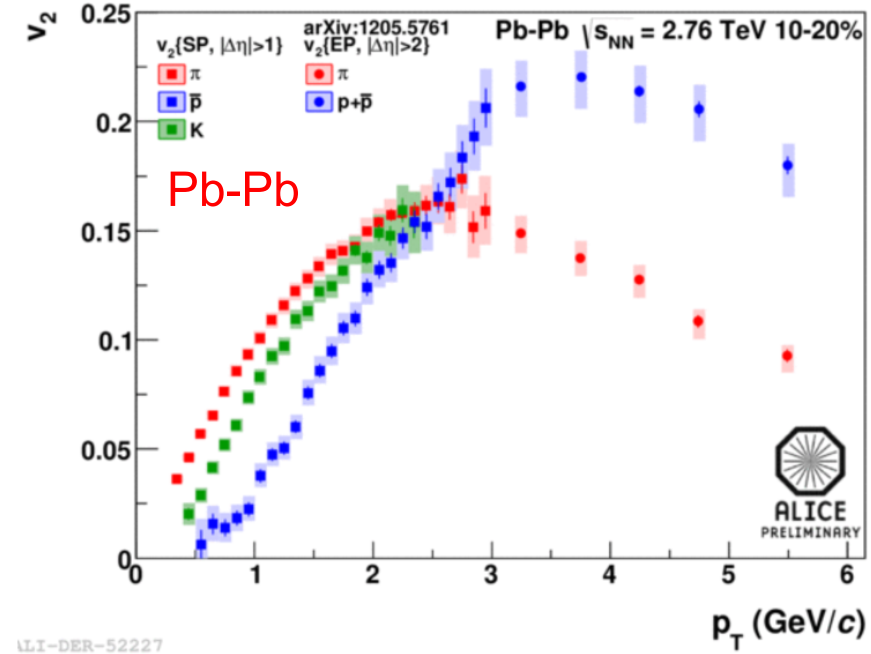
Radial flow



$$p_T^{flow} = p_T + m \beta_T^{flow} \gamma_T^{flow}$$

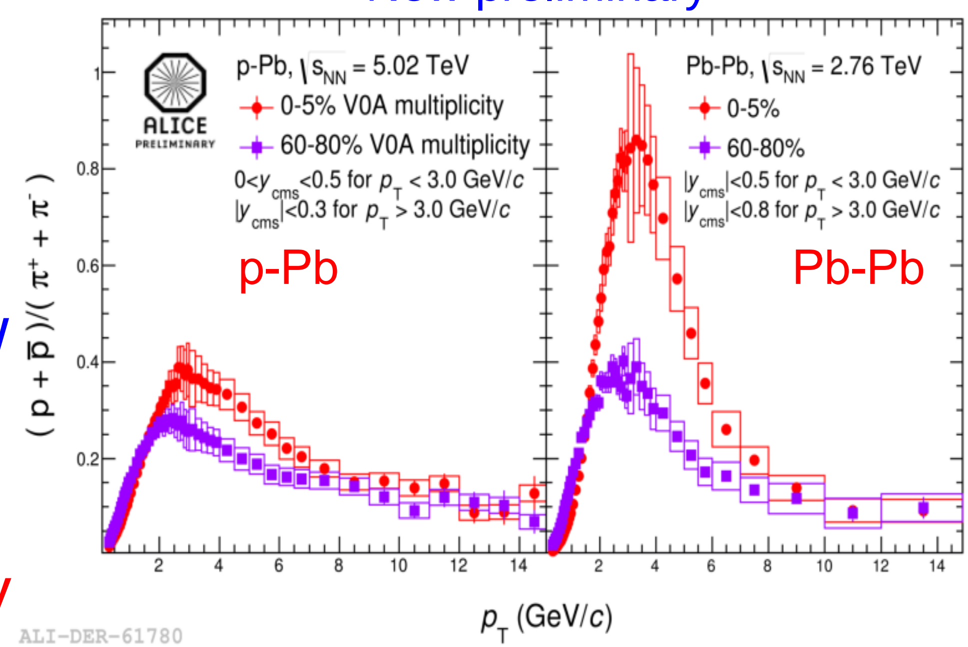
Identified particle ridge v_2 and spectra





- Double ridge in high-multiplicity p-Pb
  - Particle type dependent v_2 vs p_T
  - Characteristic mass splitting and similar p-π crossing as in Pb-Pb
    - In hydro, suggestive of radial flow
- Spectra similar features as in Pb-Pb
  - Consistent with radial flow picture
  - In pp, also modeled microscopically

New preliminary



Minijet analysis in p-Pb

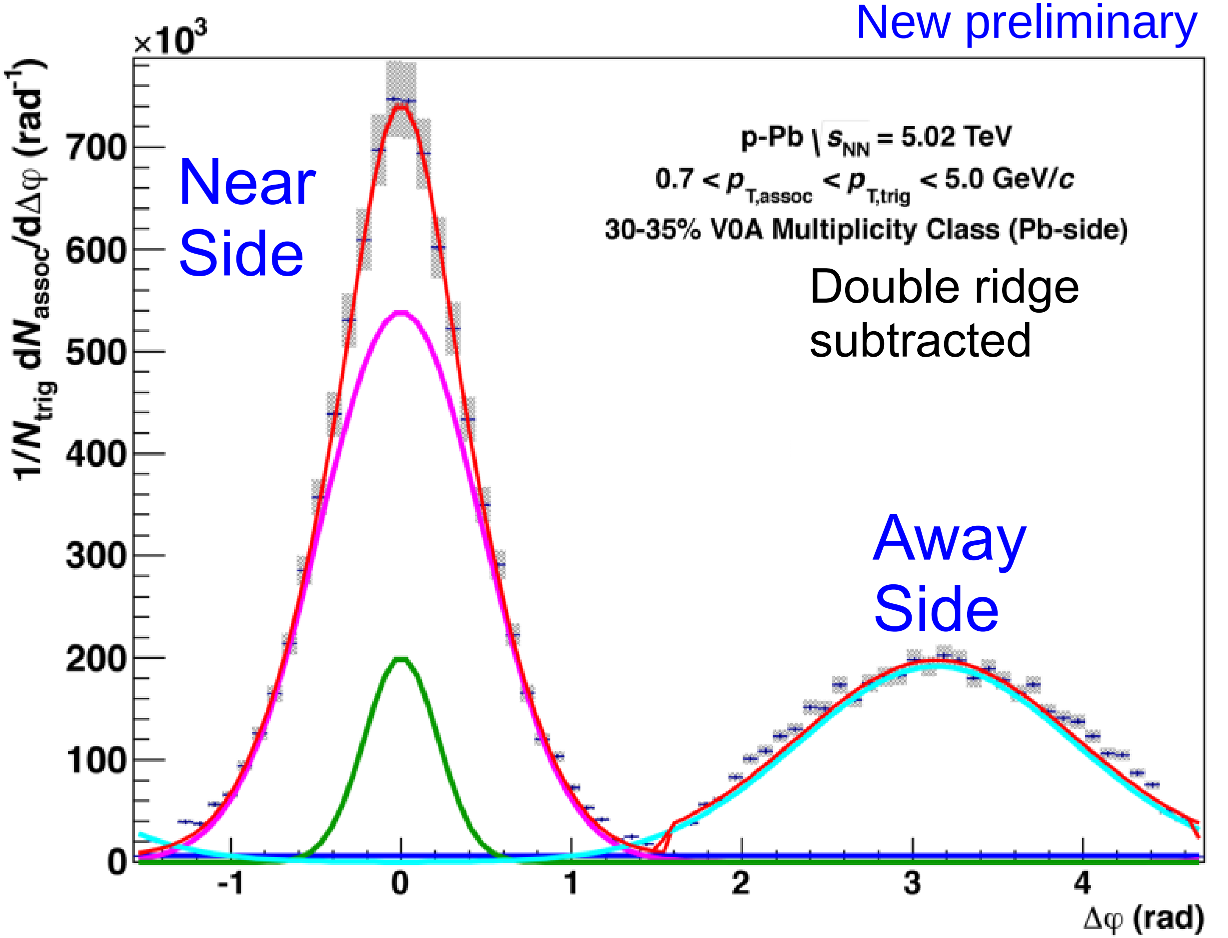
- Two-particle angular correlationsat low p_T
  - Statistically study mini-jet production
  - p_T > 0.7 GeV/c ($>>\Lambda_{QCD}$ to be insensitive to string breaking)
- Analysis similar to pp (ALICE, JHEP 1309 (2013) 049) except from subtraction of double ridge
- Obtain yields as

$$< N_{\mathrm{trigger}} >= \frac{N_{\mathrm{trigger}}}{N_{\mathrm{events}}}$$

$$< N_{\mathrm{assoc,nearside}} >= \frac{\sqrt{2\pi}}{N_{\mathrm{trigger}}}(A_1 \cdot \sigma_1 + A_2 \cdot \sigma_2)$$

$$< N_{\mathrm{assoc,awayside}} >= \frac{\sqrt{2\pi}}{N_{\mathrm{trigger}}}(A_3 \cdot \sigma_3)$$

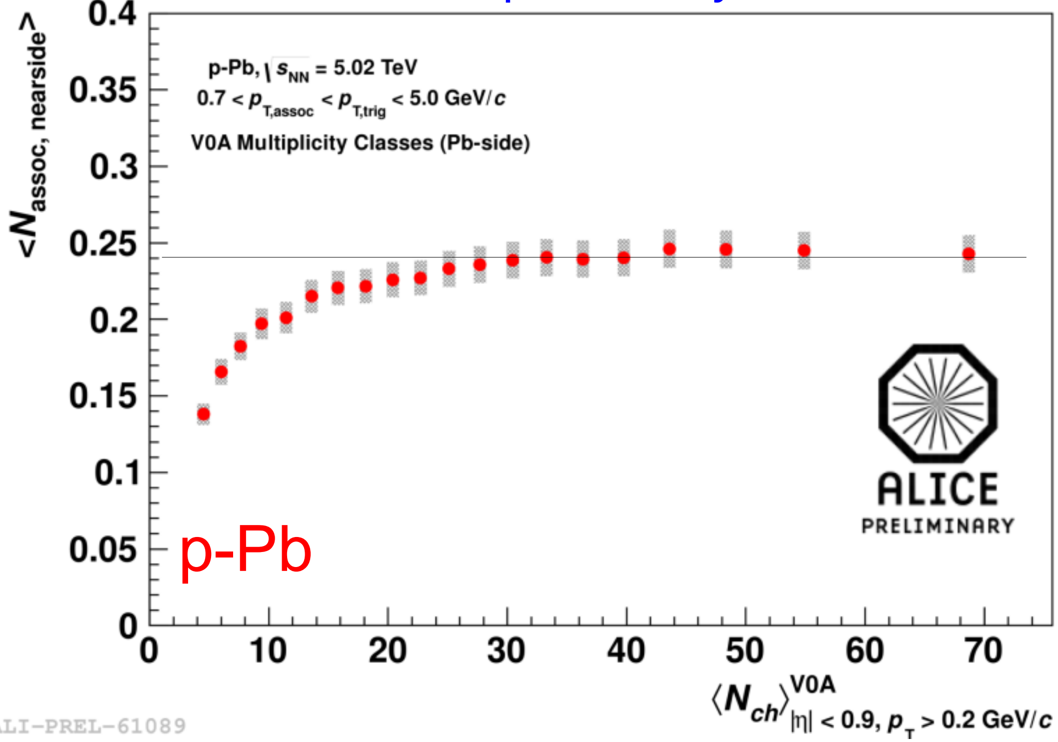
New preliminary



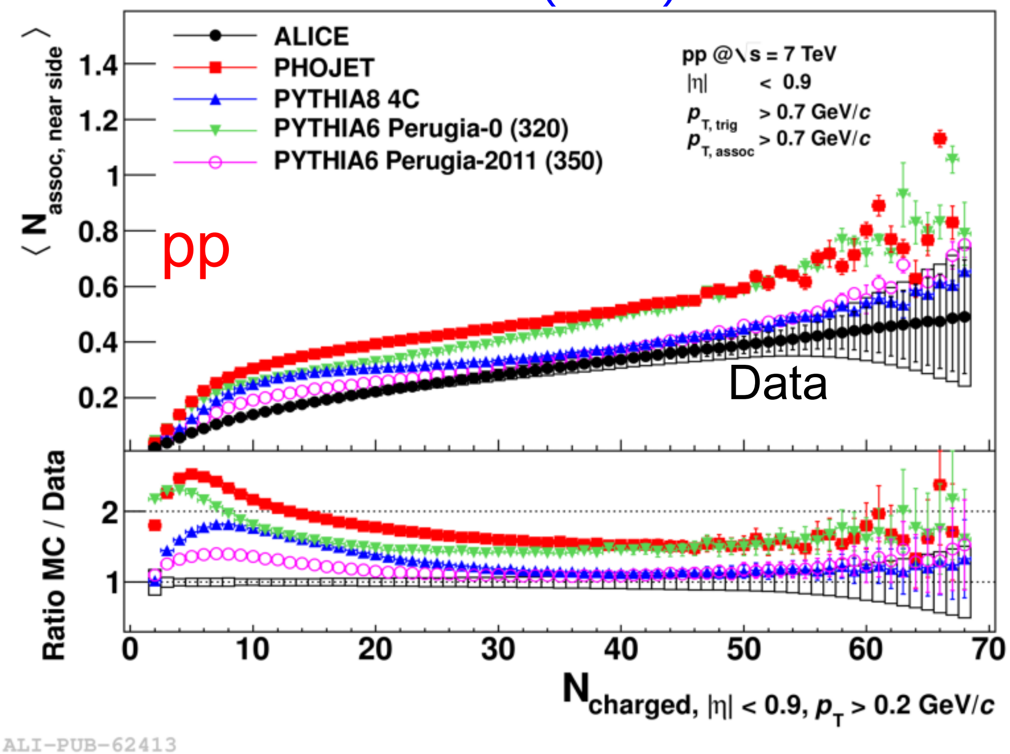
Yields extracted by bin-counting after ZYAM and ridge removal or from Gaussian fits as illustrated

Minijet near-side yield

New preliminary



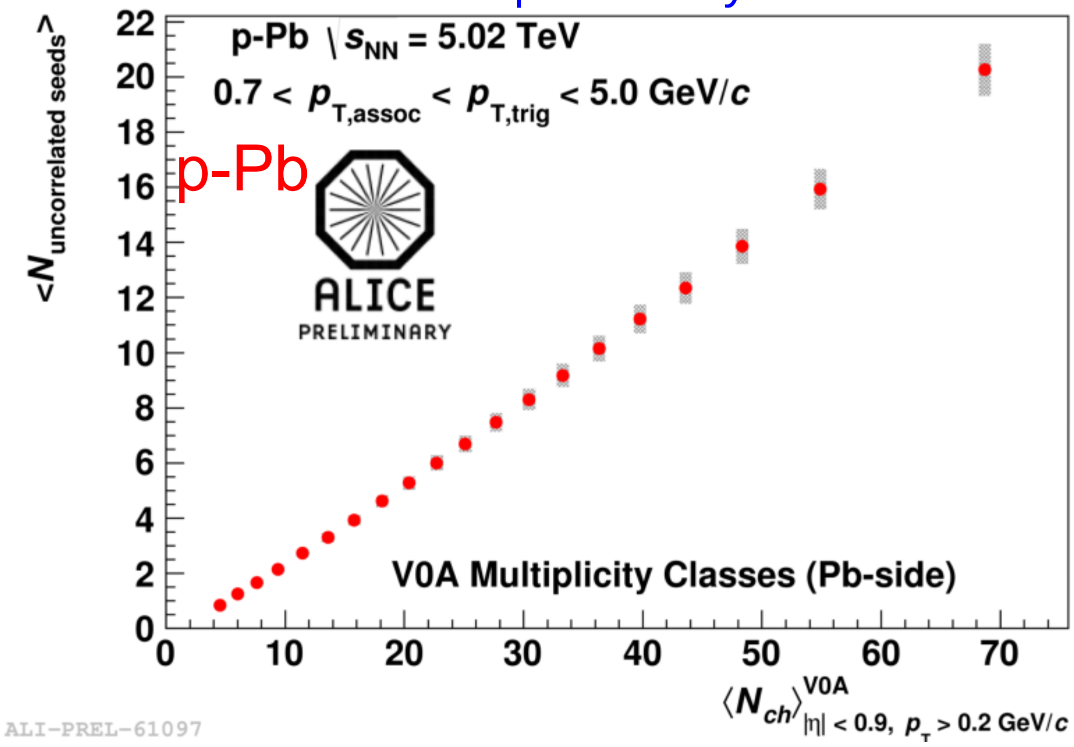
JHEP 1309 (2013) 049



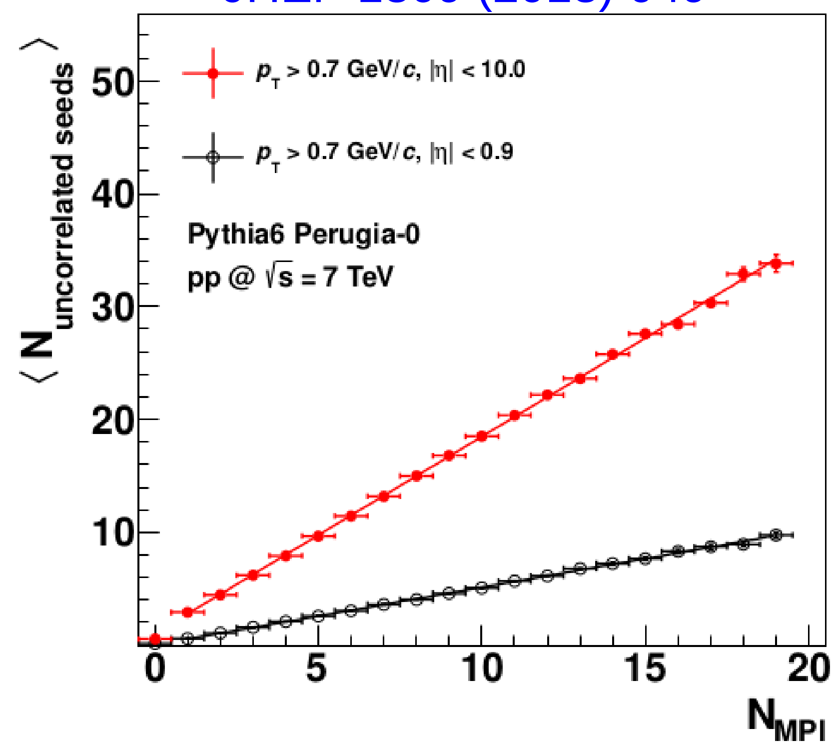
- In p-Pb, high multiplicity events are not characterized by a higher number of associated particles in jet peak
  - No bias on the near-side per trigger yield, except at low multiplicities to softer than average collisions
  - Caveat: Different event selection than in pp
- Similar findings for away-side (not shown)

Minijet uncorrelated seeds

New preliminary



JHEP 1309 (2013) 049

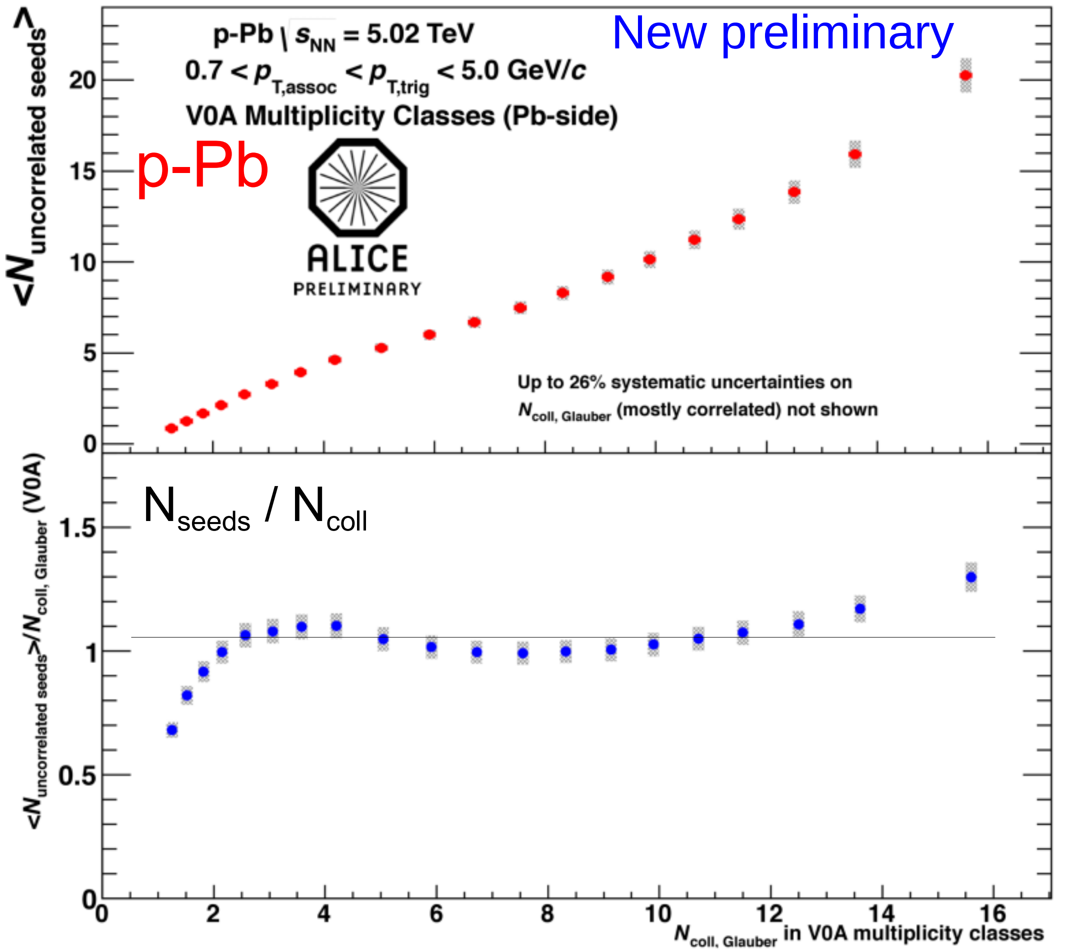


Define number of uncorrelated seeds:

