Special Requests During HL-LHC

- charge:
  – special needs for pp operation
    - at other energies than top energy
    - at other luminosities than top luminosity
  – needs for polarity reversal of spectrometers
  – needs of detectors for forward physics

Hannes Wessels
with input from: C. Roland, B. Cole, A. Dainese, M. Deile, B. Schmidt. J. Jowett, D. Manglunki…

Goals for Run 2

- complete the approved heavy ion program, i.e. collection of 1/nb in Pb-Pb collisions at top energy (13 TeV p equivalent (5.5 TeV)
- some pp reference running at corresponding top Pb-Pb energy
- likely another p-Pb run

pp reference, pA, light nuclei

- pp reference at 5.5 TeV required
  - HF: D and B cross sections can be scaled in √s with pQCD, but large scaling uncertainty for charm at low p_T (>50%)
  - Quarkonia: no robust theoretical guidance for interpolating
  - Jets: FF and jet energy scale calibration depends strongly on √s
- Required integrated luminosity for pp at 5.5 TeV
  - ALICE (for HF and charmonia needs): **~10/pb** (see CERN-LHCC-2012-012)
    - e.g. 10^6 s at 200 kHz (L leveled at 6×10^{30})
  - ATLAS / CMS: match Pb-Pb yields for high pT process, **~300/pb**
- p-Pb or p-Ar and Ar-Ar: a possibility to be considered for schedule after LS2, with priority that will be defined based on the outcome of the future data analysis (high statistics Pb-Pb and p-Pb from Run 2)

pp reference at 5.5 TeV: Heavy flavour

- pp reference used e.g. to define the nuclear modification factor:

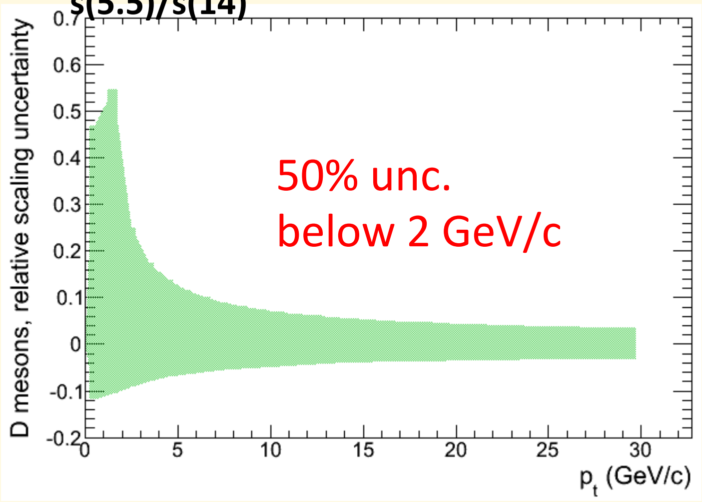
$$R_{AA}(p_T) = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T}$$

- Reference scaling from 14 to 5.5 TeV with pQCD introduces a large systematic error for low-p_T charm

Particle	D^0	
p_t interval (GeV/c)	2–3	12–16
Data syst. pp and Pb–Pb	$^{+33}_{-41}\%$	$^{+28}_{-28}\%$
Data syst. in Pb–Pb	$^{+26}_{-22}\%$	$^{+22}_{-22}\%$
Data syst. in pp	17%	17%
$\sqrt{s}$-scaling of the pp ref.	$^{+10}_{-31}\%$	$^{+5}_{-6}\%$

ALICE, JHEP 1209 (2012) 112

Relative theoretical uncertainty on D
s(5.5)/s(14)



FONLL, Cacciari et al., JHEP 1210 (2012) 137

pp reference at 5.5: Jet energy scale

- Jet Energy Scale Correction (JEC) in CMS:
  - JEC from MC + Data Driven JEC

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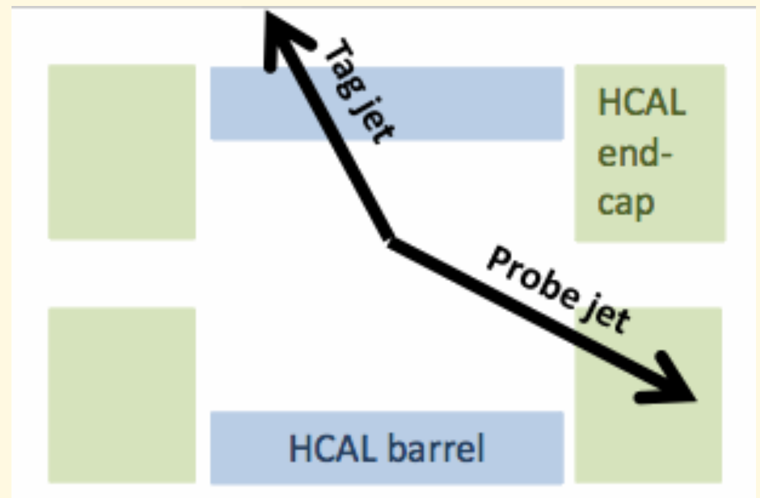
Tag & Probe

