

Special Requests During HL-LHC

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

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Goals for Run 2

- complete the approved heavy ion program, i.e. collection of at least $1/nb$ in Pb-Pb collisions at top energy (13 TeV p equivalent (5.1 TeV))
- some pp reference running at corresponding top Pb-Pb energy
- likely another p-Pb run

pp reference, pA, light nuclei (Runs 3/4)

- pp reference at 5.5 TeV required
 - HF: D and B cross sections can be scaled in \sqrt{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 \sqrt{s}
- Required integrated luminosity for pp at 5.5 TeV
 - ALICE (for HF and charmonia needs): **$\sim 10/\text{pb}$** (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 at high p_T
 $10/\text{nb (PbPb)} \rightarrow \mathbf{300/\text{pb (pp)}}$
- p-Pb, p-Ar and Ar-Ar:
 - p-Pb at high luminosity
 - p-Ar and Ar-Ar possibly to be considered for schedule after LS2
priority will be defined based on the outcome of analysis of high statistics Pb-Pb and p-Pb from Run 2

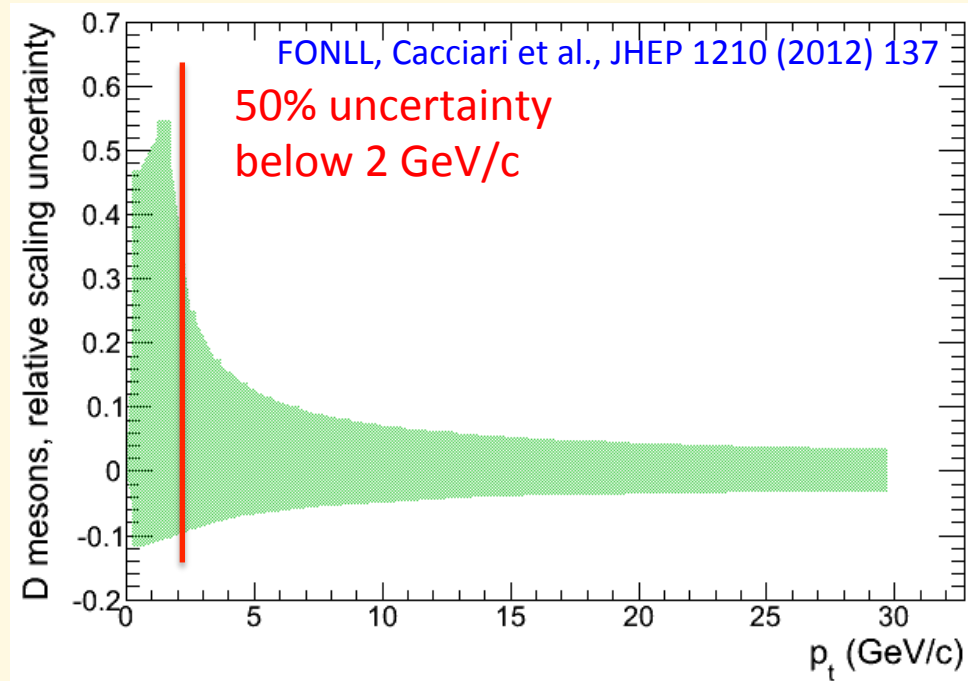
pp reference at 5.5 TeV: heavy flavour

- 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

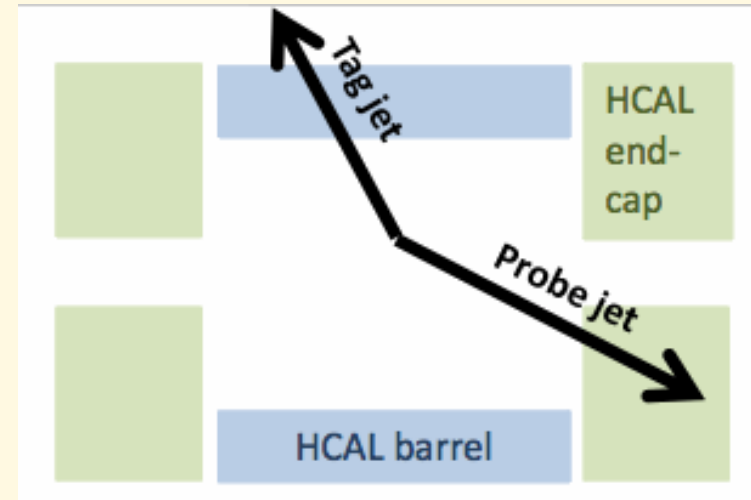
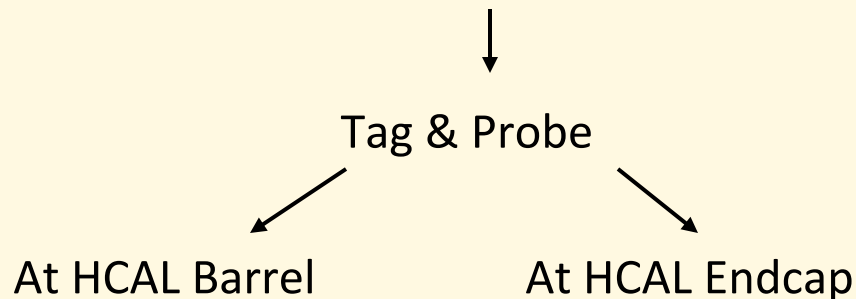
Relative theoretical uncertainty on D production vs(5.5)/vs(14)



pp reference at 5.5 TeV: jet energy scale

- Jet Energy Scale Correction (JEC) in CMS:

- JEC from MC + Data Driven JEC



- 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
 - 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 $S \gg B$ (high- p_T , jets)
 - $\text{Signif} = 1/\sqrt{S} \rightarrow S_{\text{pp}} \sim S_{\text{PbPb}} \sim N_{\text{coll}} S_{\text{pp}}$
 - and $N_{\text{coll}} \sim 1500$ in central Pb-Pb at LHC
 - for Pb-Pb 10/nb: pp $\sim 300/\text{pb}$