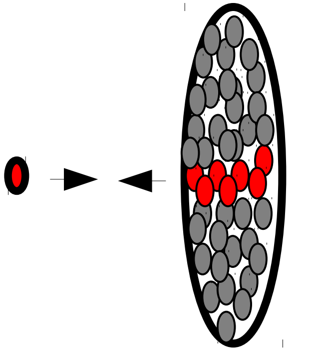
$$< N_{\text{uncorrelated seeds}} >= \frac{< N_{\text{trigger}} >}{< N_{\text{trigger correlated}} >} = \frac{< N_{\text{trigger}} >}{< 1 + N_{\text{assoc,near+away}} >}$$

- In p-Pb, the number of uncorrelated seeds scales with V0A multiplicity
- In Pythia, the number of uncorrelated seeds scale with number of MPI

Minijet uncorrelated seeds



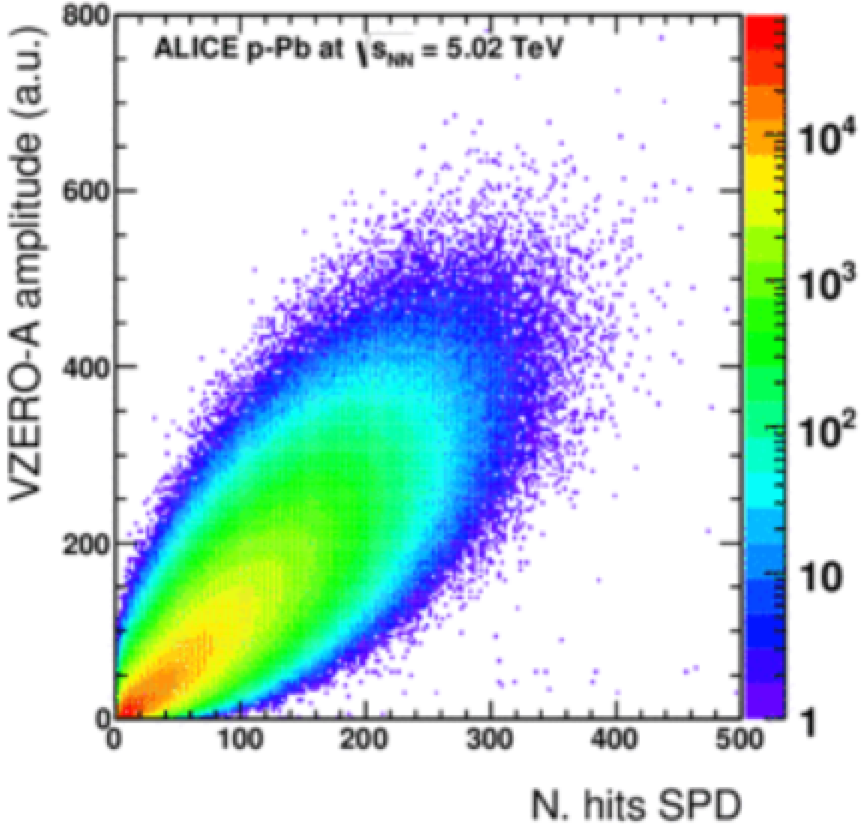
Number of collisions (N_{coll})



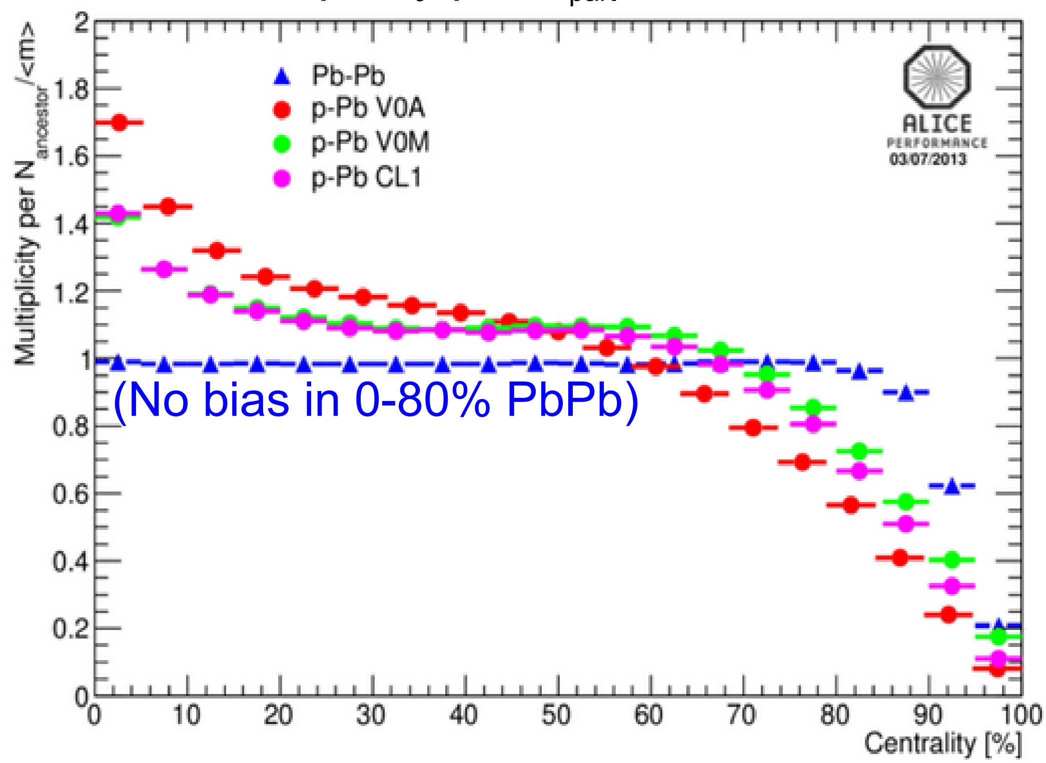
Number of collisions
(from Glauber model)

- In p-Pb, the number of uncorrelated seeds scales with V0A multiplicity
- In Pythia, the number of uncorrelated seeds scale with number of MPI
- Uncorrelated seeds do not scale with N_{coll} for low and high multiplicity
  - Consequences for centrality estimation in p-Pb

Centrality in p-Pb



Multiplicity per N_{part} / Mean NBD



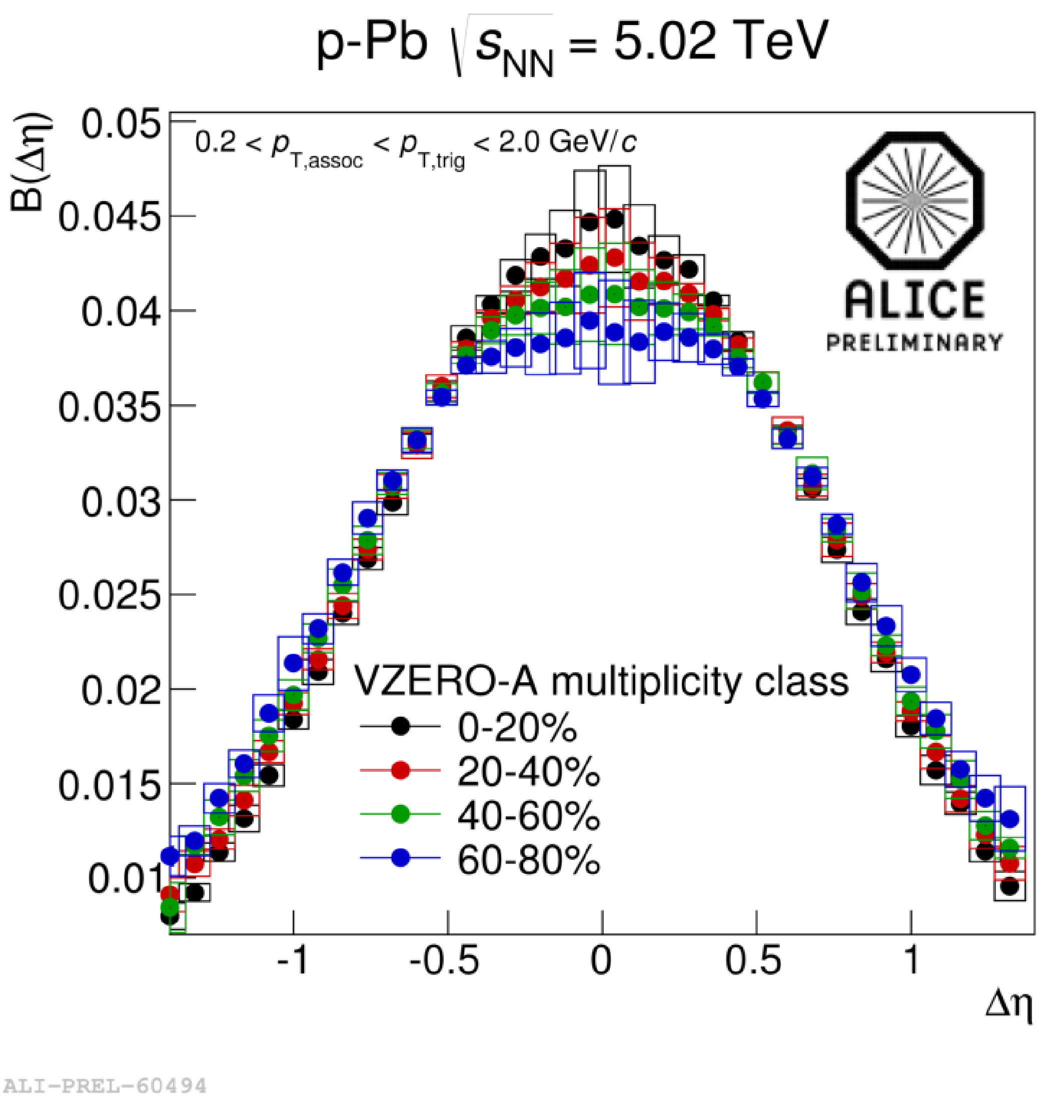
- Multiplicity fluctuations induce sizeable bias on Mult/Ncoll
- Additional for peripheral collisions
  - Mean impact parameter in NN collisions increases
  - Jet veto by cutting into the NN cross section

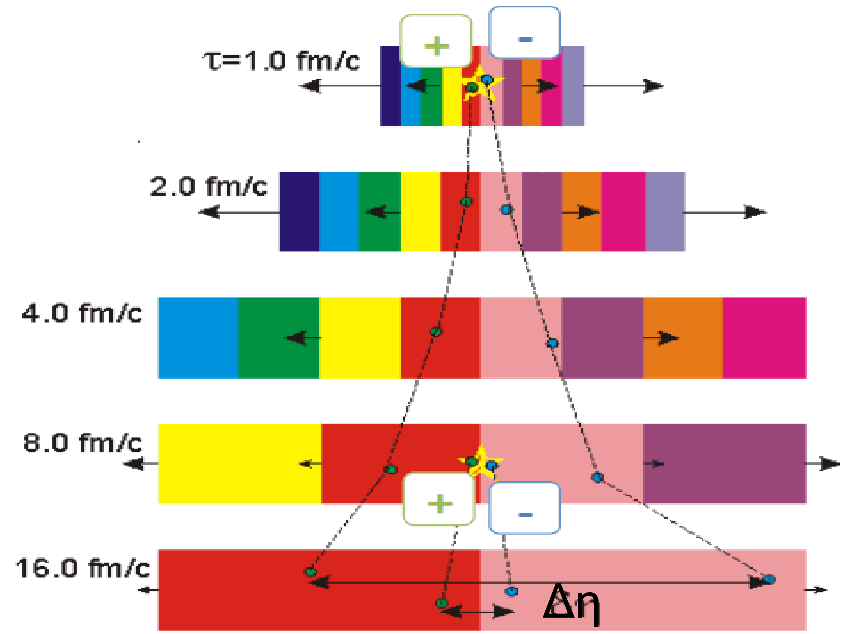
For a given centrality, hard processes expect to scale as

$$\langle N^{Glauber}_{coll,\,cent} \rangle \langle n_{hard} \rangle_{cent} / \langle n_{hard} \rangle_{pp}$$

Ongoing discussions between experiments and theorists

Charge correlations using balance function





- Study system evolution by tracing charge separation in Δη (and Δφ)

$$BF(\Delta\eta)=\frac{1}{2}\left(C_{US}(\Delta\eta)-C_{LS}(\Delta\eta)\right)$$

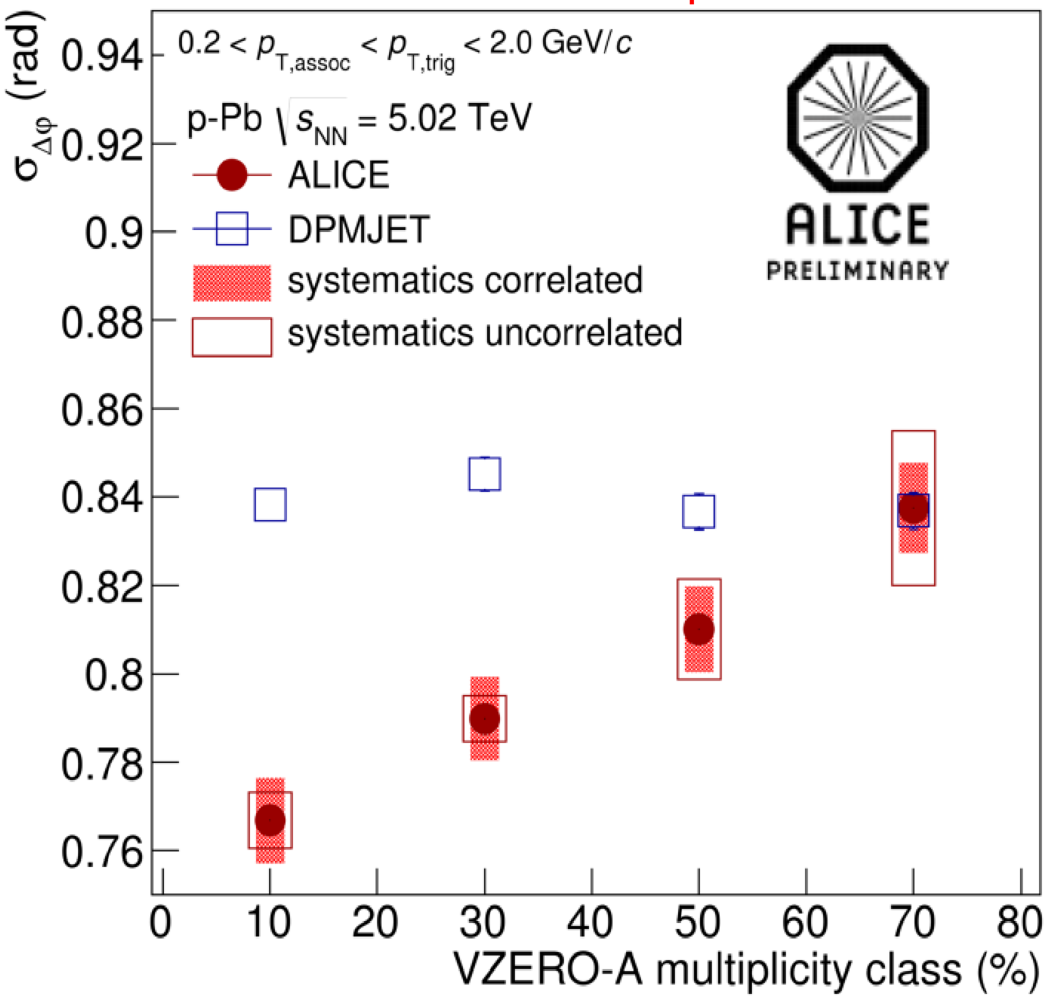
- Width depends on creation time and degree of collectivity

Distribution is narrowing with increasing multiplicity

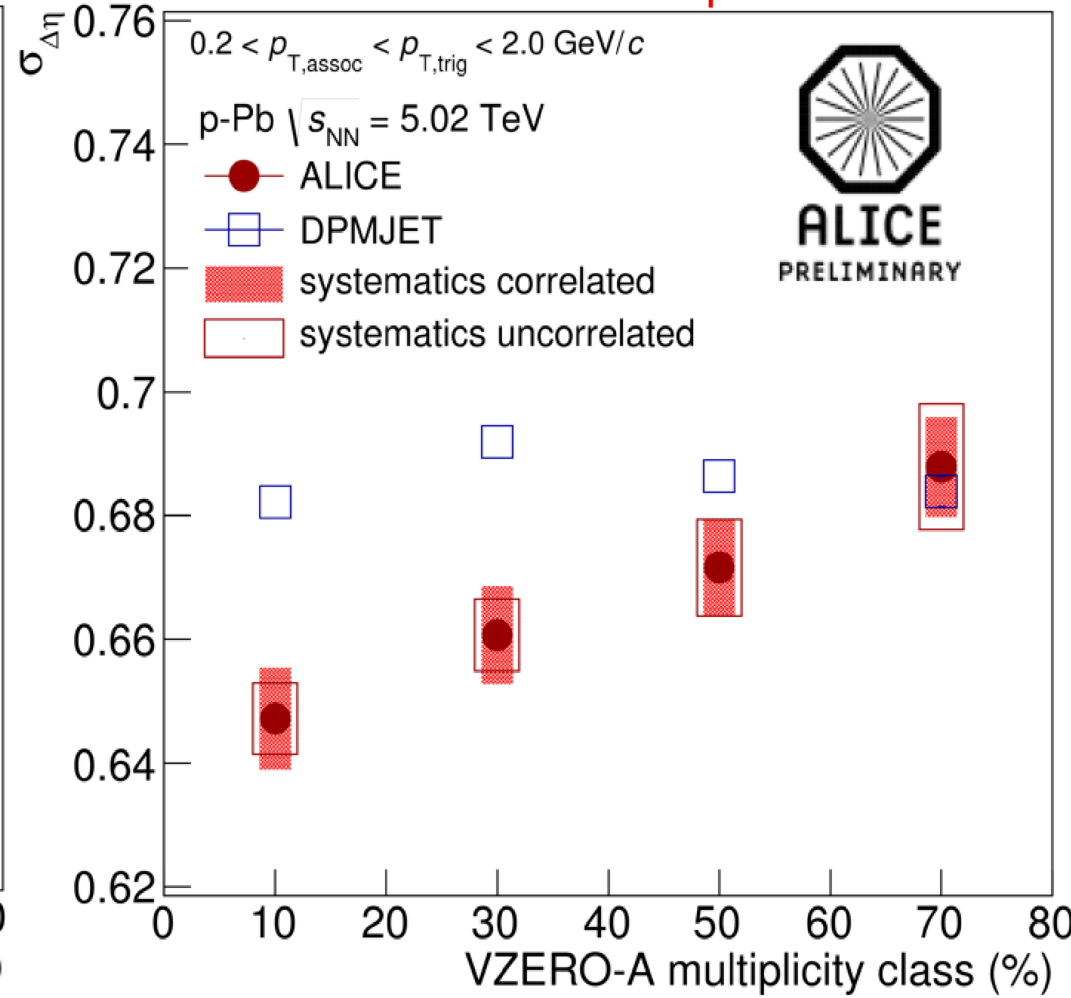
Charge correlations using balance function

New preliminary

Width in Δφ



Width in Δη

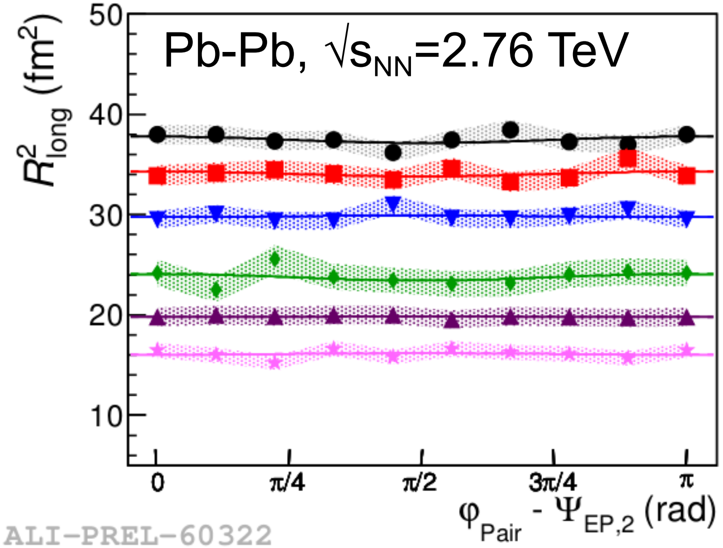


At low p_T, width decreases for increasing multiplicity (while no dependence was found at high p_T). Trend similar to Pb-Pb.