↙ ↘

At HCAL Barrel   At HCAL Endcap



  - Described in CMS, JINST 6 (2011) 11002
  - Corrects for the calorimeter response difference in data and MC
    - Calorimeter response depends on particle composition of the jet, I.e the jet fragmentation function
    - Jet fragmentation functions depend on the parton flavor composition
    - Both fragmentation function and parton flavor mix change with c.m.s energy
    - Fragmentation functions are not very well described in current event generators
  - pp data (unquenched!) crucial to establish the JEC at a given beam energy
    - Keep in mind, a 2% shift in JEC causes a ~30% change in jet yield at a given p_T

pp reference at 5.5 TeV: CMS and ATLAS request

- pp reference data at Pb-Pb cms energy
  - pp L_{int} equivalent to N_{coll}-scaled Pb-Pb L_{int}
  - Ideally the integrated luminosity of the pp reference data should follow the Pb-Pb integrated lumi, without too much delay
  - Short pp reference runs every year would be desirable
  - For Run 2 as well as after LS2

- N_{coll}-scaled equivalent luminosity:

  For S>>B (high-p_T, jets)

  → Signif = 1/sqrt(S) → $S_{pp} \sim S_{PbPb} \sim N_{coll}\, S_{pp}$

  and N_{coll} ~ 1500 in central Pb-Pb at LHC

  → for Pb-Pb 10/nb: pp ~ few 100/pb

pp reference at 5.5 TeV: ALICE request

- ALICE LOI: assessment of pp reference for low-p_T, low S/B measurements: charm mesons and baryons, charmonia
- Statistical error on pp reference should be negligible wrt Pb-Pb (e.g. √2 times smaller) → $N_{pp}=2\ N_{PbPb}\ [(\text{Signif/ev})_{PbPb}/(\text{Signif/ev})_{pp}]^2$
- For L_{int}^{PbPb} = 10/nb:
  - D^0 → $\mathbf{L_{int}^{pp} \sim 6/pb}$ (4x10^{11} events)
    - Valid also for D-from-B and for D_s measurement
  - J/y, L_c → $\mathbf{L_{int}^{pp} \sim 0.6/pb}$

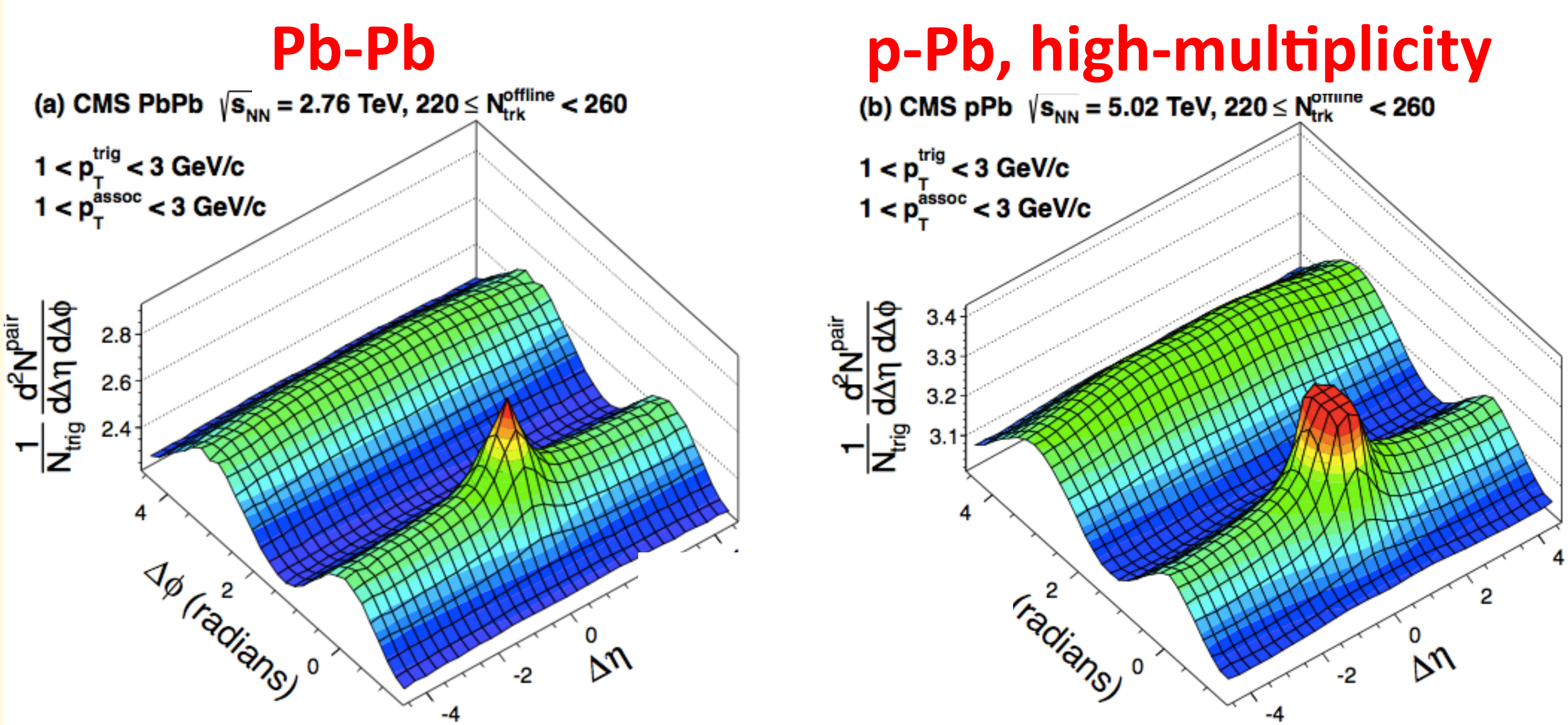
e.g. 10^6 s (1 month) at ~10^6 s at 200 kHz (L leveled at 6x10^{30})