pp reference at 5.1 TeV: ALICE request

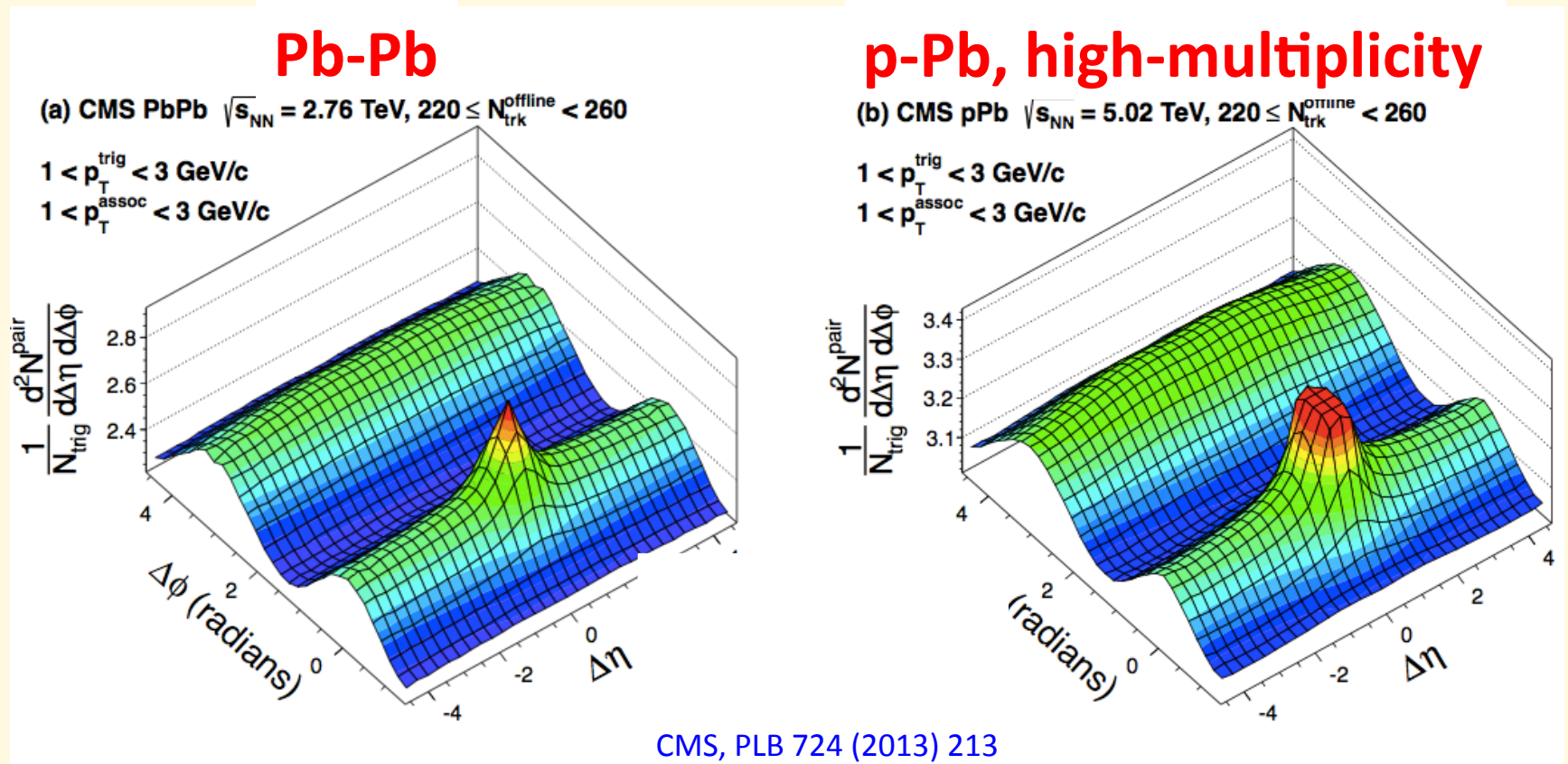
- ALICE LOI: assessment of pp reference for low- p_T , low S/B measurements: charm mesons and baryons, charmonia
- Statistical error on pp reference should be negligible wrt Pb-Pb (e.g. $\sqrt{2}$ times smaller) $\rightarrow N_{pp} = 2 N_{PbPb} [(Signif/ev)_{PbPb} / (Signif/ev)_{pp}]^2$
- ◆ For $L_{int}^{PbPb}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

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

p-Pb 2013 run: high multiplicity

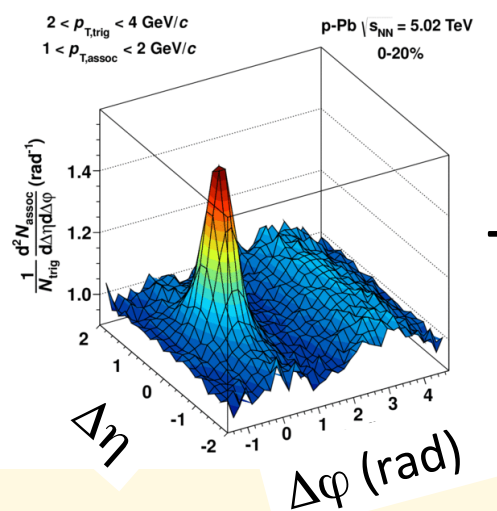
- Near-side ridge (long-range correlation in η at $\Delta\phi=0$) observed in high-multiplicity pp and p-Pb (CMS)