Bulk observables in Pb-Pb

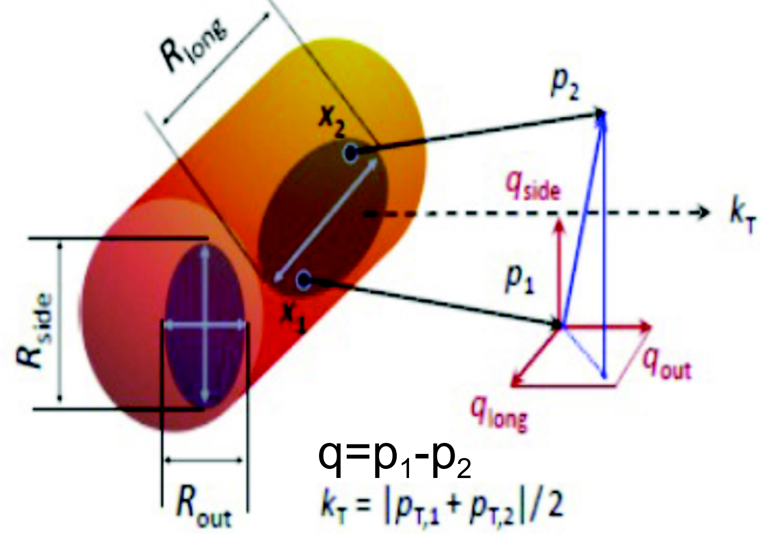
Azimuthally sensitive pion femtoscopy

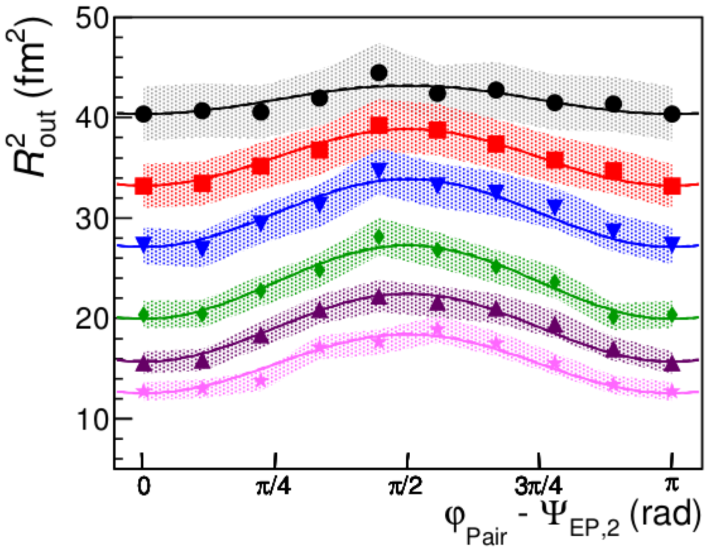
New preliminary

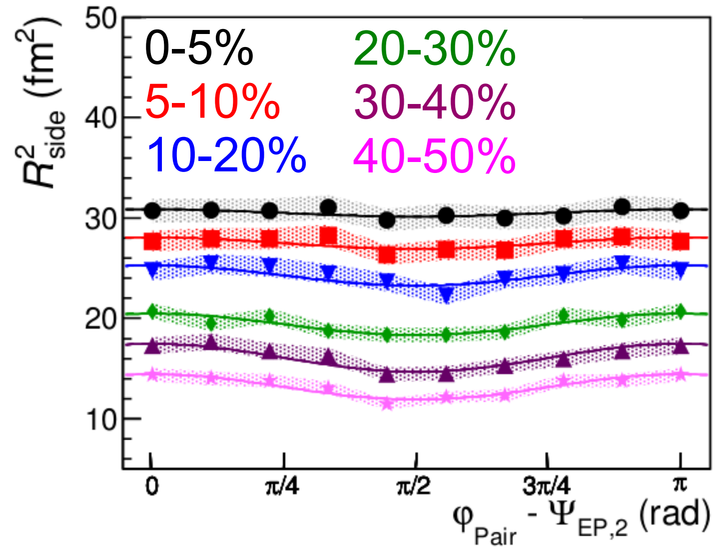


Local co-moving system (LCMS)

Δφ=0
Rside large
Rout small







Expected dependence of 3D radii in LCMS relative to event plane angle

Femtoscopy using 3-pion cumulants

New arXiv:1310.7808

- 3-pion cumulants
  - Enhances Bose-Einstein (QS) signal
  - Suppresses (2-pion) background
- Measure 3-pion correlations

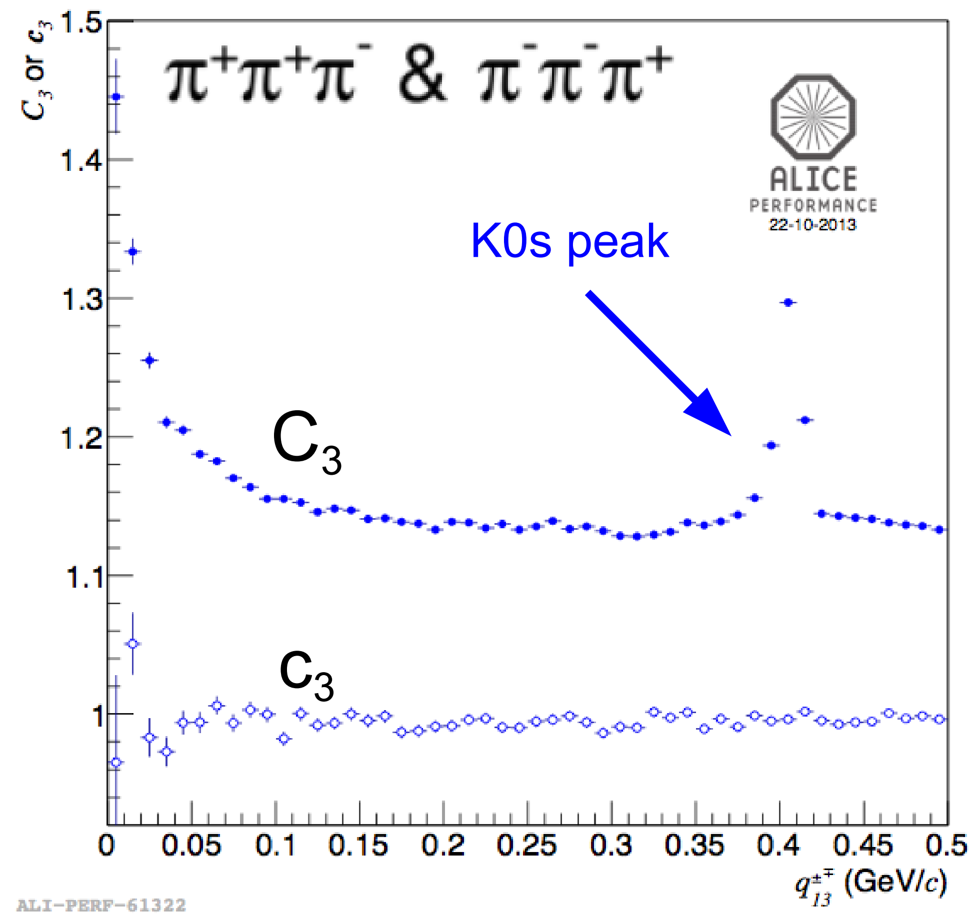
$$C_3(p_1, p_2, p_3) = \frac{N_3(p_1, p_2, p_3)}{N_1(p_1)N_1(p_2)N_1(p_3)}$$

- Remove all 2-pion QS correlations to arrive at 3-pion cumulant c_3 (formula in backup)
- Express correlation (C_3) and cumulant (c_3)
  - vs momentum transfer

$$Q_3 = \sqrt{q^2_{inv,12} + q^2_{inv,13} + q^2_{inv,23}}$$

  - for triplet momentum

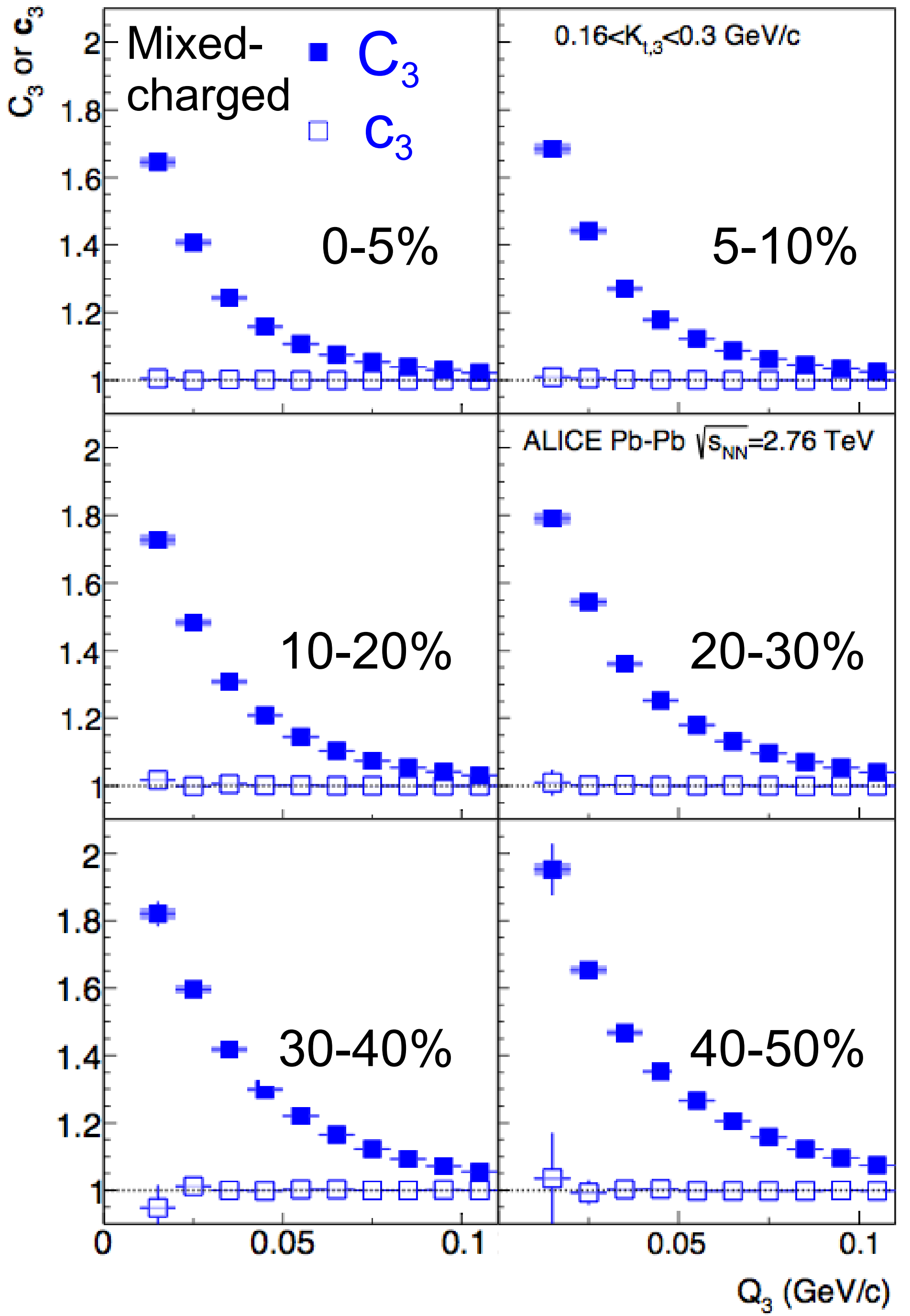
$$K_{t,3} = \frac{|\mathbf{p}_{T,1} + \mathbf{p}_{T,2} + \mathbf{p}_{T,3}|}{3}$$



Demonstration of 3-pion cumulant performance for mixed-charge case when projected onto 2-pion momentum space

3-pion mixed-charged correlations

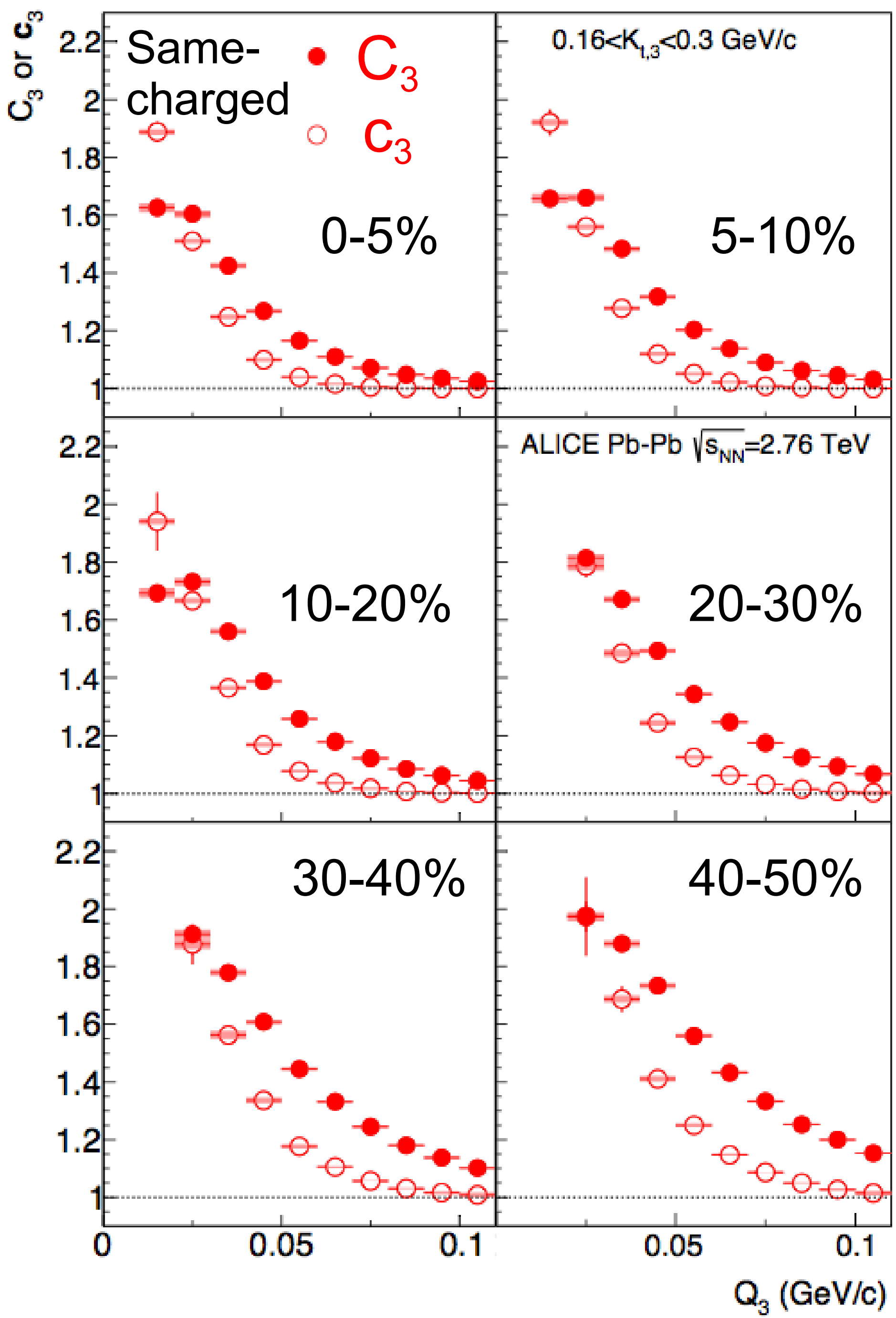
New arXiv:1310.7808



- At low Q_3, two- and three-particle correlations (C_3) dominated by final state interactions (FSI)
  - Mainly Coulomb interactions
  - Obtain corrections from Therminator
- Use mixed charged correlation to benchmark performance of FSI corrections
- Mixed-charged cumulant (c_3) consistent with unity
  - Mixed charged case well understood
  - FSI (Coulomb) corrections work well
    - Small residuals from unity treated as systematic uncertainty for same charge cumulant

3-pion same-charged correlations

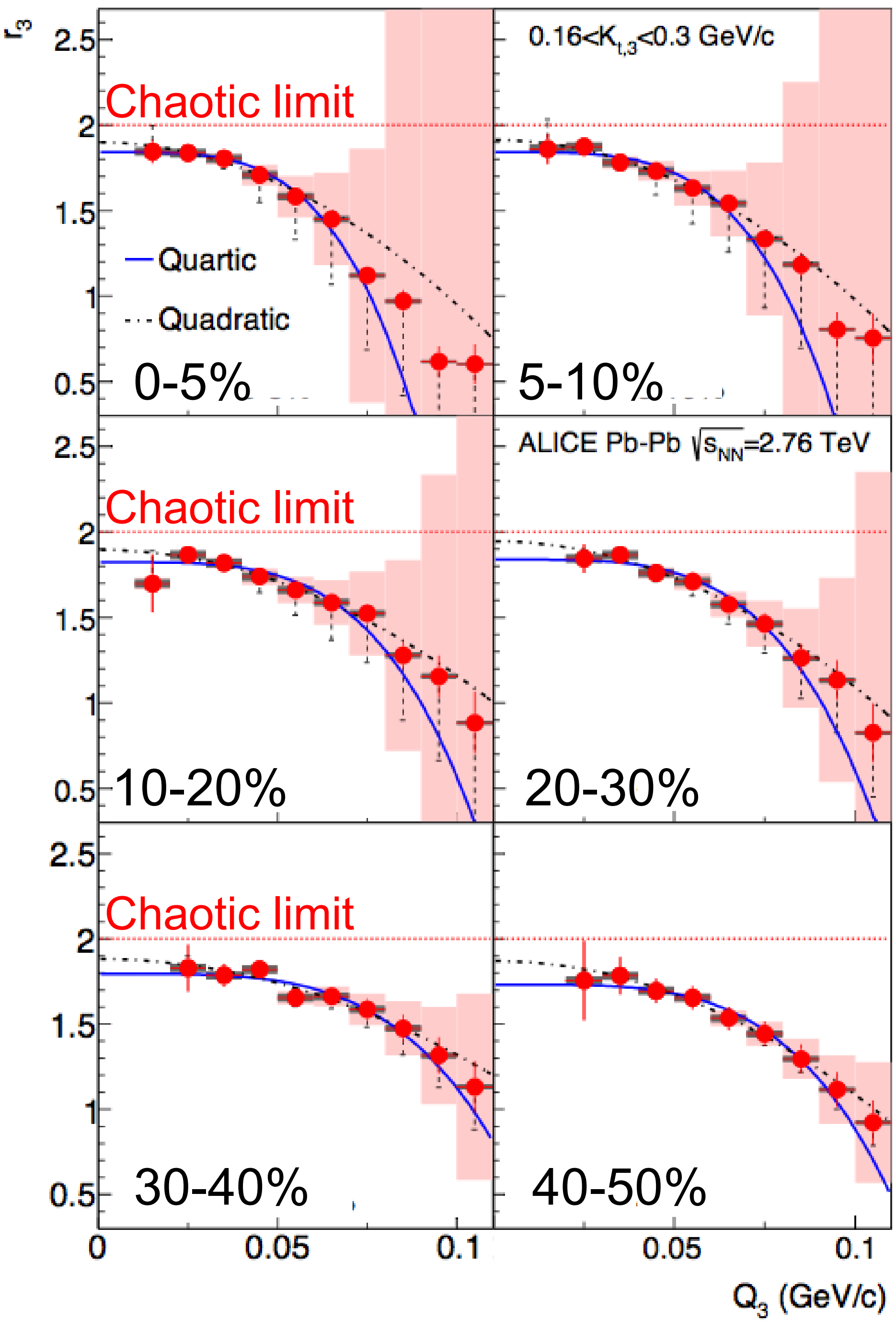
New arXiv:1310.7808



- After FSI corrections large same-charged cumulant (c_3)
- Genuine 3-pion Bose-Einstein correlations
  - Extract femtoscopic source radii (work in progress)

3-pion to 2-pion ratio r_3

New arXiv:1310.7808

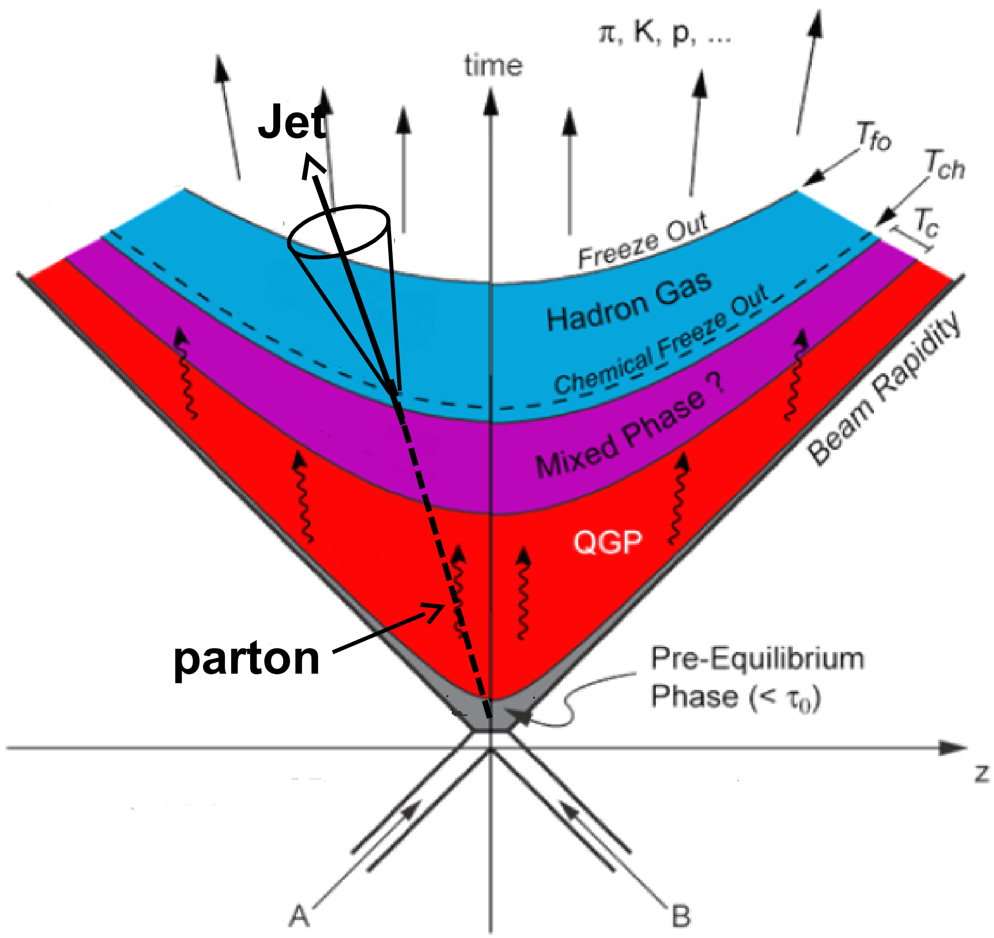


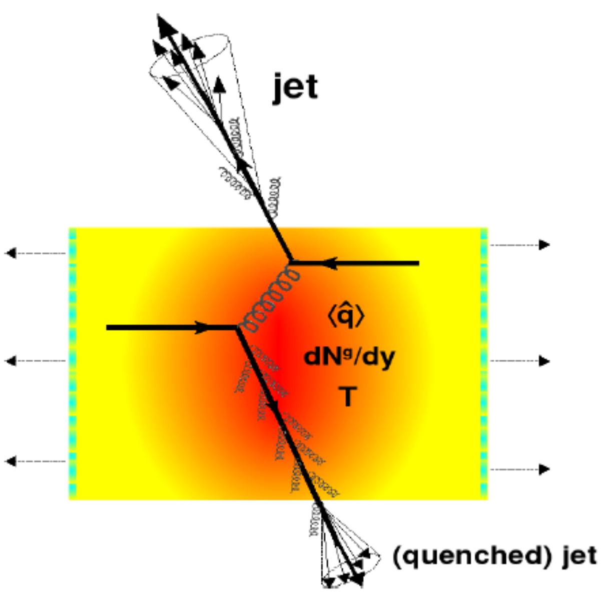
- Measure ratio of 3-pion over 2-pion QS correlations

$$r_3(Q_3)=\frac{c_3(Q_3)-1}{\sqrt{(C_2^{QS}(Q_{12})-1)(C_2^{QS}(Q_{13})-1)(C_2^{QS}(Q_{23})-1)}}$$