- For high-p_T measurements / jets: the current ALICE baseline is to use pp data at 7-8-13-14 TeV and scale / interpolate with pQCD

ALICE, CERN-LHCC-2012-012

p-Pb 2013 run: high multiplicity

- Near-side ridge (long-range correlation in η at $\Delta\phi$=0) observed in high-multiplicity pp and p-Pb (CMS)

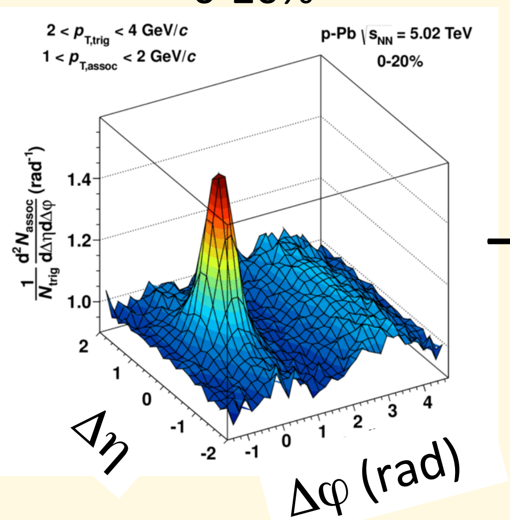


CMS, PLB 724 (2013) 213

Double-ridge in p-Pb!

p-Pb, high-multiplicity

0-20%



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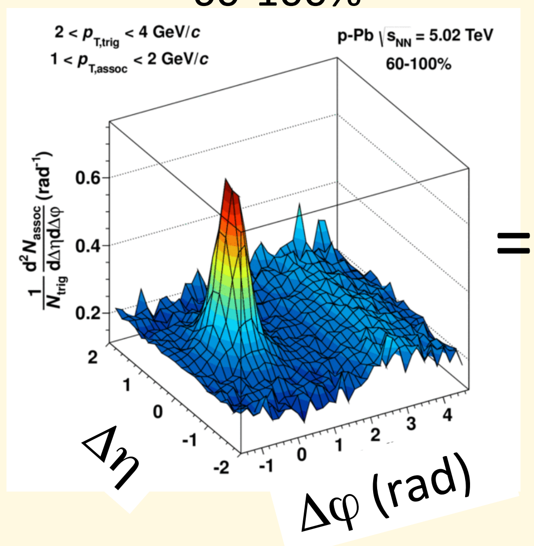
p-Pb, low-multiplicity