Double-ridge in p-Pb

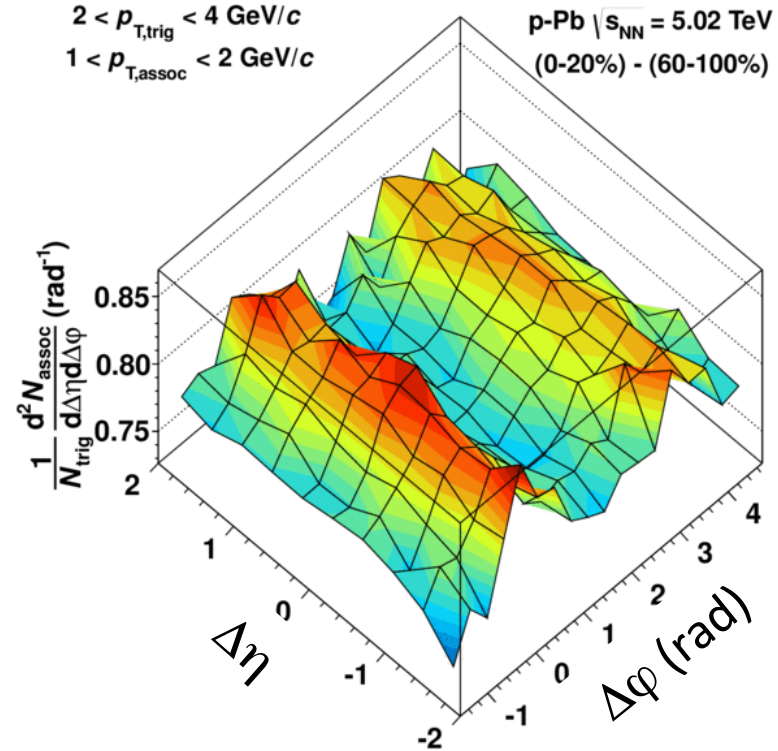
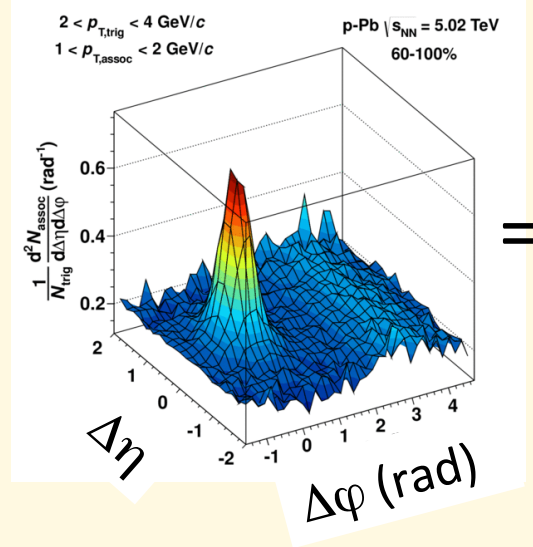
p-Pb, high-multiplicity