- Extract $r_3(Q_3 \rightarrow 0) = \gamma$
  - For chaotic particle production, expect $\gamma=2$
- Measure r_3 about 1.5σ below chaotic limit (from two types of fits) at low triplet momentum
  - Possible interpretation: About 22% ± 12% of low momentum pions are emitted coherently
    - Possible/speculative source: Color Glass Condensate formation

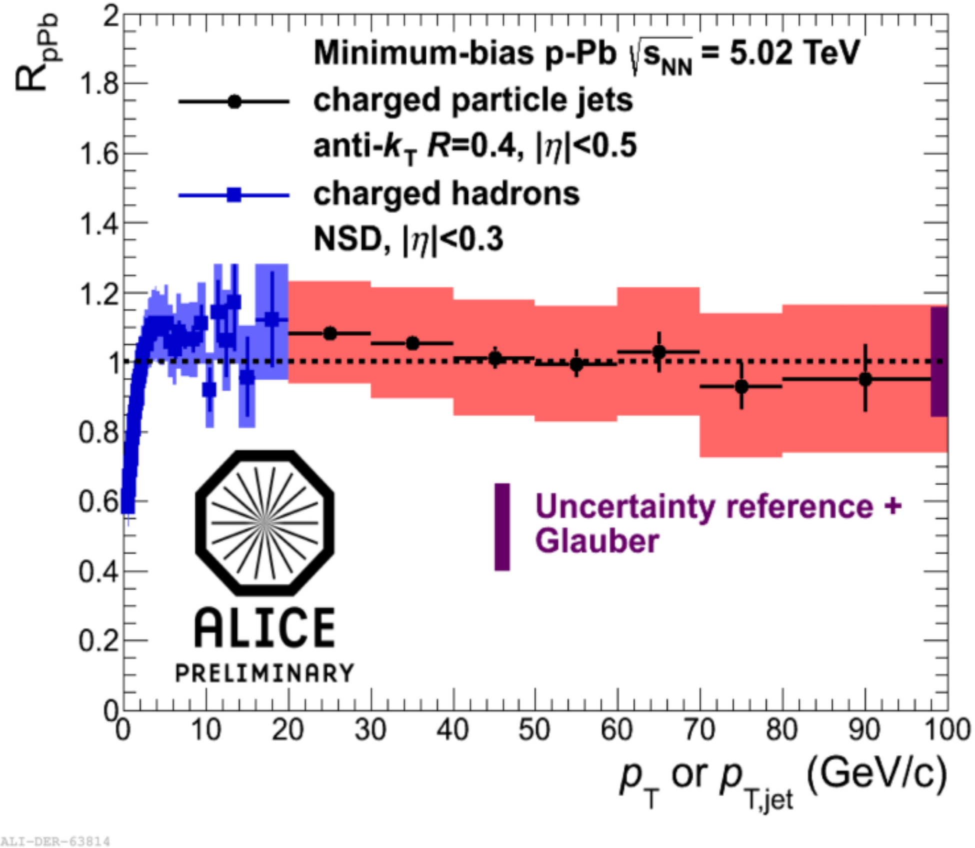
Jet quenching

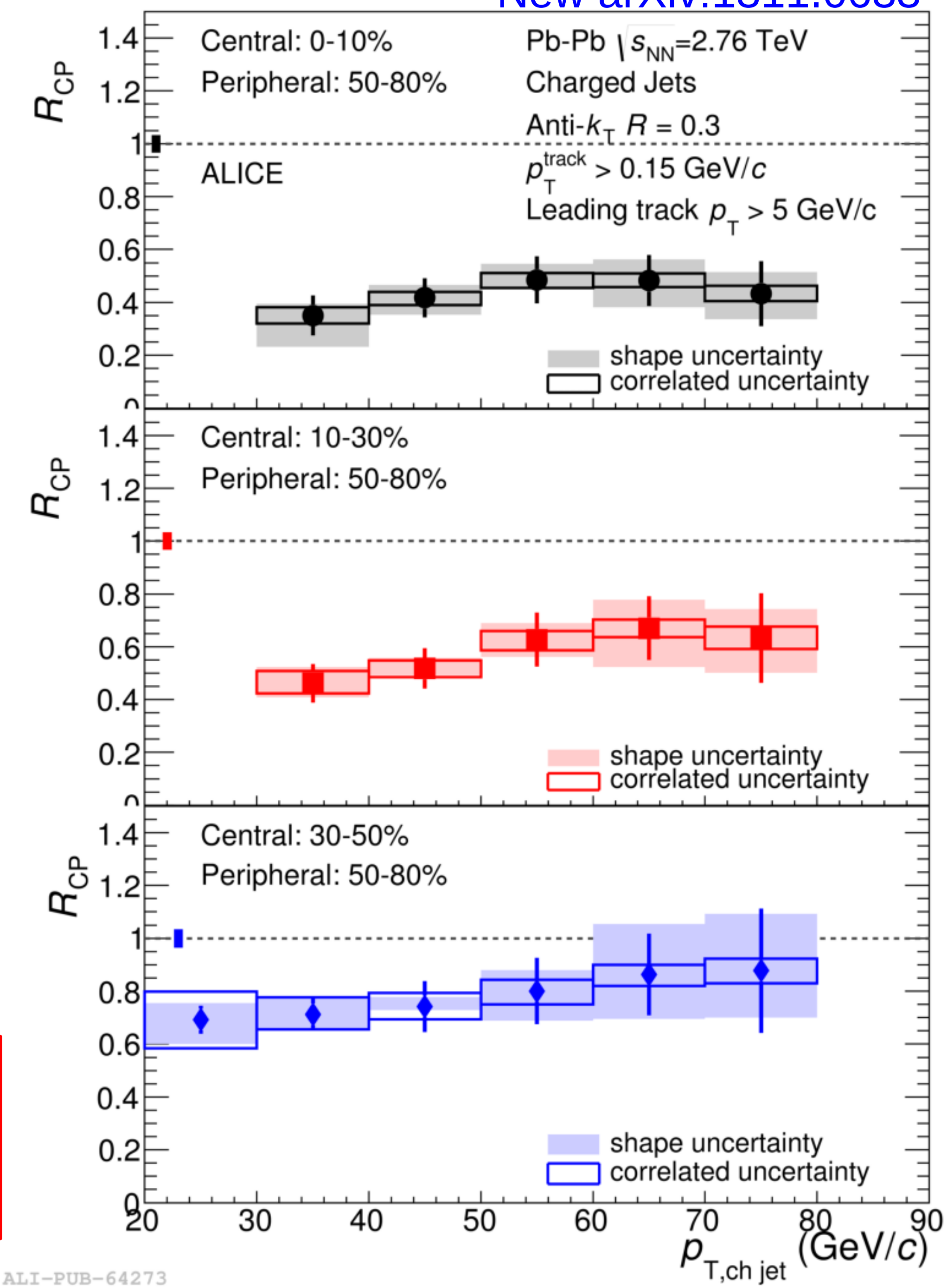




Jet yield in p-Pb and Pb-Pb

New arXiv:1311.0633





$$R_{CP} = \frac{N_{coll}^{P} \, dN^{C}/dp_T}{N_{coll}^{C} \, dN^{P}/dp_T}$$

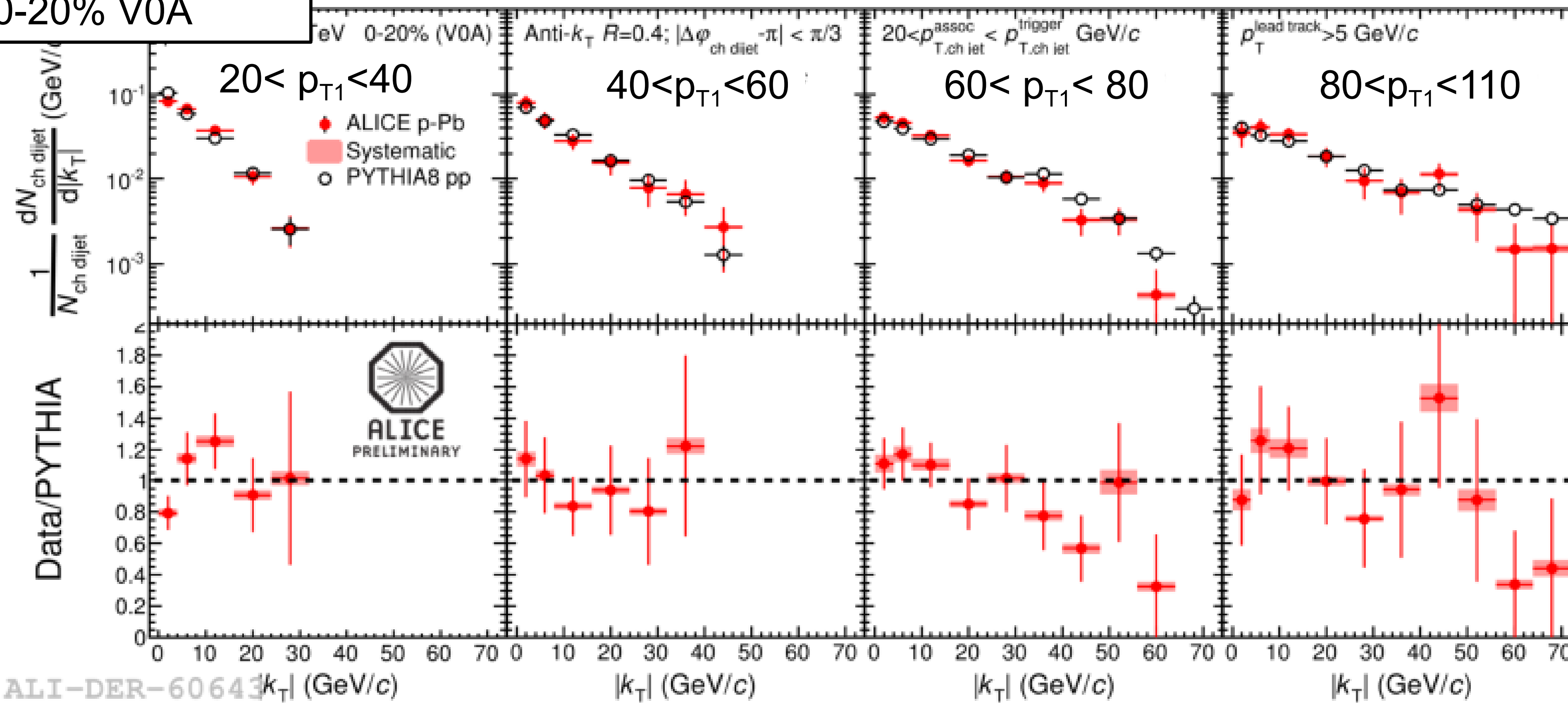
Unlike in p-Pb, jets are strongly suppressed, hence jet quenching is a final state effect

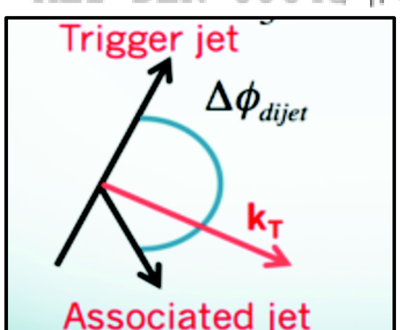
Dijet acoplanarity in p-Pb

New preliminary

Jet p_{T2}>20 GeV/c
R=0.4, $|\eta_{lab}|$<0.5
0-20% V0A

Charged jet trigger p_{T1}



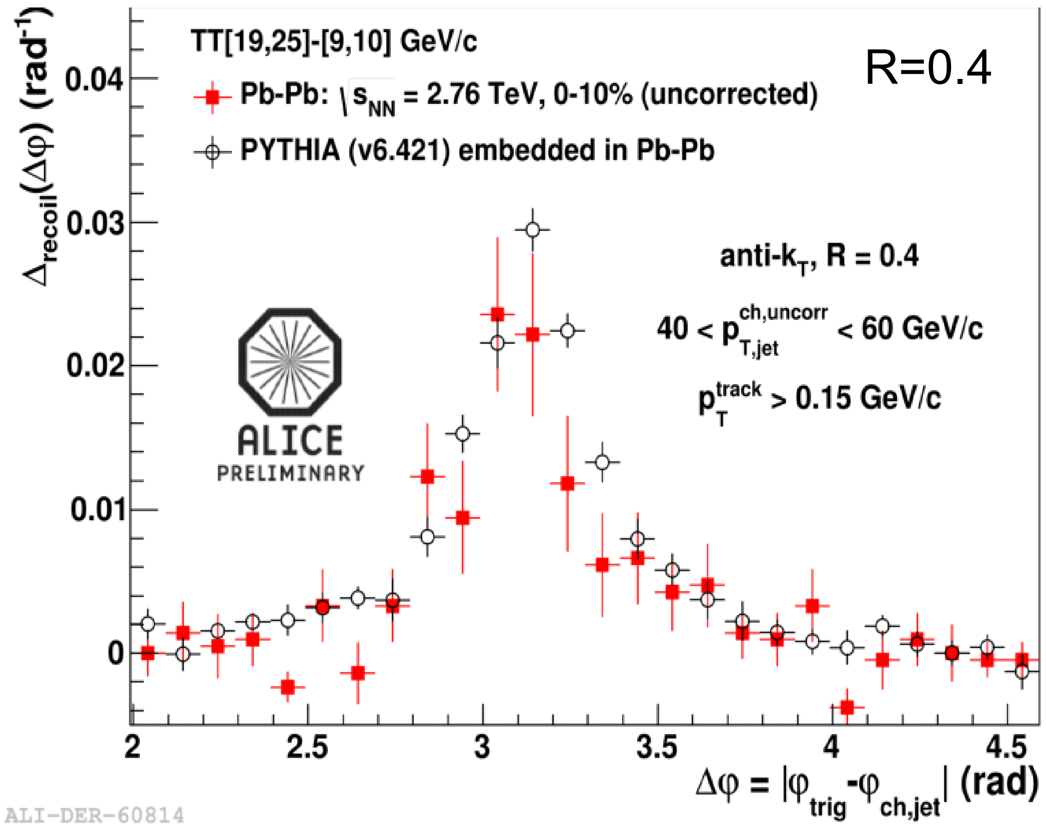


$$k_T = p^{trigger}_{T,ch\ jet}\sin(\Delta\varphi_{dijet})$$

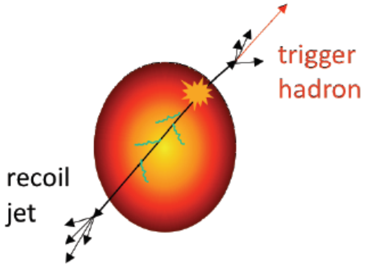
No indication for k_T broadening, even not in high-multiplicity p-Pb events (relative to PYTHIA 8, tune 4C, k=0.7)

Hadron-jet correlations in Pb-Pb

New preliminary



- Hadron-jet angular recoil $\Delta\varphi$ distribution consistent with Pythia (embedded in data)
  - No indication for medium induced acoplanarity (at low jet p_T)



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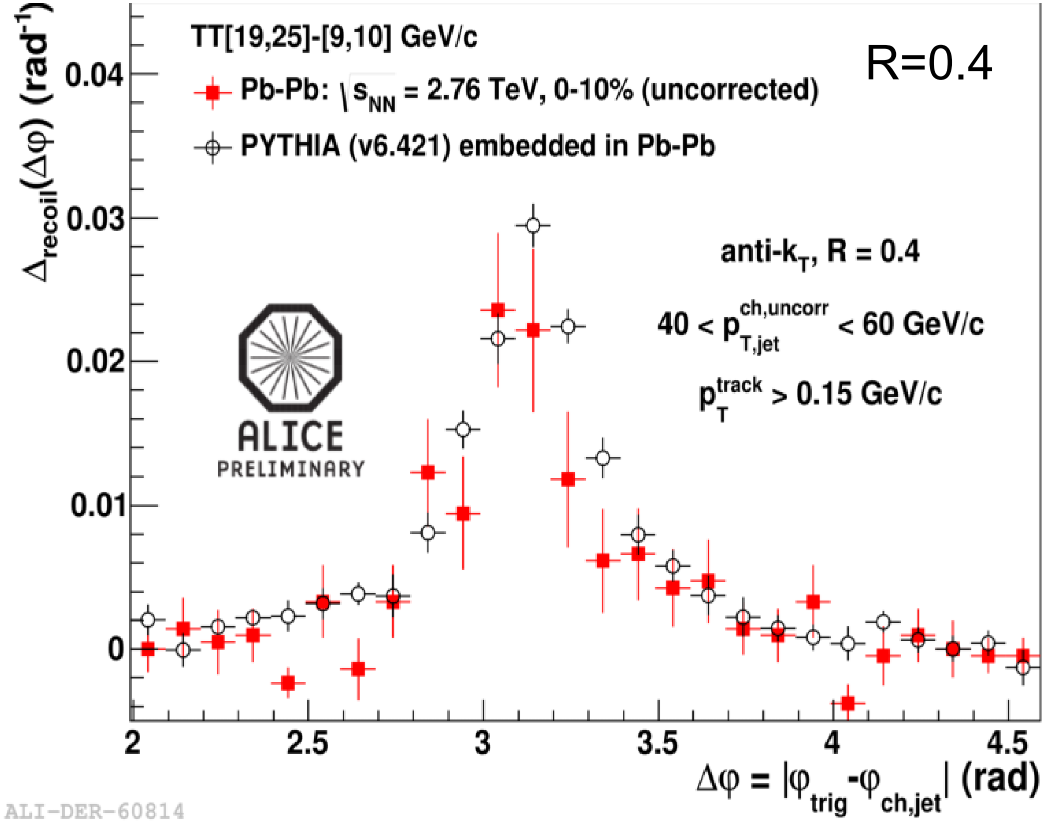

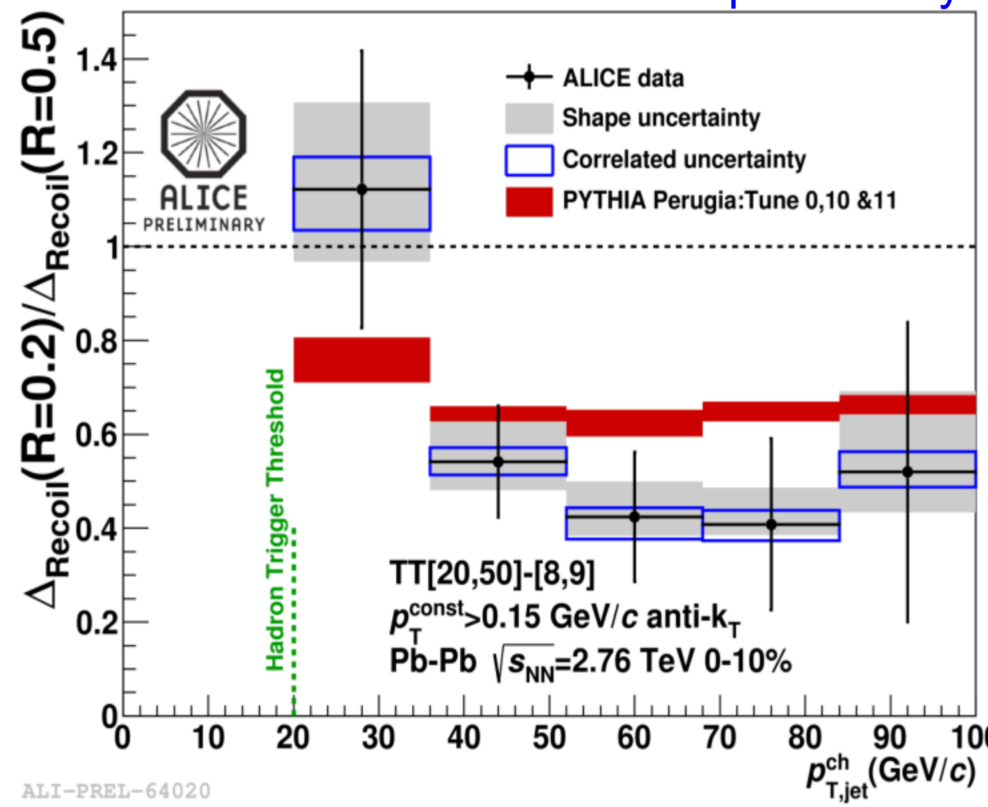

- Hadron-jet angular recoil Δφ distribution consistent with Pythia (embedded in data)
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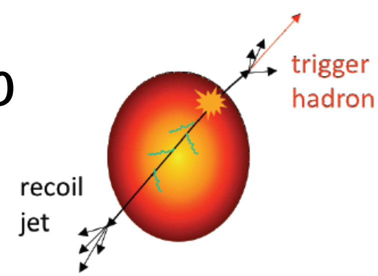
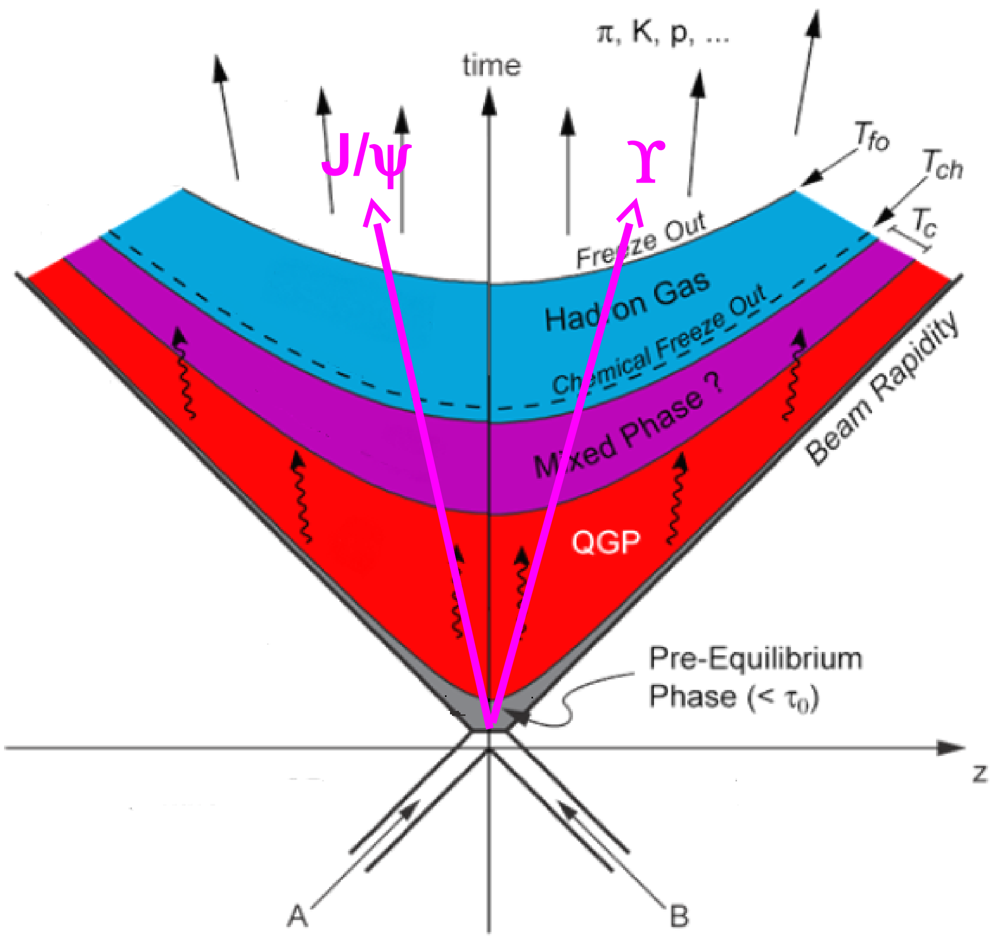