60-100%



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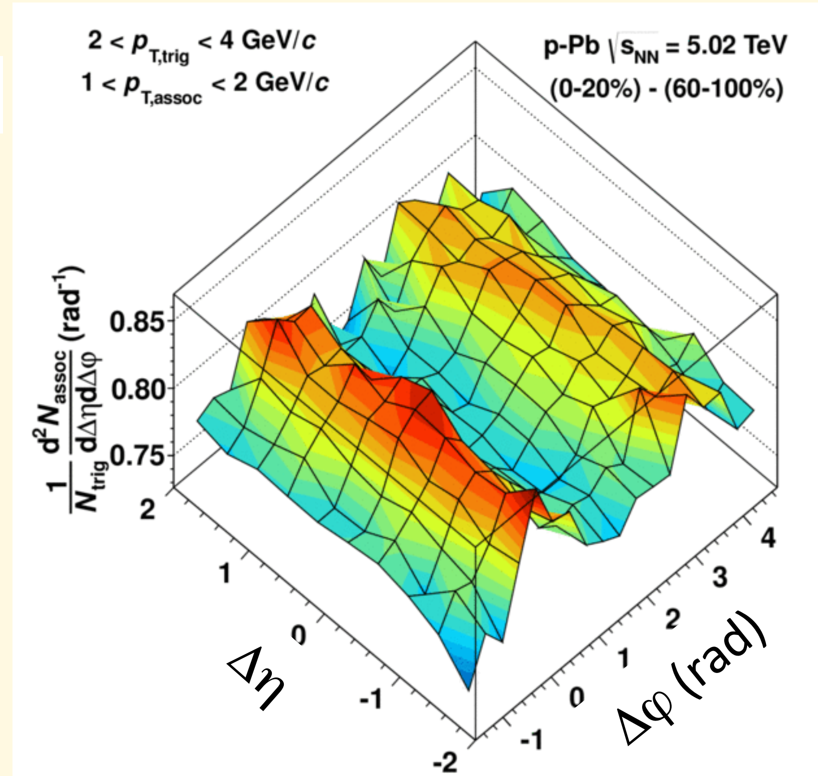
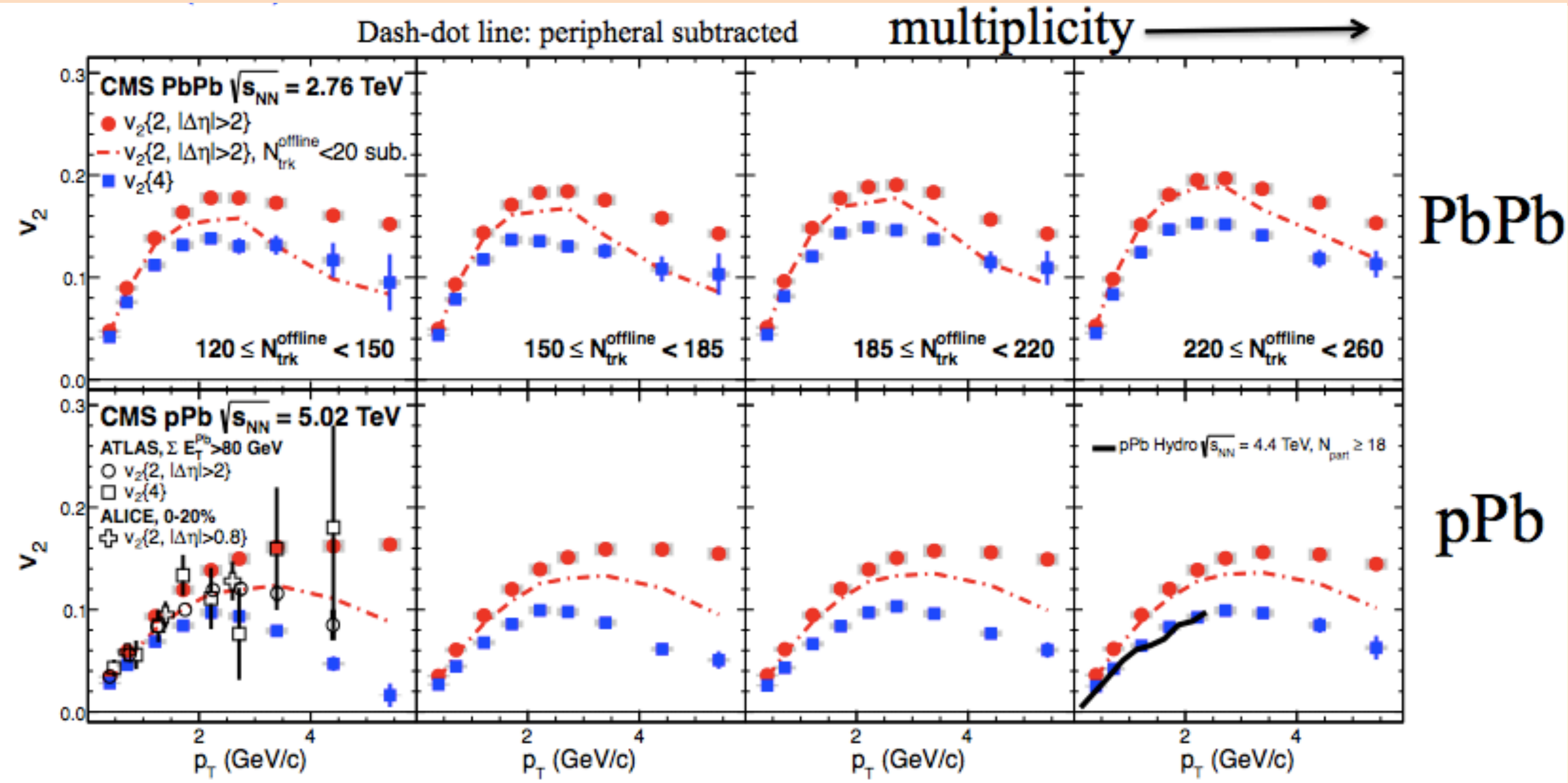