0-20%



p-Pb, low-multiplicity

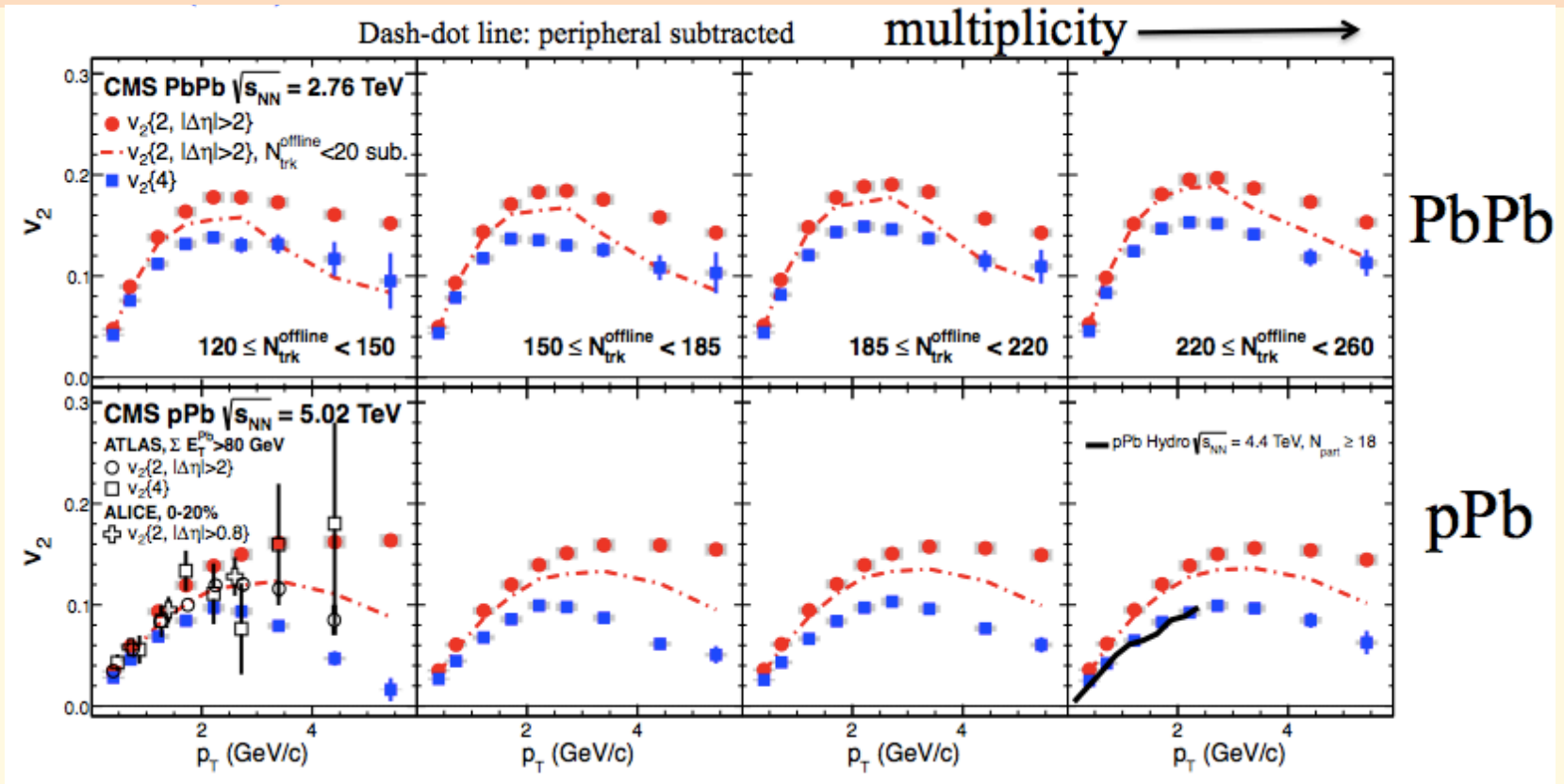
60-100%



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

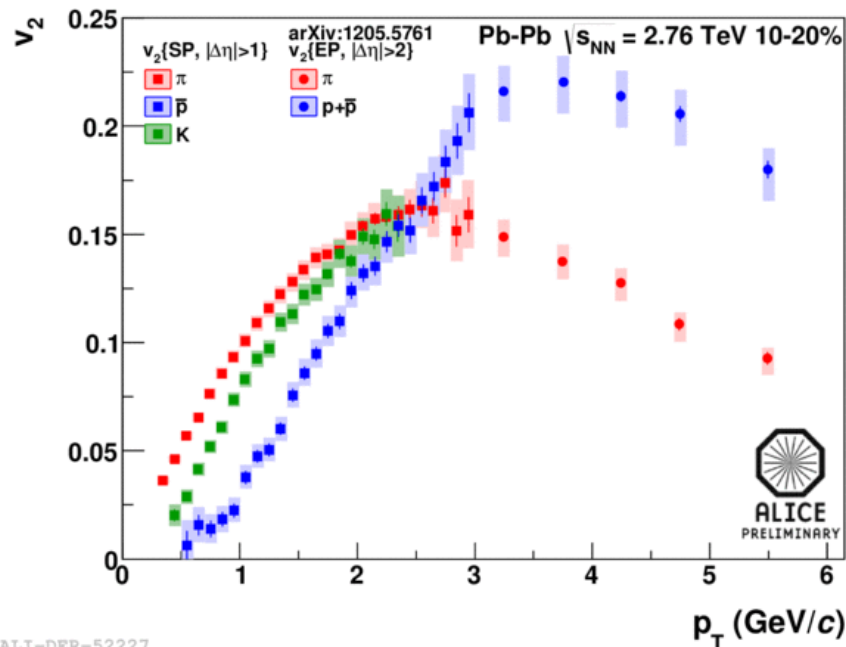


- v_2 vs. p_T and multiplicity with various methods
- Similar pattern in p-Pb and Pb-Pb
- v_2 rises to 2 GeV, then \sim flattens out to \sim 5 GeV

Is there *flow* in p-Pb?