- Hadron-jet recoil ratio consistent with Pythia
  - No significant energy redistribution within R=0.5

Quarkonia



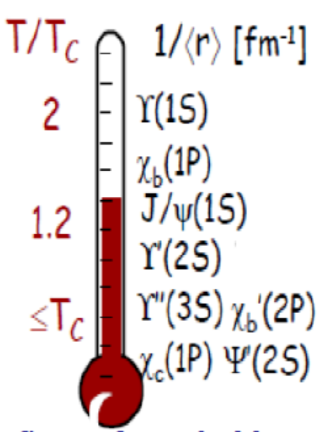
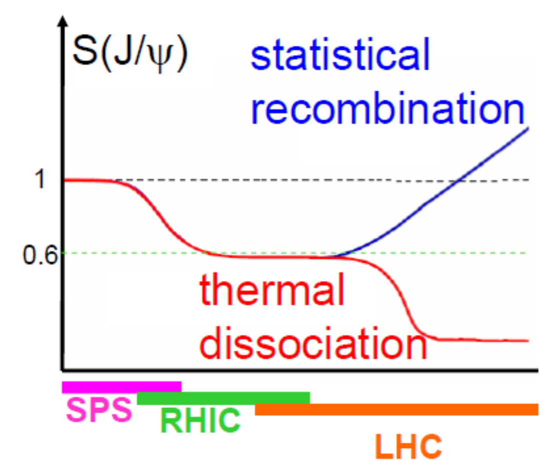
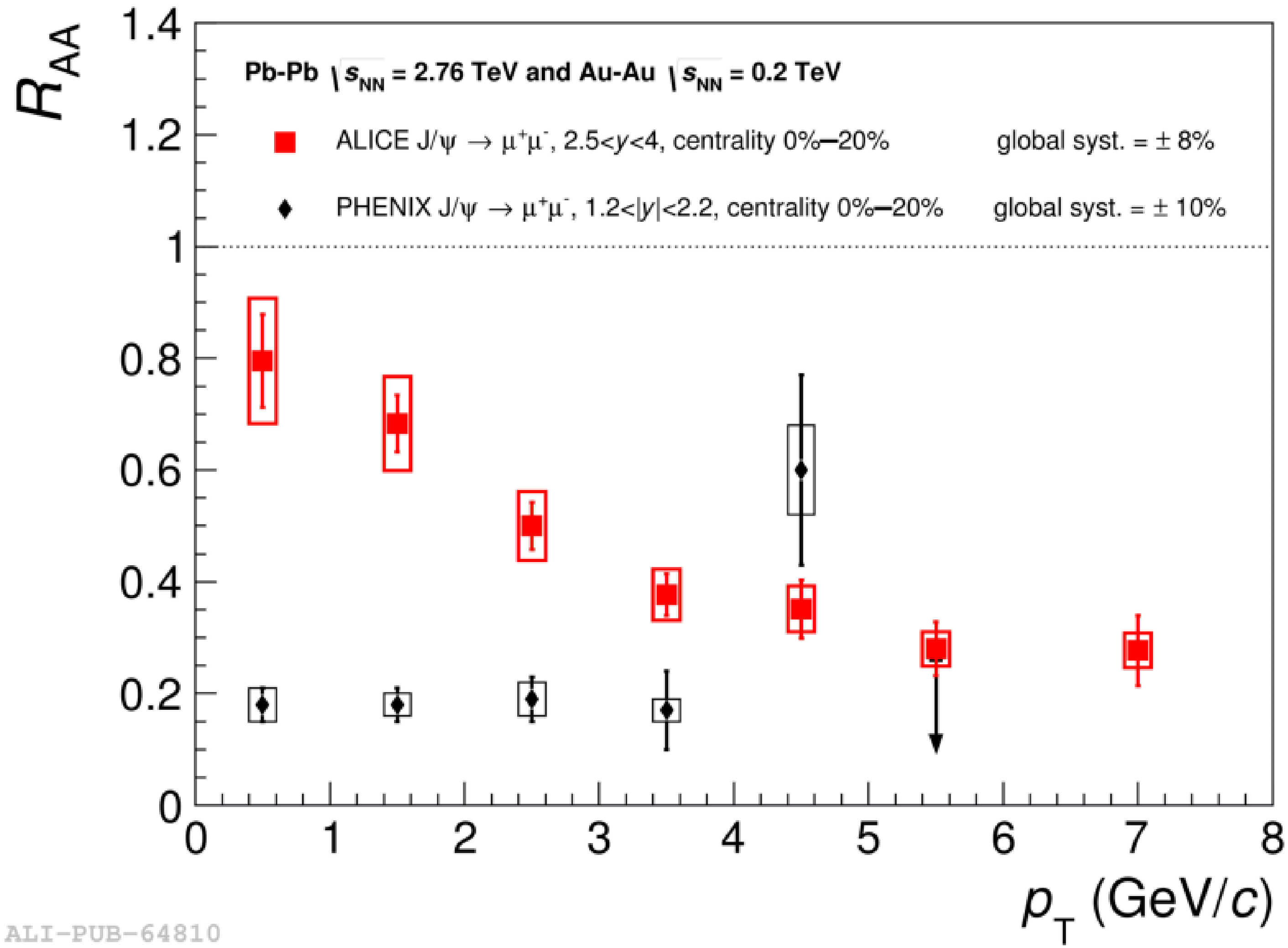


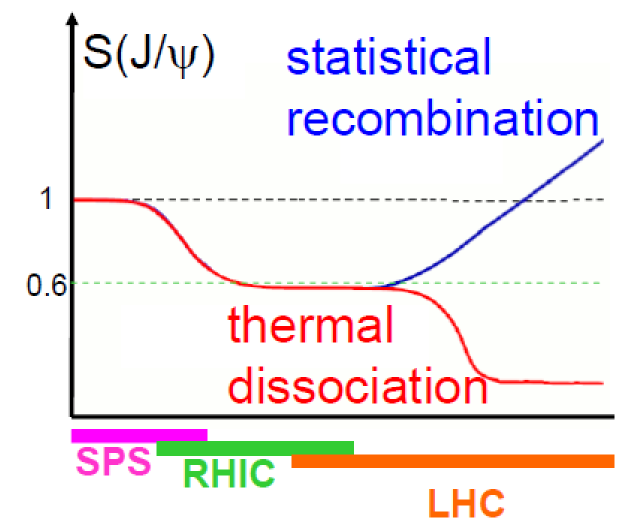
figure from A. Mocsy



J/ψ production in Pb-Pb

New arXiv:1311.0214

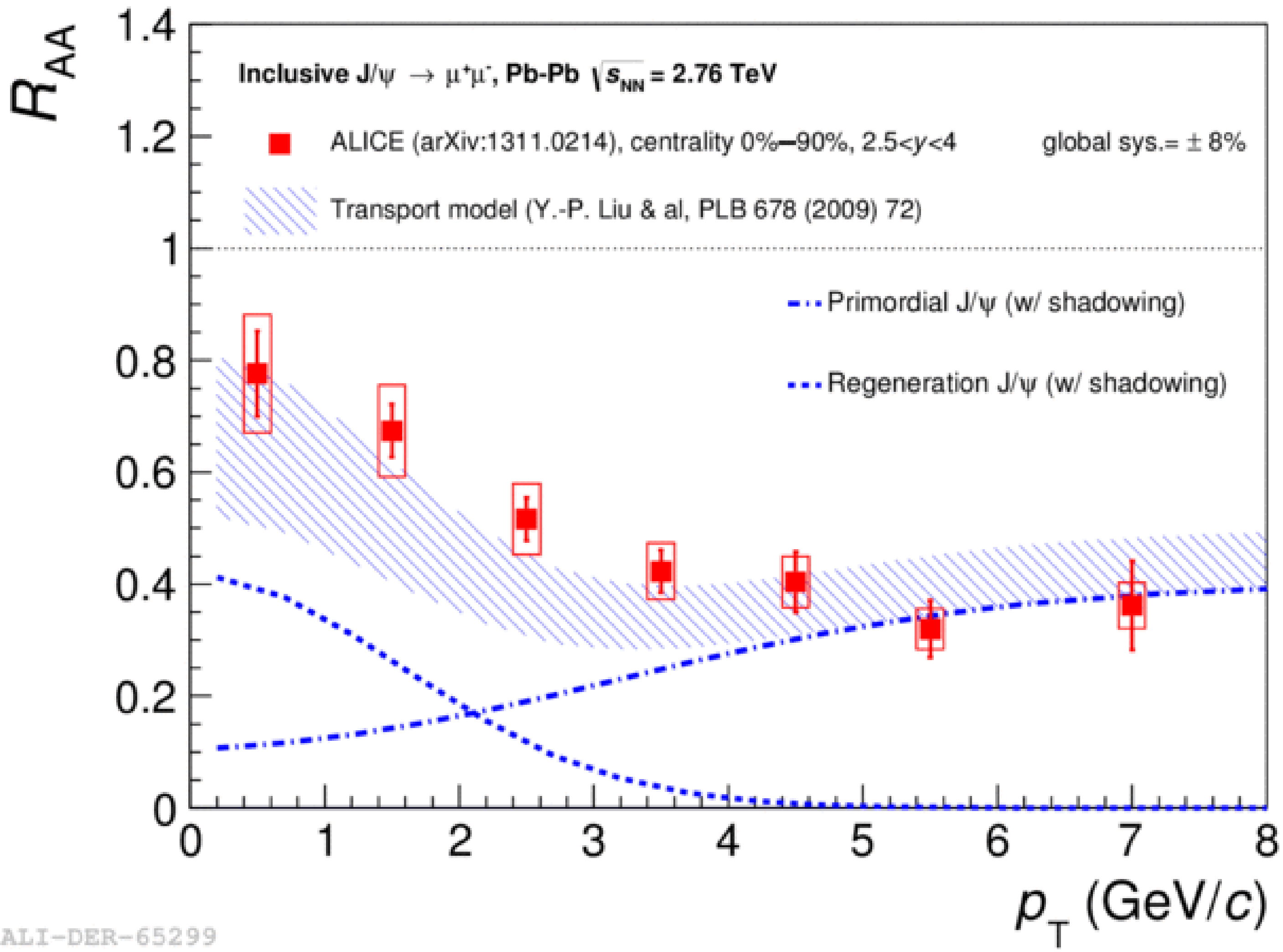


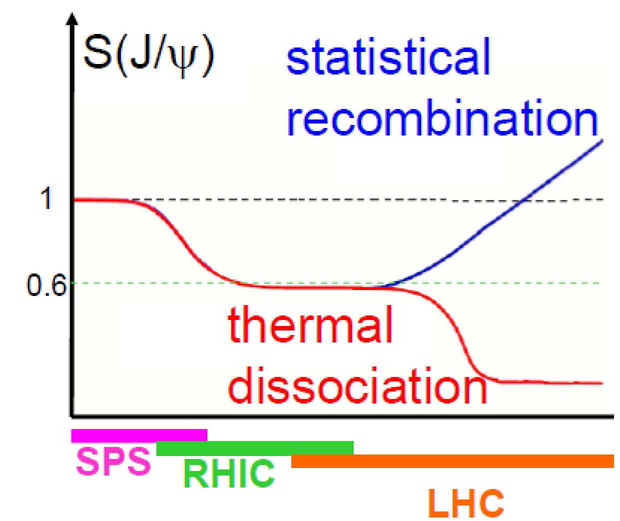


Different p_T (and centrality) dependence of J/ψ R_{AA} at LHC and RHIC

J/ψ production in Pb-Pb

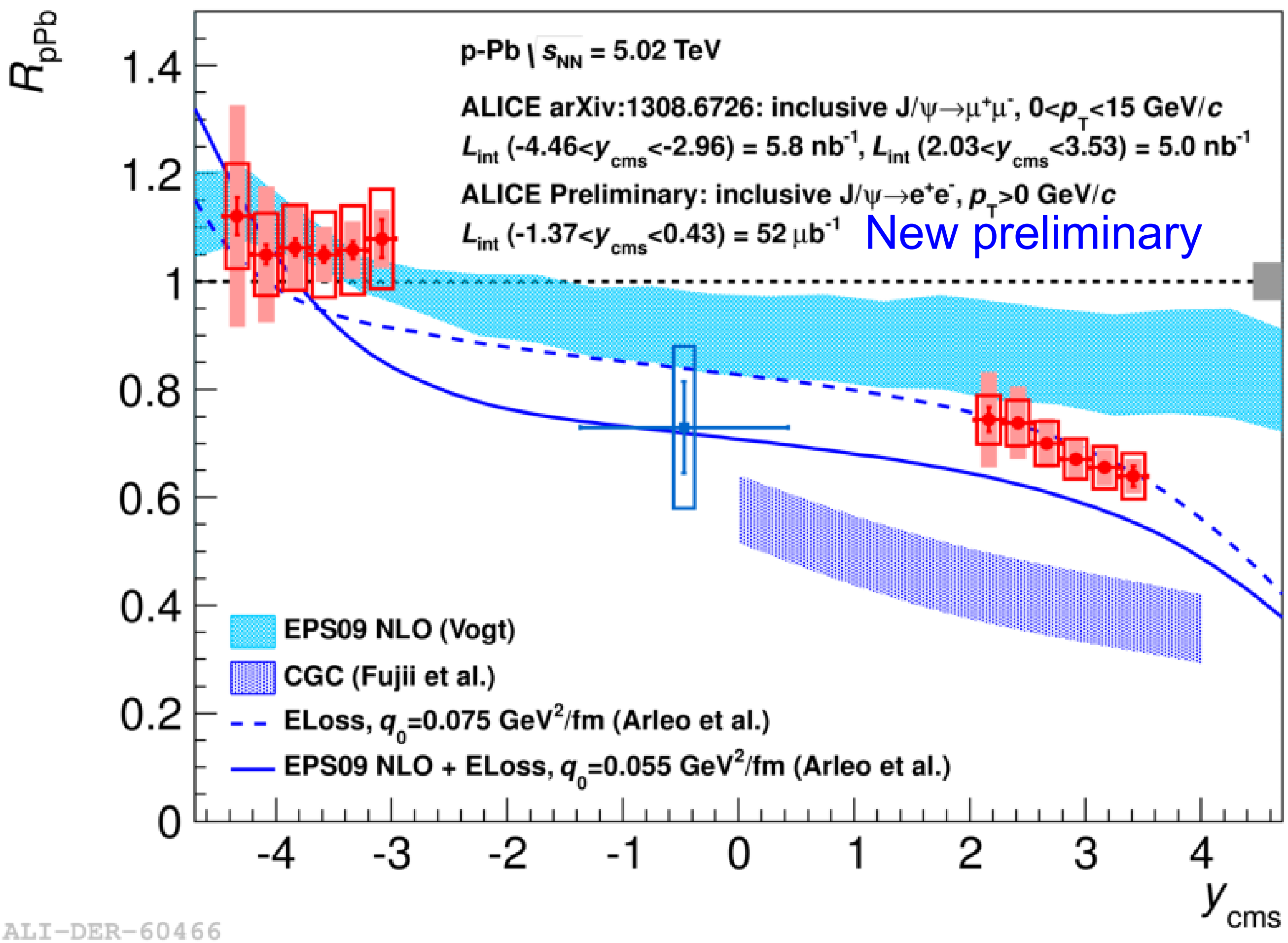
New arXiv:1311.0214



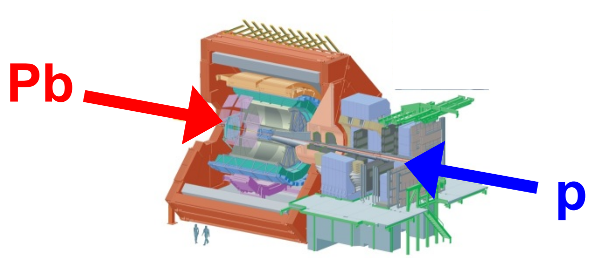


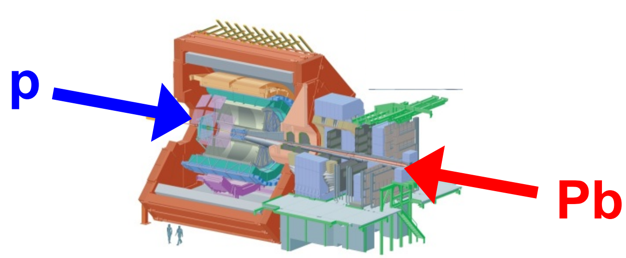
As expected in a scenario with $c\bar{c}$ recombination, especially at low p_T

J/ψ production versus rapidity in p-Pb



- Suppression at mid- and forward rapidity
  - Consequences for R_{AA}: Suggests even stronger recombination
- Consistent with shadowing models (EPS09 NLO) and/or coherent parton energy loss
- Specific CGC calculation disfavored