ALICE, PLB719 (2013) 29

- Idea: subtract the “pp-like” structure of low-multiplicity p-Pb from the structure of high-multiplicity p-Pb
- Double ridge discovered by ALICE, followed by ATLAS
- Resembles the structure that in Pb-Pb is attributed to collective flow

Quantifying the modulation: v_2

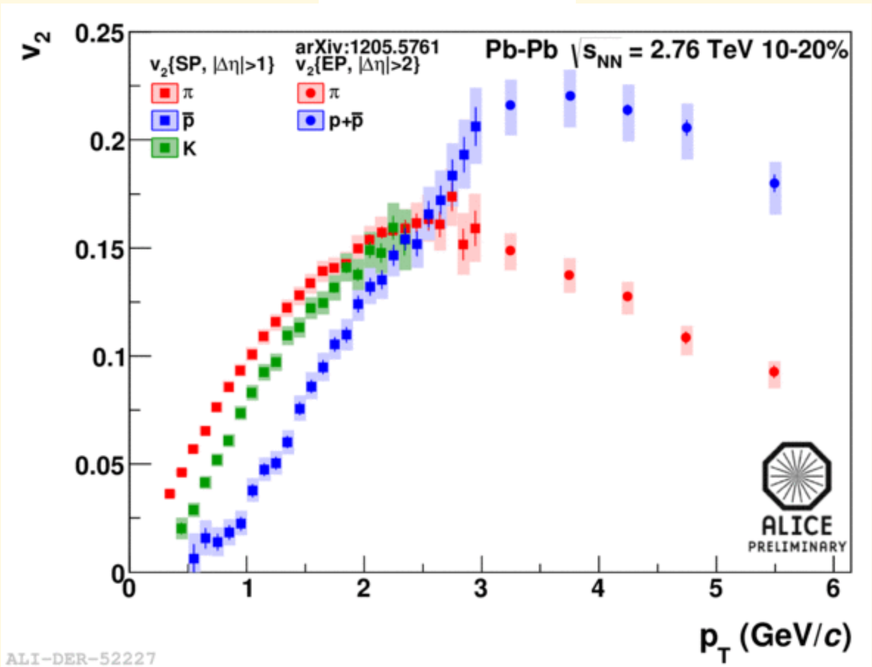


- v_2 vs. p_T and multiplicity with various methods
- Similar pattern in p-Pb and Pb-Pb
- v_2 rises to 2 GeV, then ~flattens out to 5

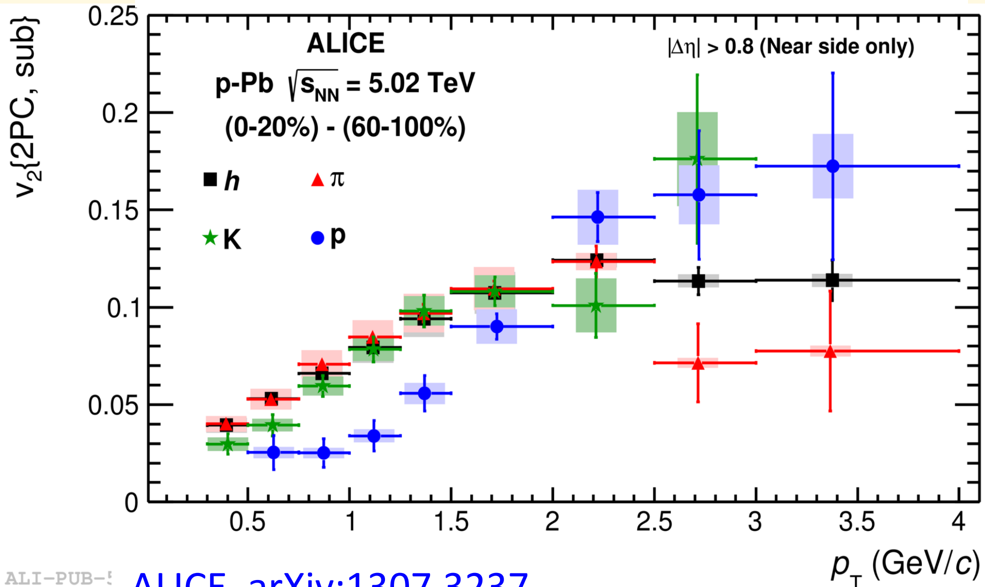
CMS, PLB 724 (2013) 213

Is there *flow* in p-Pb? Look at identified particles

Pb-Pb



p-Pb, high-multiplicity



ALICE, arXiv:1307.3237

- Mass ordering, interpreted in terms of collective radial and elliptic flow

- Clear indication for mass ordering in p-Pb
- Resembles Pb-Pb and supports "flow" picture

pA in Run 2 and after LS2

- In view of the intriguing findings in high-multiplicity p-Pb:
- p-Pb run in Run 2 requested by all exp.
  - To be agreed on the energy (either 5.1 like PbPb) or maximum energy ~8 TeV
    - Argument for 5.1: p-Pb running at the same cms energy as PbPb instead of the top energy could be preferable, in order to limit the number of pp reference data sets needed. Needs more physics studies to balance the gain in high p_T statistics vs availability of reference data
- Requested a very high lumi p-Pb run after LS2
  - Exploiting the upgraded detector capabilities

Light ion (Ar or O) pA / AA

To be finalised

- Light ion running could be interesting to study
  - jet quenching (AA)
  - onset of "flow-like" effects (pA)
- Lower underlying event multiplicity reduces systematic error on measurements
- Potentially higher N_{coll} weighted Luminosity achievable

- a possibility to be considered for schedule after LS2, with priority that will be defined based on the outcome of the future data analysis (high statistics Pb-Pb and p-Pb from Run 2)

ALICE Upgrade

Probably will be removed (covered in other talks)

- ALICE will install its major detector upgrade during LS2 in 2018
  The upgrade aims at precision measurements of the Quark Gluon Plasma (QGP), with a factor 100 gain in statistics (x10 luminosity, x10 via pipelined readout)

- The plan is to run at Pb-Pb luminosities of $7x10^{27}$ $cm^{-2}s^{-1}$ following the upgrade in LS2
- The ALICE upgrade program assumes an integrated luminosity of $>10nb^{-1}$ achieved during a 6-7 year program after LS2
- The basic assumption is to continue the pattern of one month LHC heavy ion operation per year

Scope of ALICE Upgrade

Probably will be removed (covered in other talks)

- new, ultra-low mass silicon tracker
  around a very small beam-pipe (ID 34.4 mm)
- upgrade of the TPC with GEM detectors for continuous (un-gated) readout
- electronics upgrade of the other sub-detectors
- major upgrade of the online systems to process all Pb-Pb collisions upon a (minimum bias) interaction trigger

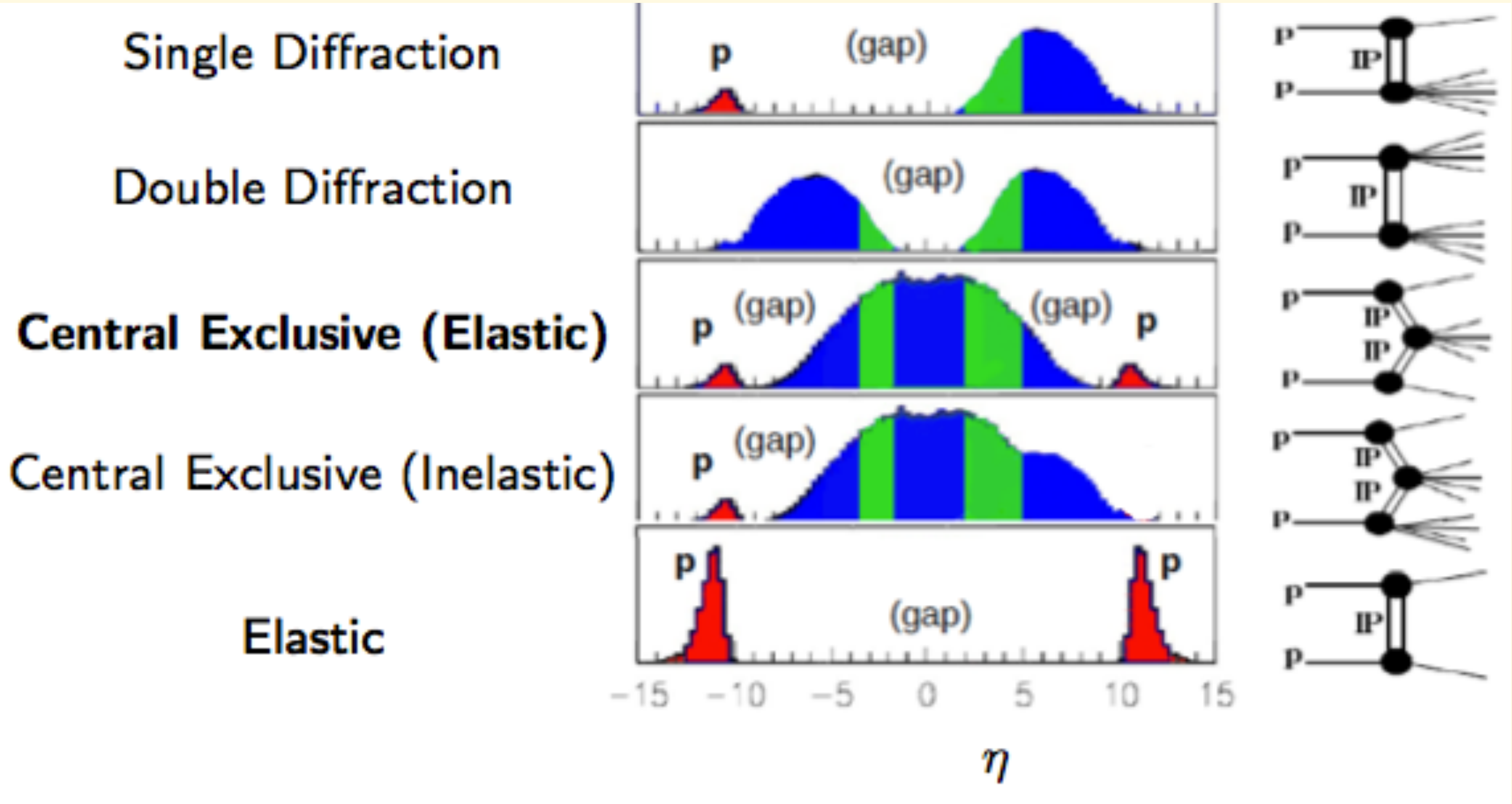
In parallel to HL-LHC, a HL-PbPb-LHC program is needed