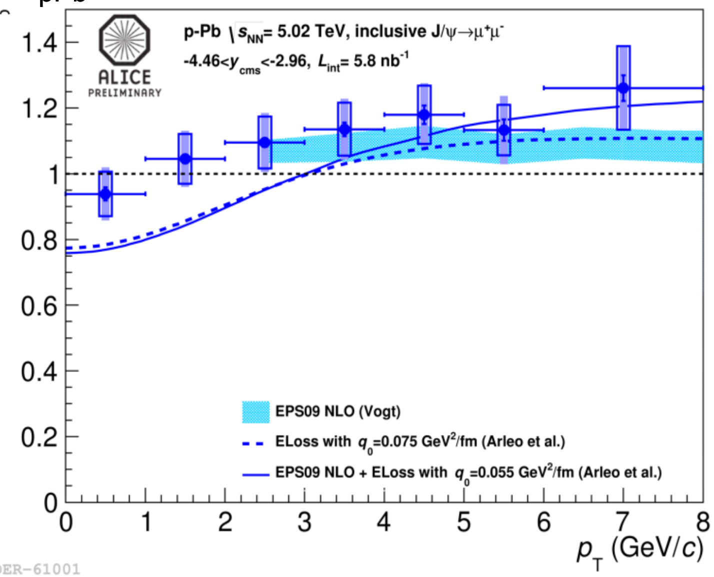




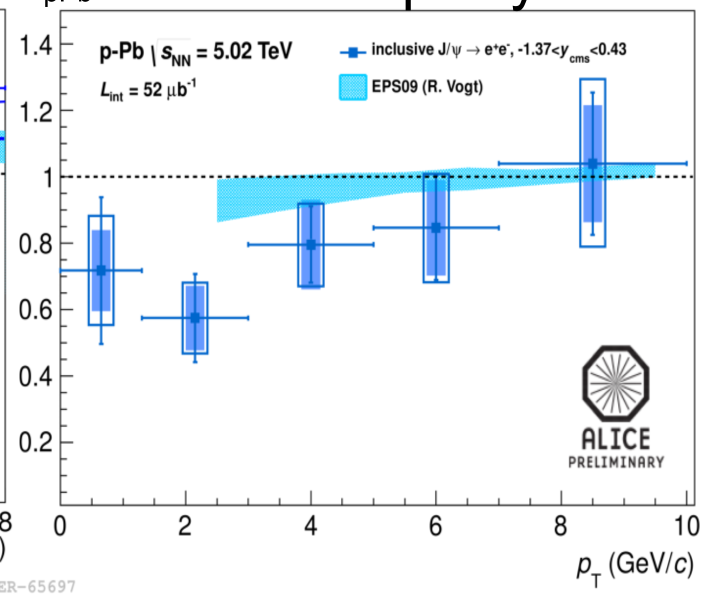
J/ψ production versus p_T in p-Pb

New preliminary

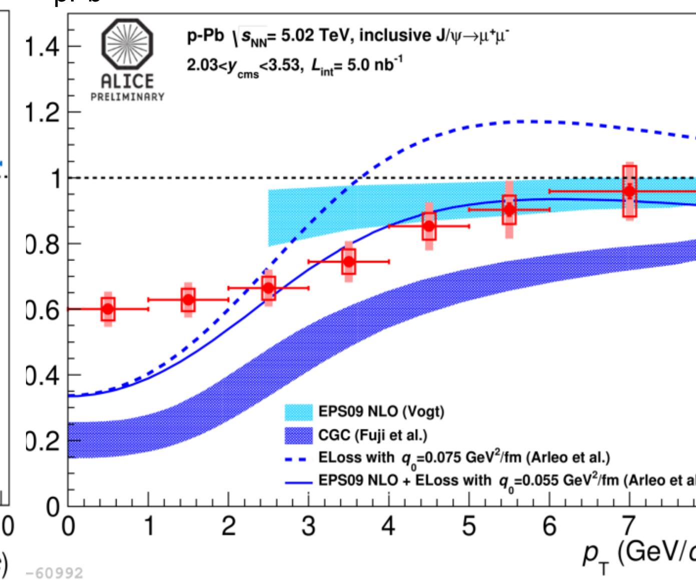
R_{pPb} Backward



R_{pPb} Mid-rapidity



R_{pPb} Forward

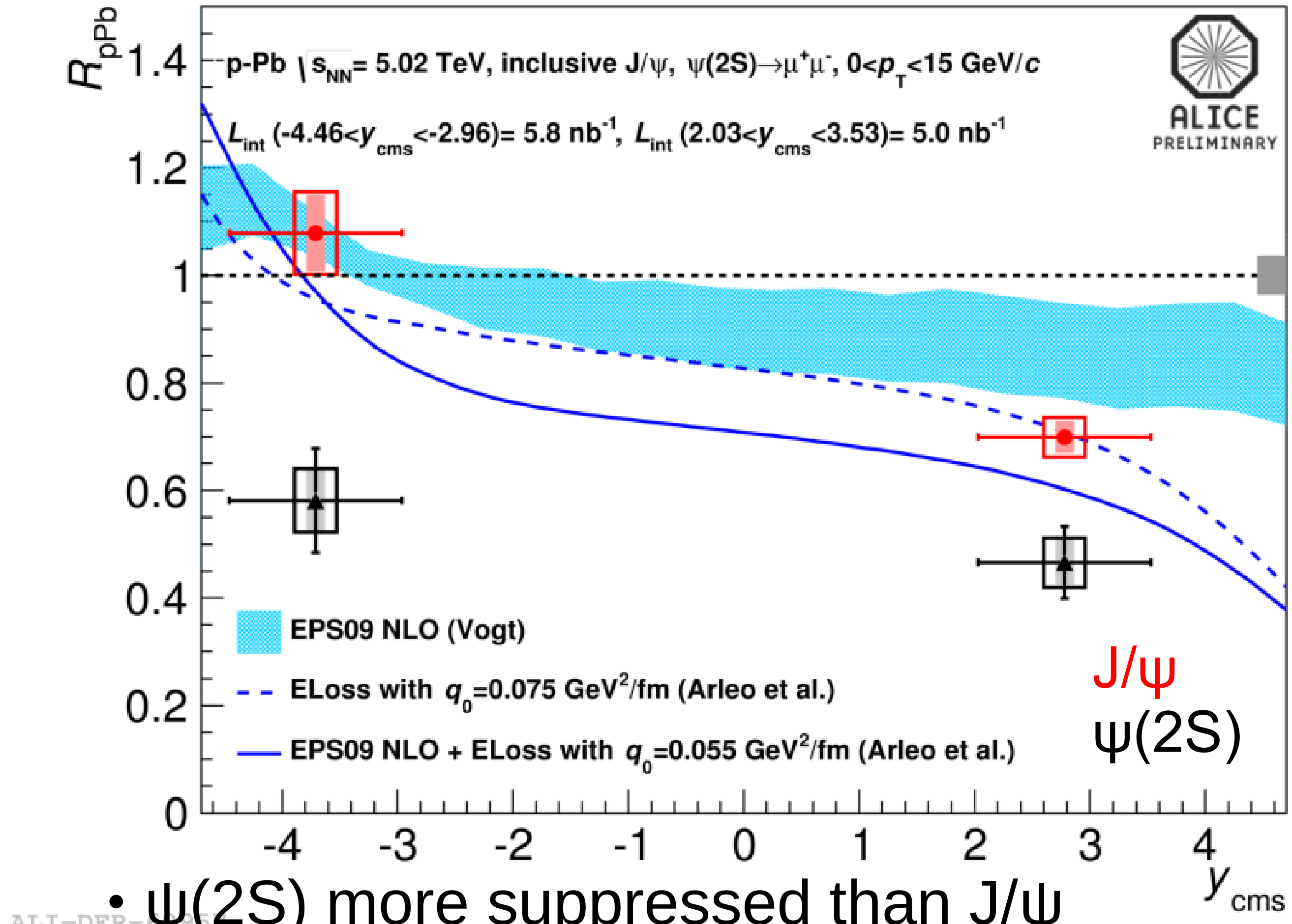


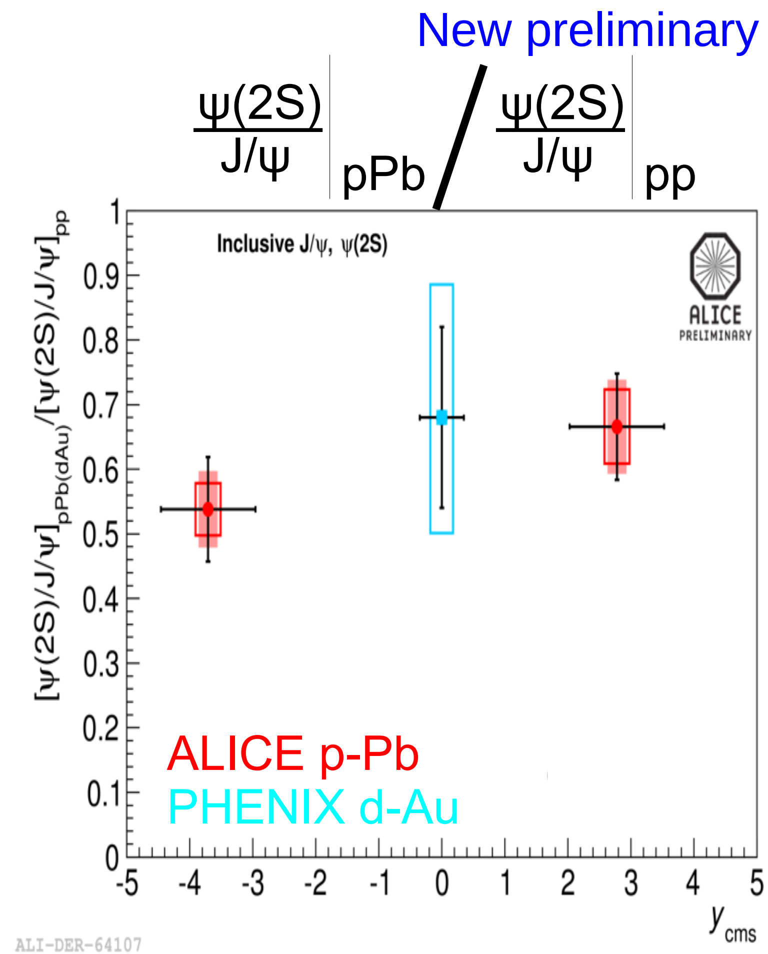
- R_{pPb} close to one
- Little p_T dependence

- R_{pPb} below one
- More precision needed to see if there is a p_T dependence

- R_{pPb} below one, in particular at low p_T
- Significant p_T dependence
  - Additional constraints on models

ψ(2S) production in p-Pb

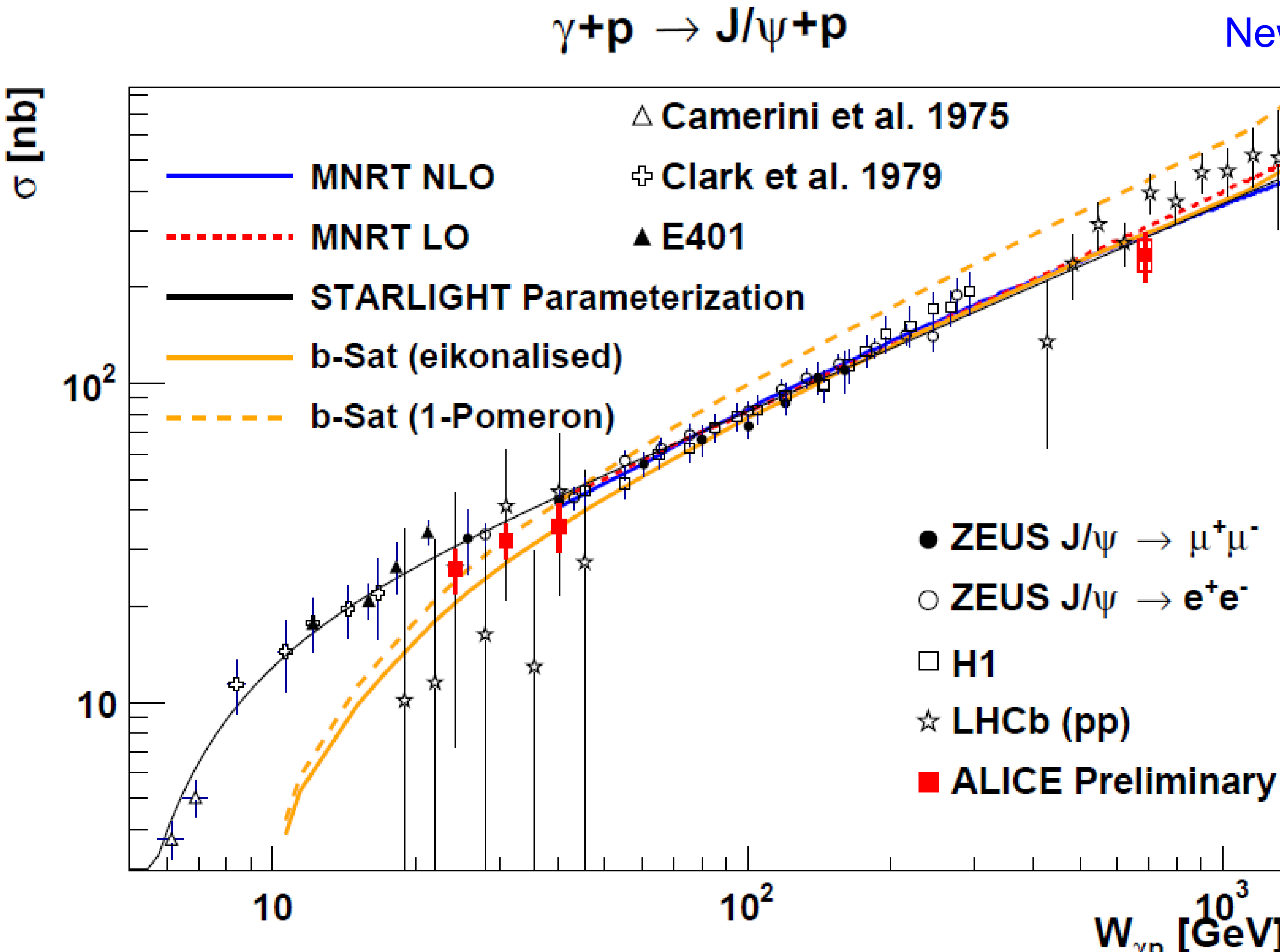




- ψ(2S) more suppressed than J/ψ
  - Not expected by initial state CNM effects and coherent energy loss
- Stronger relative suppression in backward direction
  - Qualitatively expected from break-up due to comoving system
- But also strong suppression in forward direction
  - Final state effects?

J/ψ photoproduction in pPb

New preliminary



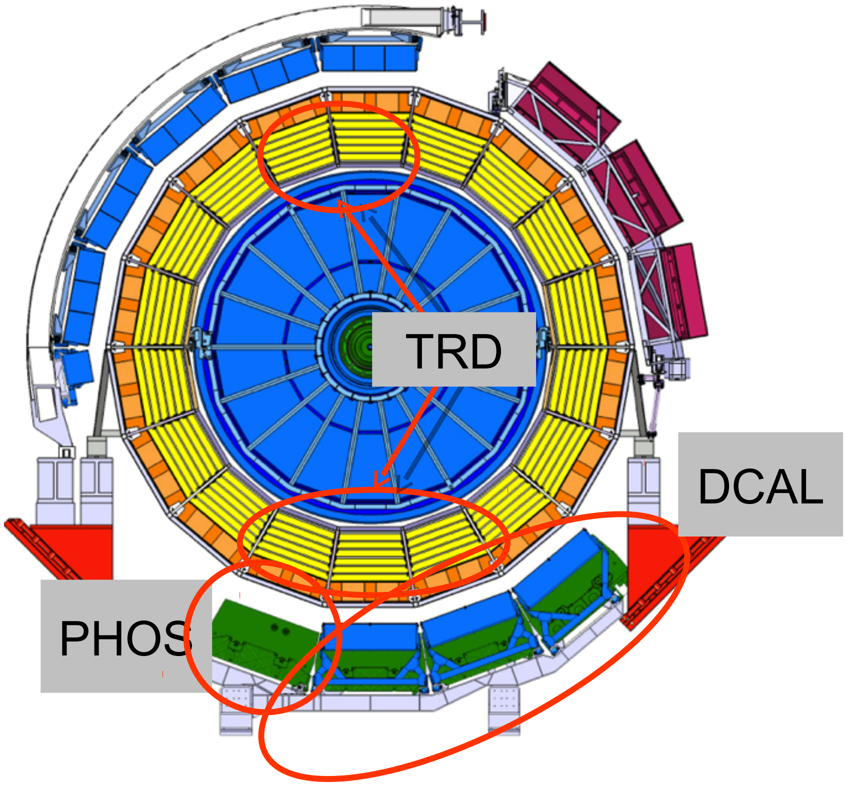
Topic of upcoming CERN seminar

- Access to gluon distribution in proton target at low x
  - Advantage of p-Pb that photon source is known
  - More results to come from barrel/barrel and barrel/muon

LS1 activities

Main activities for LS1

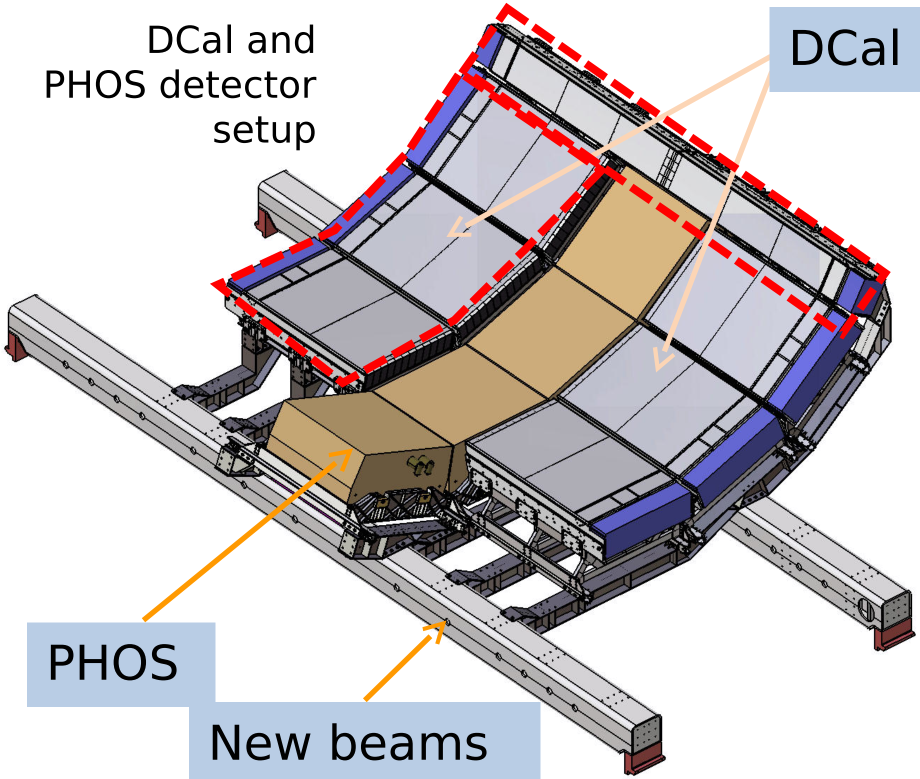
- Complete TRD (+5 supermodules)
- Install DCal calorimeter (8 supermodules)
- Install one additional PHOS supermodule
- Numerous detector and infra-structure consolidation and restructuring efforts



On track with LS1 schedule, but still a lot of work ahead

DCal installation

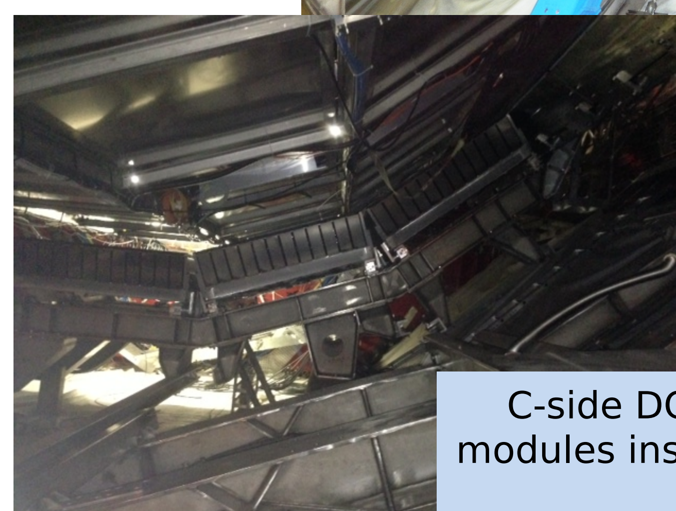
DCal and PHOS detector setup



- New beams installed inside L3 magnet in June
- C-side plus two 1/3 modules done in October
- PHOS and A-side Dcal SM installation in Sep 2014 (after new PHOS readout is ready)

Installation of new beams inside L3 (old beams removed)

Both 1/3 modules (C and A side) installed

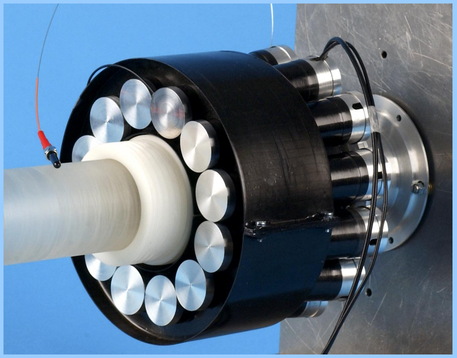


C-side DCAL modules installed

Detector and services rework

Muon Tracker LV rework

- Repaired almost 90 chambers
- Re-solder LV busbar connection in order to fix the occupancy issues
- Tests ongoing for DCS and DAQ



T0 Rework

- Production of new QTC modules underway for 25ns beam
- Relocate electronics to C side (C33-34)
- Reduce trigger generation latency (to 430ns) ongoing
- Tuning scheduled for February 2014

TRD LV rework

- LV issue: hot connections due to not proper tightening of cables on patch-panel
- Fix: de-install 6 TRD SMs, rework LV distribution and re-install them in LS1
- Completion during this week

DAQ

- Pause/recover framework (40% faster)
- New cluster: Global service back June 2014

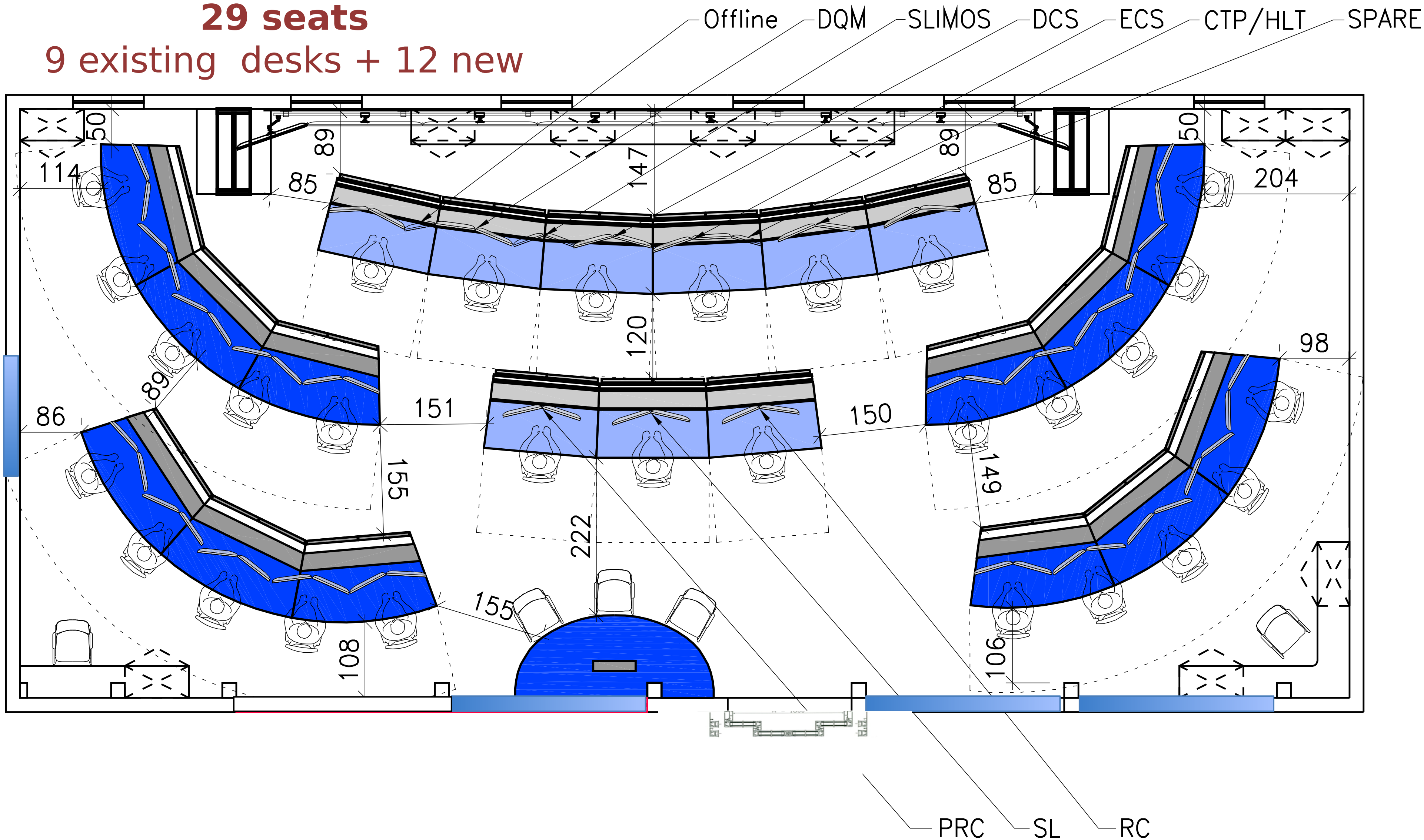
HLT

- New cluster procurement Q4/13 + Q1/13
- Q2/Q3 2014 installation + commissioning

ALICE run-control center (ACR)