LHCb Upgrade

- Burkhard pls add correspondingly

Forward Physics - LHCb

- for Run 2, installation of trigger counters FSC – Forward Shower Counters is planned. operation at μ~1 is routinely achieved



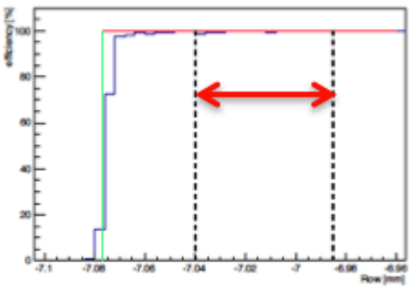
LHCb Forward Physics after Upgrade

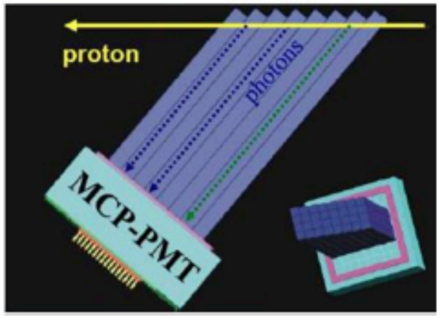
- add proton tagging with Roman Pots (given compatibility with LHCb upgrade)

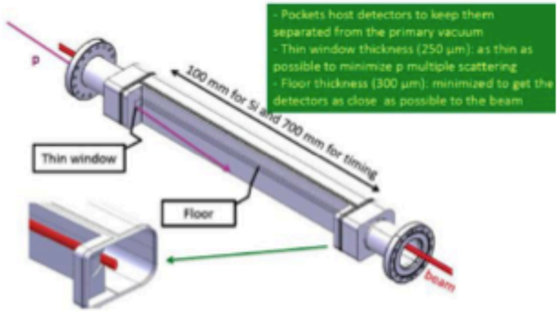
Good spatial resolution (~10 μm) for ~ 1 μrad angular resolution ☑
Silicon sensor radiation hardness ☑
Minimum dead space at edge of silicon sensor ☑
40 MHz readout fully integrated at trigger level – unique to LHCb! ☑

10 ps timing ☒
Mechanics, beam location ☒

LHCb: edgeless pixels

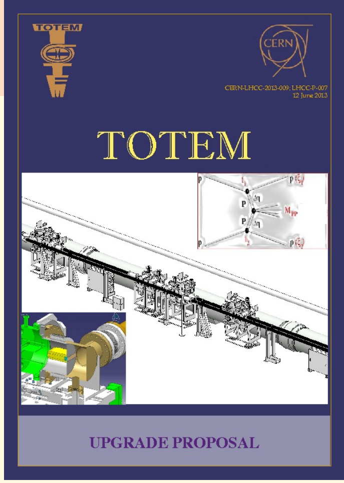






Christophe Royon: AFP developments

TOTEM Consolidation and Upgrade

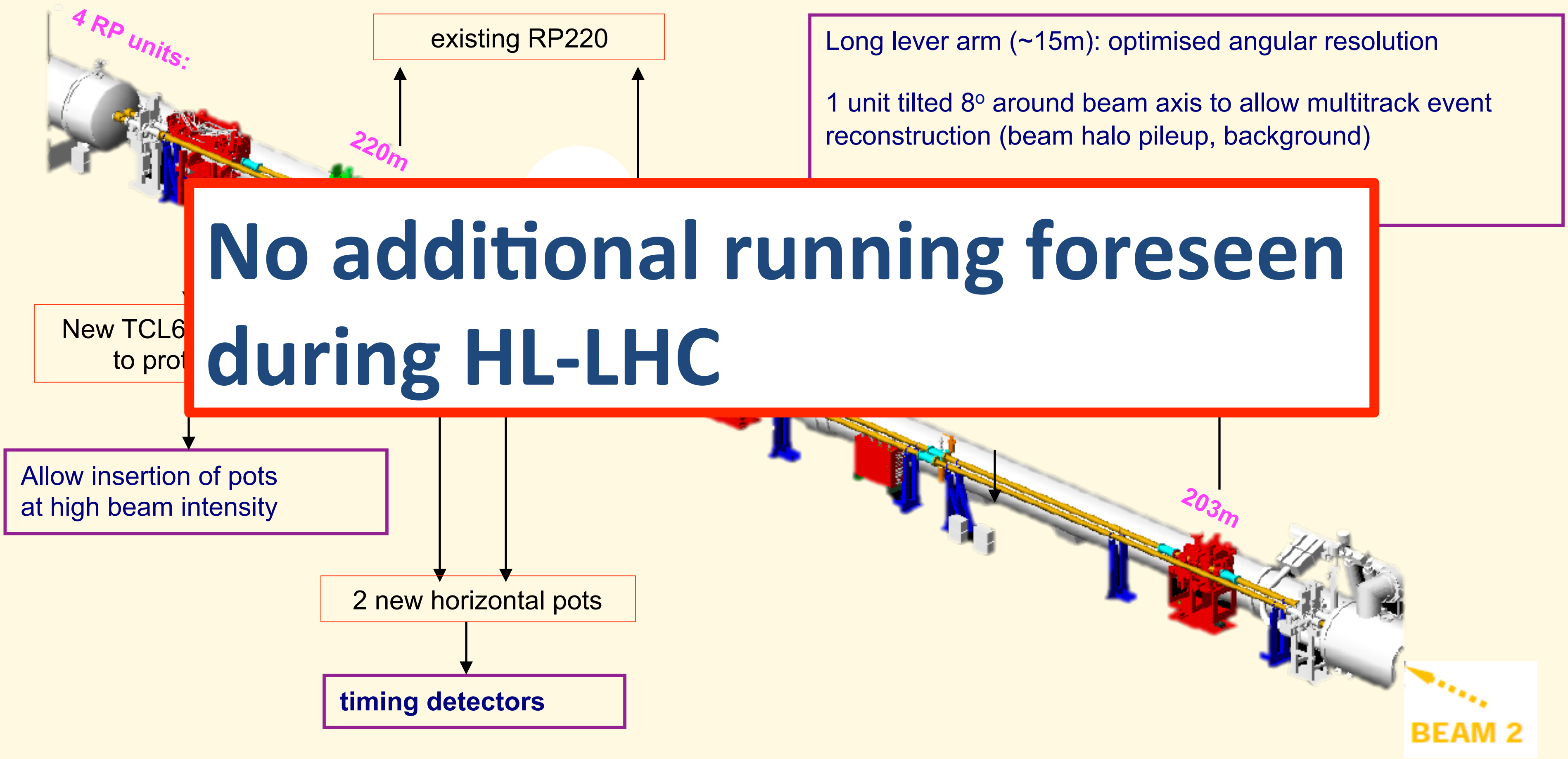


From LS1 to LS3:

- Complete TOTEM's approved standalone physics programme at maximum LHC energy
- Common forward physics programme with CMS: central production, hard diffraction

→ keep existing RP220 station unchanged for high-β* operation

→ upgrade RP spectrometer for operation at low β* and high luminosities:
pileup resolution with timing detectors, multi-track resolution with pixel detectors



No additional running foreseen during HL-LHC

Machine Needs for LS2

1. Upgrade of **SPS injection system**
2. Installation of **collimators** in dispersion suppression region around IR2 (possibly also in IR7) for ions

Polarity Reversal in Spectrometers

- For complete control of systematics especially in very rare decay channels, LHCb will need roughly equal statistics for both sprectrometer settings for all relevant triggers
- ALICE will need infrequent polarity changes for control on space charge distortions at very high luminosity

EXTRA SLIDES

Possible Future Running Scenario

ALICE Upgrade LOI, CERN-LHCC-2012-012

Not to be shown in this form

- Possible running scenario after upgrade:
  - 2019 – Pb–Pb 2.85 nb^{-1}
  - 2020 – Pb–Pb 2.85 nb^{-1} (low magnetic field)
  - 2021 – pp reference run
  - 2022 – LS3
  - 2023 – LS3
  - 2024 – Pb–Pb 2.85 nb^{-1}
  - 2025 – ½ Pb–Pb 1.42 nb^{-1} + ½ p–Pb 50 nb^{-1}
  - 2026 – Pb–Pb 2.85 nb^{-1}