29 seats

9 existing desks + 12 new



Redesigned open space to improve efficiency of operation

CERN groups involved at P2 during LS1

- EN-EL:
  - upgrade and consolidation of the UPS network
  - cabling new ACR
  - electrical maintenance and tests
  - installation optical fibers and test
- EN-CV:
  - chilled water upgrade, L3 ventilation upgrade
  - standard maintenance, cleaning cooling towers
  - replacement detector cooling tanks
  - cooling new ACR
- EN-MEF:
  - primary gas supply and gas dewar refurbishment
  - safety coordination
  - cabling and scaffolding coordination
- EN-HE:
  - transport coordination
  - refurbishment of cranes, anti-collision system
  - maintenance lifts and doors
- TE-VSC:
  - removal RB24 beampipe, venting and neon flushing of central beampipe
  - installation of additional gauge in RB24 pipe
- GS-SEE:
  - coordination ACR renovation
  - maintenance of buildings (leaks)
  - new storage building (2014) and removal of barracks
- GS-IS:
  - cleaning
- BE-ABP:
  - survey
- PH-DT:
  - consolidation magnet control and DSS systems
  - maintenance gas systems and gas re-circulation for MTG
- IT-CS:
  - IT network installation and upgrade
  - IT cables new ACR

A special acknowledgment to all CERN groups, for the invaluable support provided to the experiment during 2013 and for their commitments for the rest of LS1

Upgrade plans for LS2

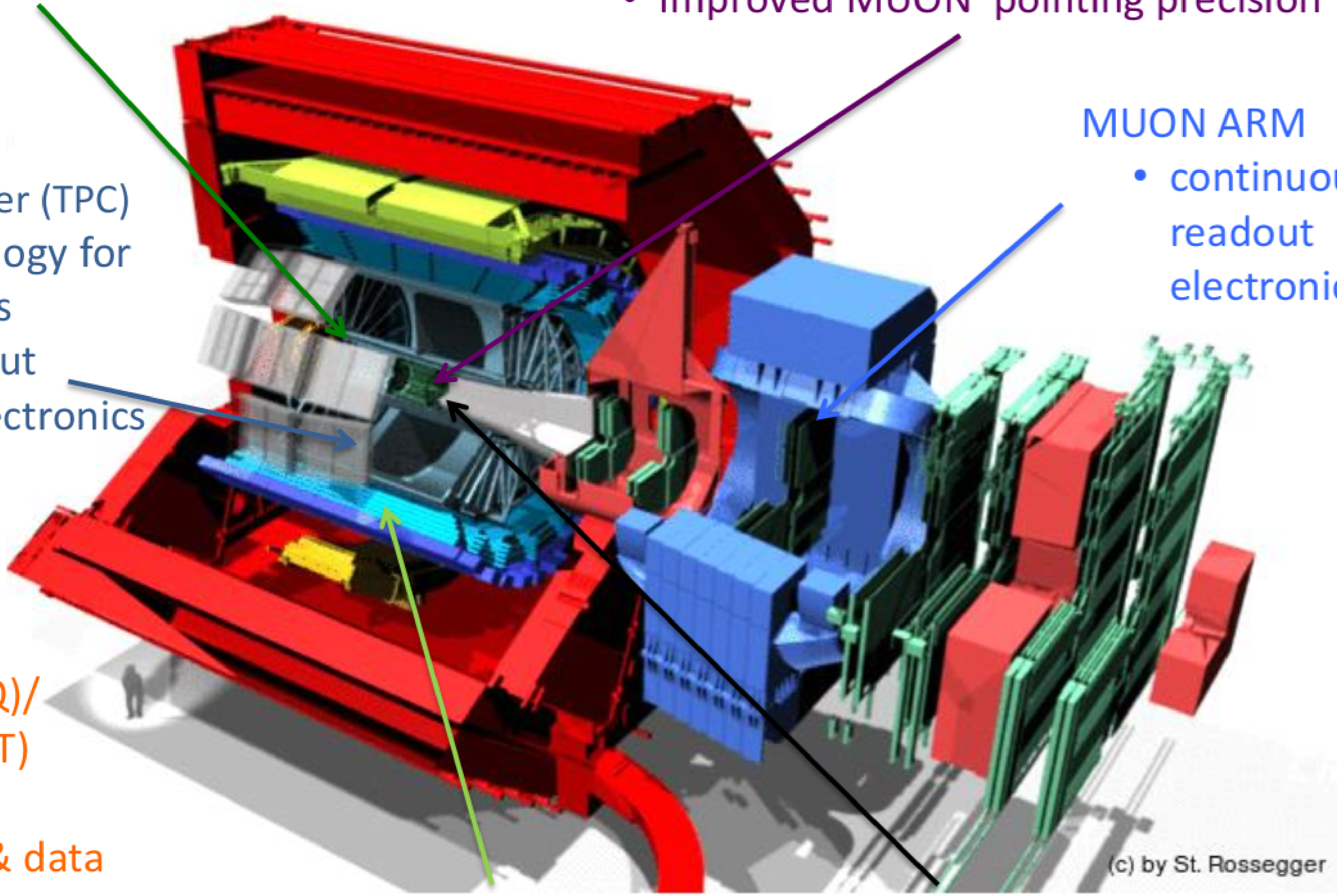
ALICE upgrades for LS2

New Inner Tracking System (ITS)
- improved pointing precision
- less material -> thinnest tracker at the LHC

Muon Forward Tracker (MFT)
- new Si tracker
- Improved MUON pointing precision

MUON ARM
- continuous readout electronics

Time Projection Chamber (TPC)
- new GEM technology for readout chambers
- continuous readout
- faster readout electronics



Data Acquisition (DAQ)/
High Level Trigger (HLT)
- new architecture
- on line tracking & data compression
- 50 kHz PbPb event rate

TOF, TRD
- Faster readout

New Trigger Detectors (FIT)

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...ng precision

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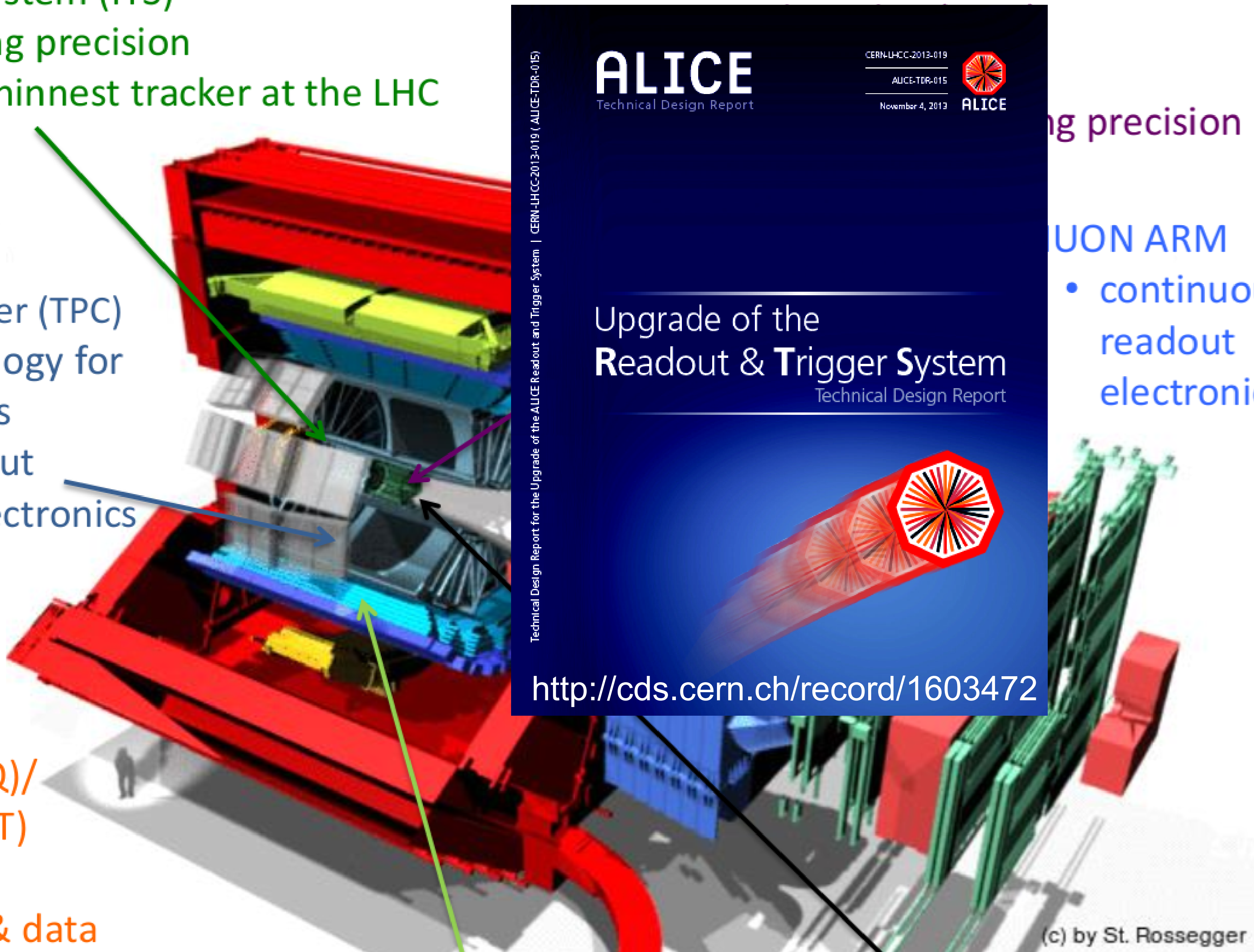

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Time Projection

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- continuou
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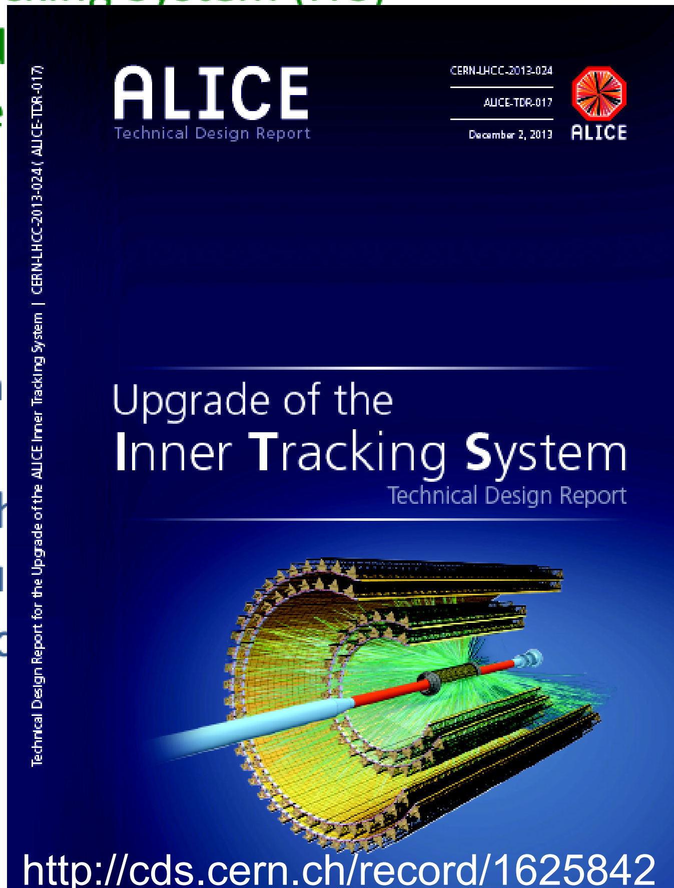


(c) by St. Rossegger

Data Acquisition (DAQ)/
High Level Trigger (HLT)

- new architecture
- on line tracking & data compression
- 50kHz Pbb event rate

TOF, TRD

- Faster readout

New Trigger Detectors (FIT)

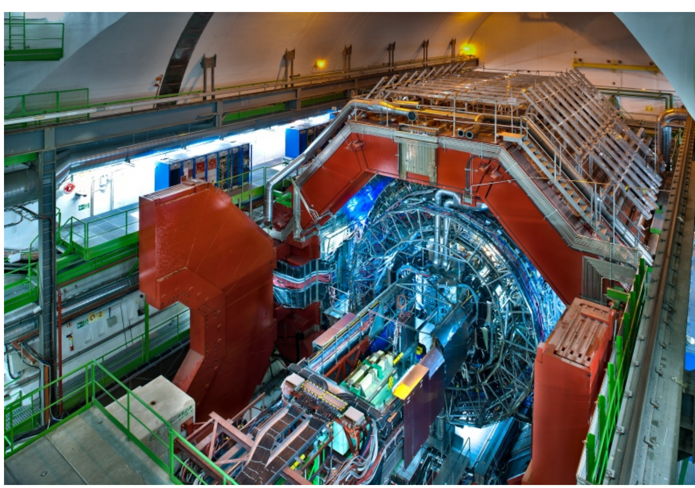
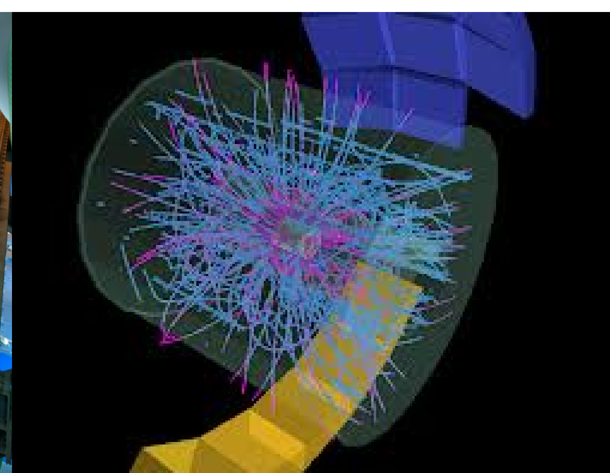
Summary of physics (from ITS TDR)

New wrt CDR (orange arrow) | Full MC (green arrow)

New wrt CDR	Full MC	Observable	Current, 0.1 nb^{-1}		Upgrade, 10 nb^{-1}	
			p_T^{min} (GeV/c)	statistical uncertainty	p_T^{min} (GeV/c)	statistical uncertainty
		Heavy Flavour				
	→	D meson R_{AA}	1	10 %	0	0.3 %
→		D_s meson R_{AA}	4	15 %	< 2	3 %
	→	D meson from B R_{AA}	3	30 %	2	1 %
→		J/ψ from B R_{AA}	1.5	15 % (p_T-int.)	1	5 %
→	→	B^+ yield	not accessible		3	10 %
	→	Λ_c R_{AA}	not accessible		2	15 %
	→	Λ_c/D^0 ratio	not accessible		2	15 %
→	→	Λ_b yield	not accessible		7	20 %
	→	D meson v_2 ($v_2 = 0.2$)	1	10 %	0	0.2 %
→		D_s meson v_2 ($v_2 = 0.2$)	not accessible		< 2	8 %
	→	D from B v_2 ($v_2 = 0.05$)	not accessible		2	8 %
→		J/ψ from B v_2 ($v_2 = 0.05$)	not accessible		1	60 %
→	→	Λ_c v_2 ($v_2 = 0.15$)	not accessible		3	20 %
		Dielectrons				
		Temperature (intermediate mass)	not accessible			10 %
		Elliptic flow ($v_2 = 0.1$) [14]	not accessible			10 %
		Low-mass spectral function [14]	not accessible		0.3	20 %
		Hypernuclei				
→	→	${}^{3}_{\Lambda}H$ yield	2	18 %	2	1.7 %

Summary

- Continue to obtain wide range of measurements in pp, p-Pb and Pb-Pb collisions with the same analysis method
  - Address aspects of initial and final state effects through detailed system comparisons
    - Suppression of inclusive jets and recombination of inclusive J/ψ in Pb-Pb
    - More observables on bulk particle production in p-Pb (not yet conclusive on the origin of the ridge)
  - New measurement on chaoticity from 3-pion cumulants
- Activities ongoing at Point 2 are on track with schedule
- Substantial progress on upgrades for run 3


Extra

Identified particle ridge v_2 and spectra

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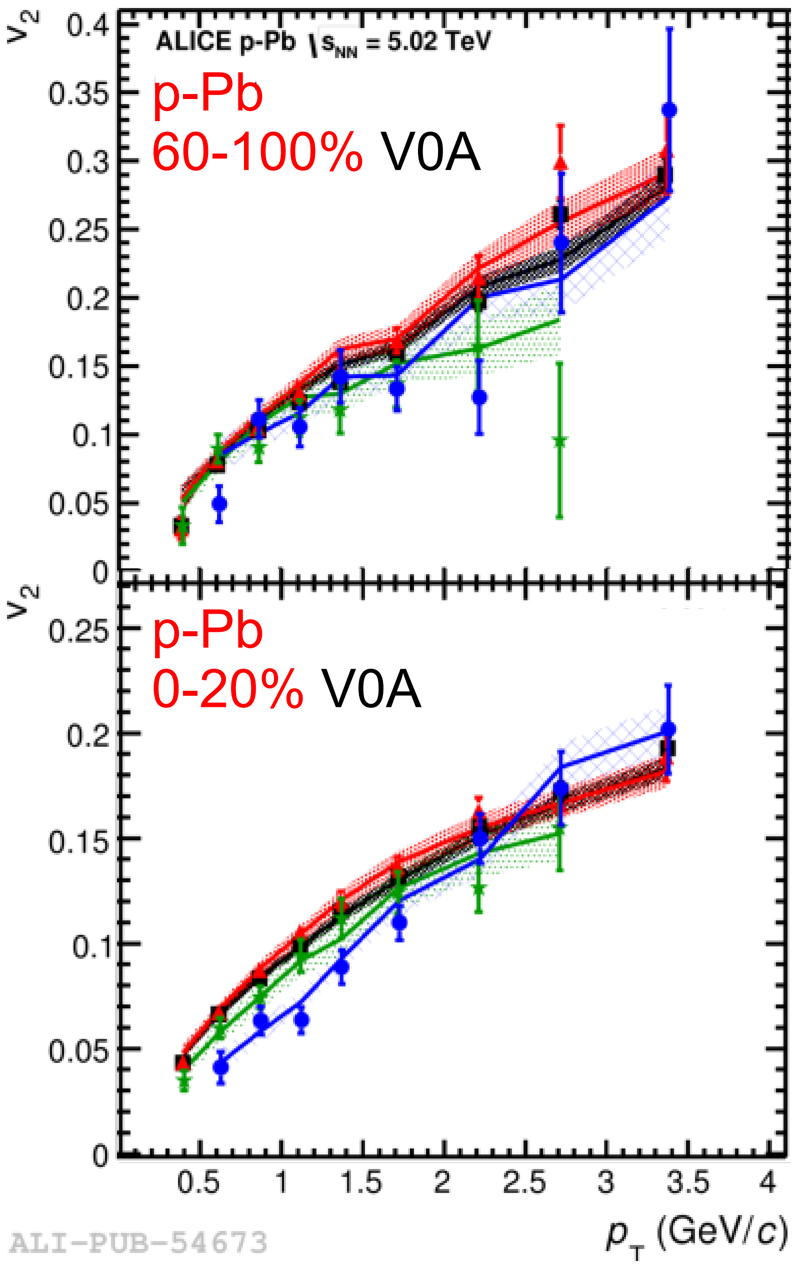
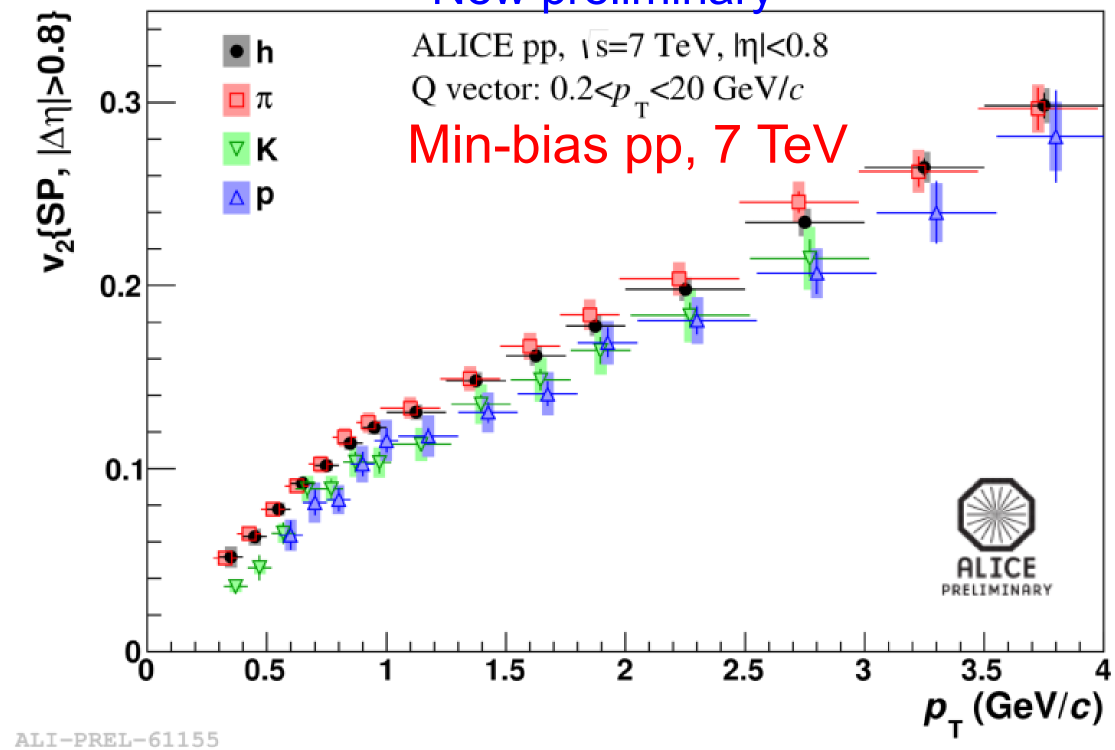


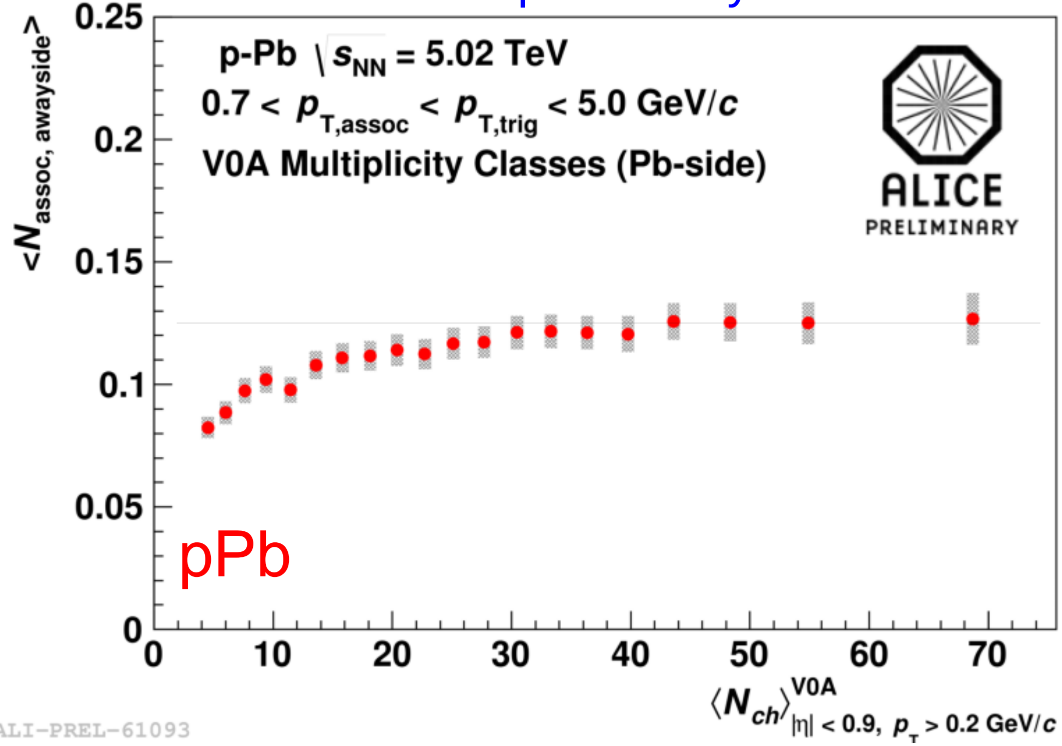
New preliminary



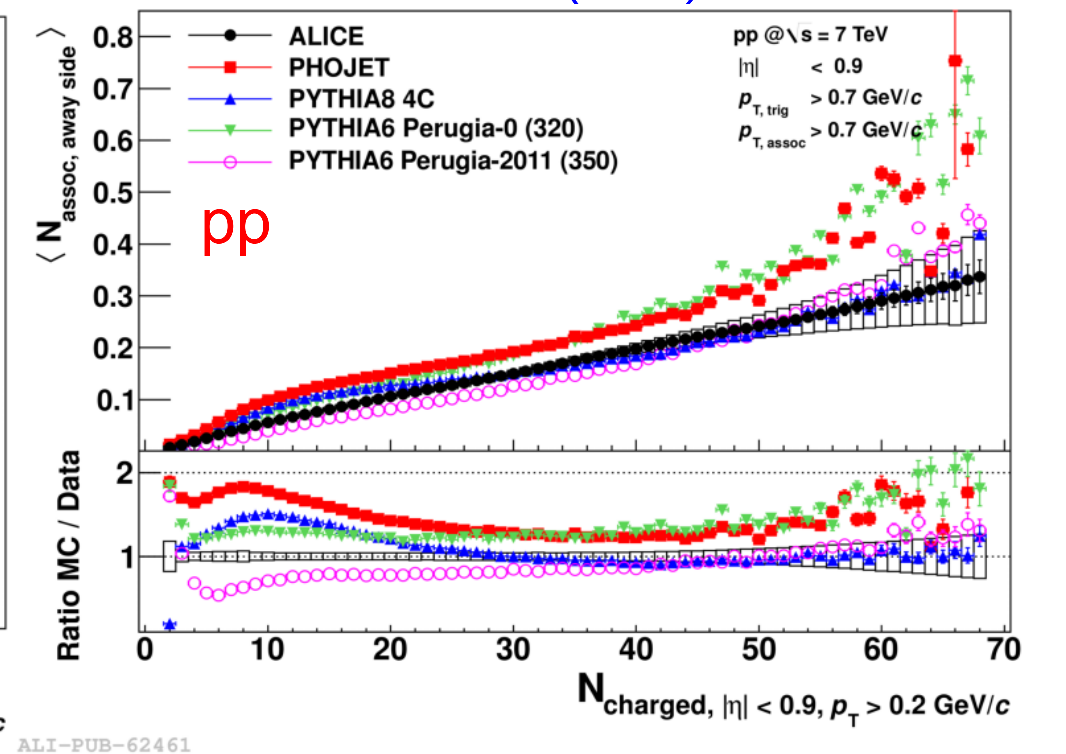
- Classical flow (scalar-product) method
  - Low multiplicity p-Pb and minbias pp show no mass ordering
  - High multiplicity p-Pb events exhibit mass ordering

Minijet away-side yield

New preliminary



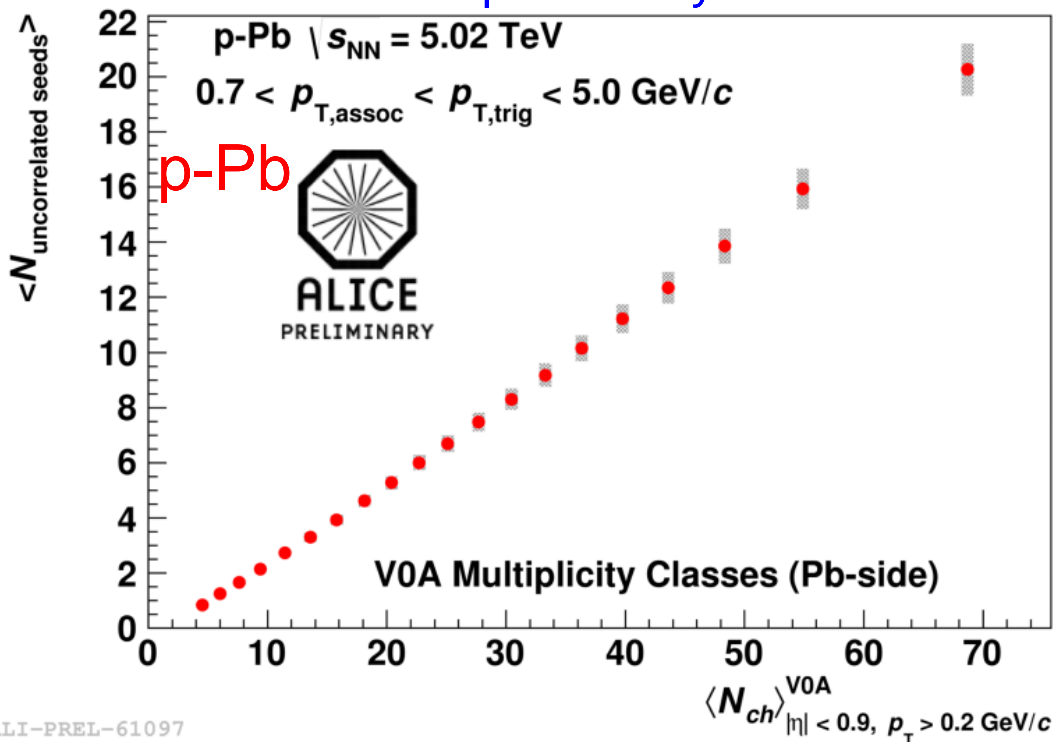
JHEP 1309 (2013) 049



- In p-Pb, high multiplicity events are not characterized by a higher number of associated particles on away-side
  - No bias on the near-side per trigger yield, except at low multiplicities to softer than average collisions
- Caveat: Different event selection than in pp

Minijet uncorrelated seeds

New preliminary



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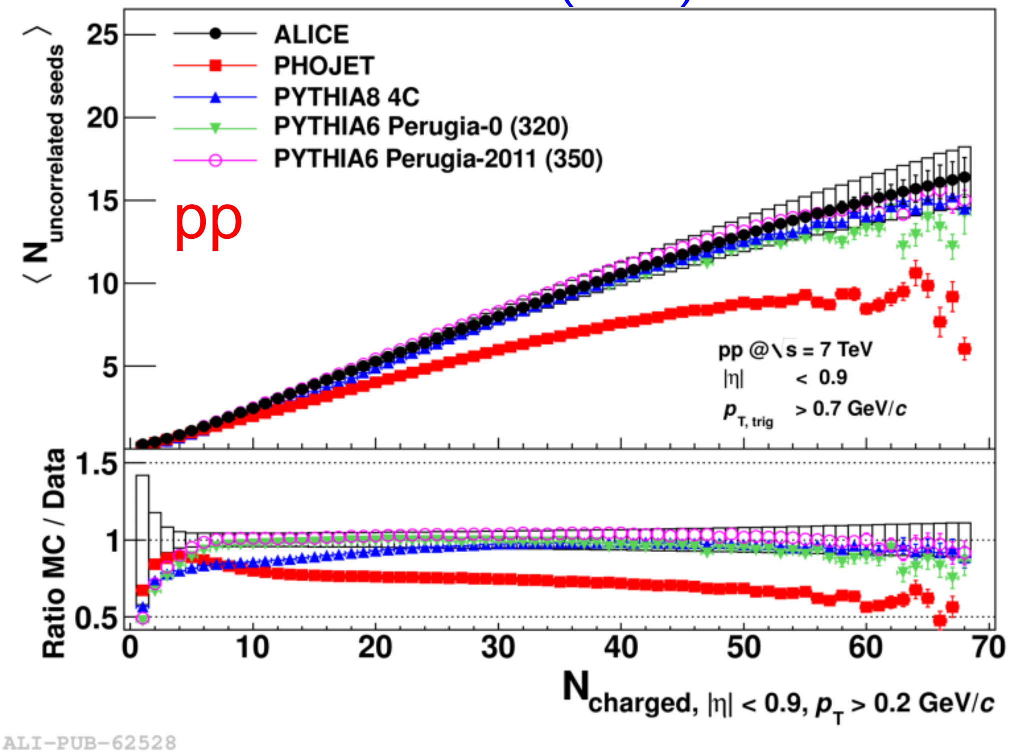

Define number of uncorrelated seeds:

$$< N_{\text{uncorrelated seeds}} > = \frac{< N_{\text{trigger}} >}{< N_{\text{trigger correlated}} >} = \frac{< N_{\text{trigger}} >}{< 1 + N_{\text{assoc,near+away}} >}$$

- In p-Pb, the number of uncorrelated seeds scales with V0A multiplicity
- In pp, saturation is reached for highest multiplicity (limited number of MPIs)
  - Caveat: Different event selection than in pp

Charge correlations using balance function

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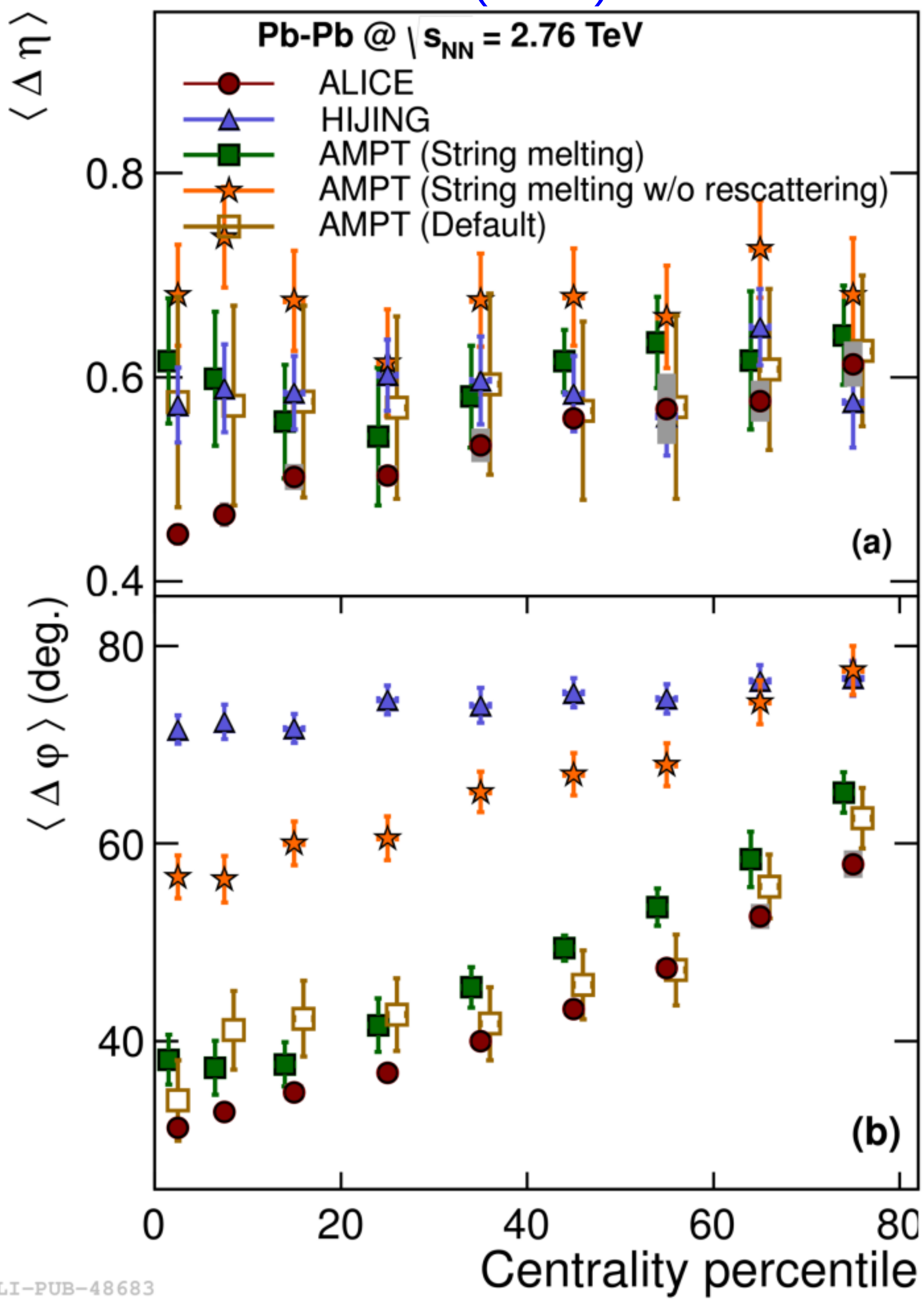
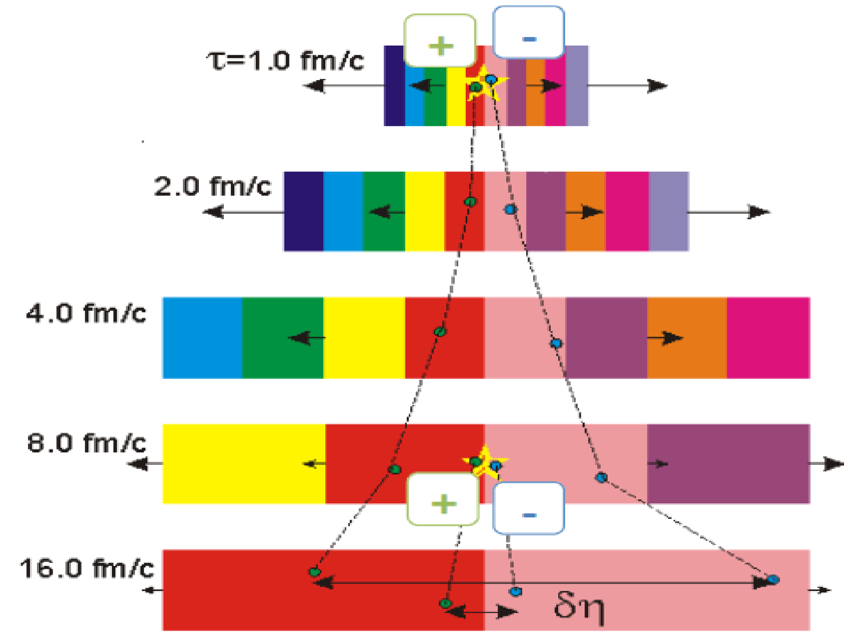




- Study system evolution by tracing charge separation in δη (and δφ)

$$BF(\delta\eta)=\frac{1}{2}\left(C_{US}(\delta\eta)-C_{LS}(\delta\eta)\right)$$

- Width depends on creation time and degree of collectivity

In Pb-Pb width decreases with increasing centrality and constrains models.

3-pion correlation formalism

$$
\begin{aligned}
N_3(p_1,p_2,p_3) &= f_1 N_1(p_1)N_1(p_2)N_1(p_3) \\
&+ f_2\left[N_2(p_1,p_2)N_1(p_3)+N_2(p_3,p_1)N_1(p_2)+N_2(p_2,p_3)N_1(p_1)\right] \\
&+ f_3 K_3(q_{\mathrm{inv},12},q_{\mathrm{inv},31},q_{\mathrm{inv},23})N_3^{QS}(p_1,p_2,p_3), \\
\mathbf{c}_3(p_1,p_2,p_3) &= 1+[2N_1(p_1)N_1(p_2)N_1(p_3) \\
&- N_2^{QS}(p_1,p_2)N_1(p_3)-N_2^{QS}(p_3,p_1)N_1(p_2)-N_2^{QS}(p_2,p_3)N_1(p_1) \\
&+ N_3^{QS}(p_1,p_2,p_3)]/N_1(p_1)N_1(p_2)N_1(p_3).
\end{aligned}
$$

$$
r_3(p_1,p_2,p_3) = \frac{\mathbf{c}_3(p_1,p_2,p_3)-1}{\sqrt{(C_2^{QS}(p_1,p_2)-1)(C_2^{QS}(p_3,p_1)-1)(C_2^{QS}(p_2,p_3)-1)}}
$$

In Core/Halo picture, given λ, the probability of choosing N particles from the core is $\lambda^{N/2}$

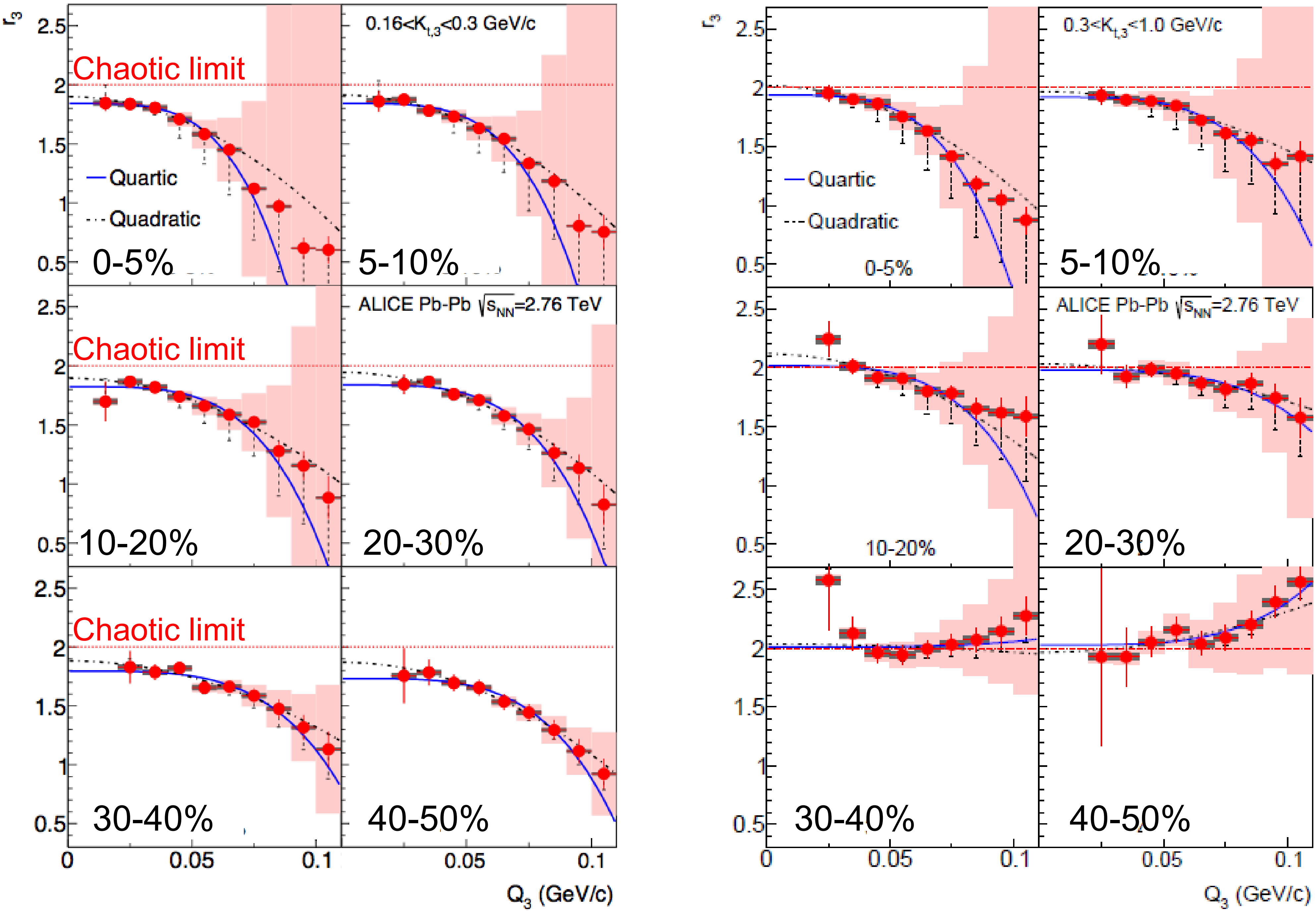
$f_1 = (1-\lambda^{1/2})3 + 3(1-\lambda^{1/2})2\lambda^{1/2} - 3(1-\lambda^{1/2})(1-\lambda)$

$f_2 = (1-\lambda^{1/2})$

$f_3 = \lambda^{3/2}$

3-pion to 2-pion ratio r_3

New arXiv:1310.7808



PHOS readout upgrade tasks

- SRU production Jan 2014
- TRU production planned for first part of 2014
- 1 module re-worked and FEE-DTC tested (global)
- 1 module re-worked and FEE-DTC tested (standalone)
- 2 modules FEEs being re-worked
- Feed-through for R/O (RJ45) in production and for programming JTAG designed
- Minor changes to analysis software
- Infrastructure in P2 designed