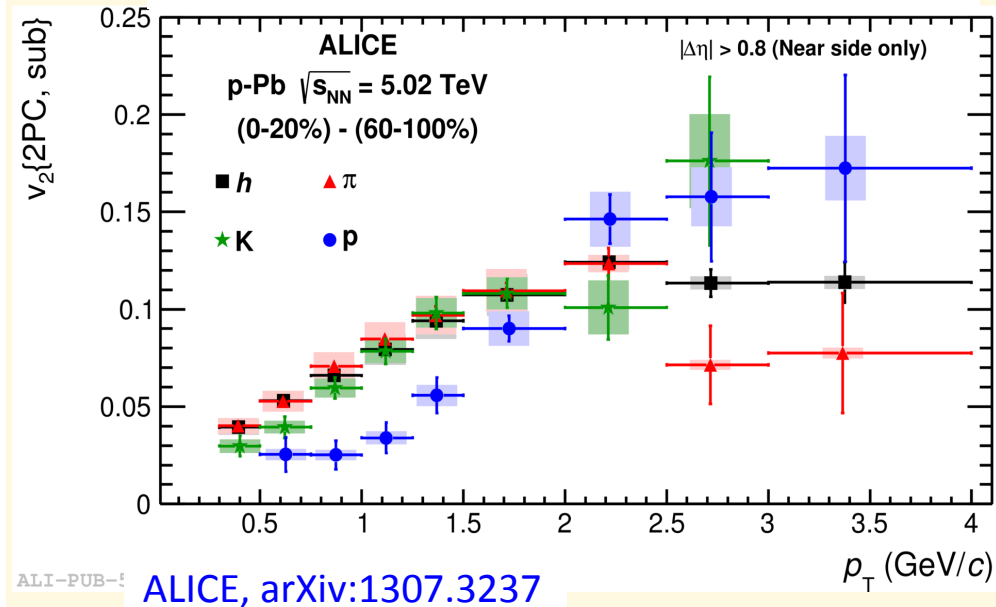
Look at identified particles

Pb-Pb



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

p-Pb, high-multiplicity



- 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:

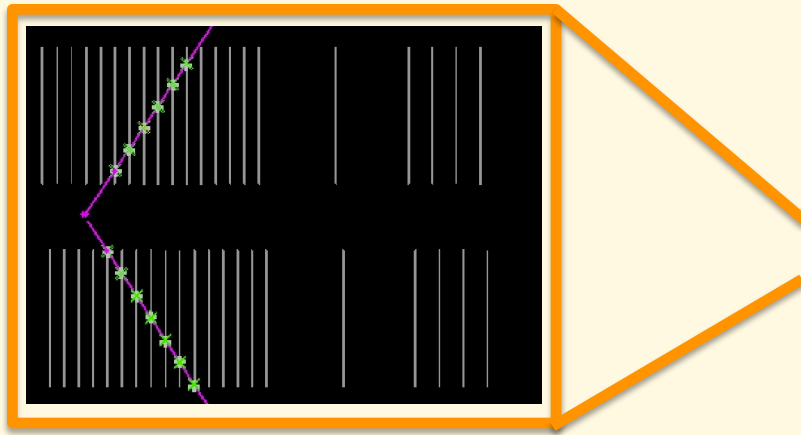
- p-Pb run in Run 2 requested by all experiments ($\sim 50/\text{nb}$)
 - Preferred energy under discussion: either 5.1 TeV like PbPb or maximum energy ~ 8 TeV
 - Argument for 5.1 TeV: limit the number of pp reference data sets needed (needs more physics studies to balance the gain in high p_T statistics vs. availability of reference data)
 - Argument for maximum energy: ultra-peripheral collisions (unique γp collider), measure the total $\sigma_{\gamma p}$ at the maximum possible energy
- Request for a very high lumi ($\sim 1/\text{pb}$) p-Pb run after LS2
 - Exploiting the upgraded detector capabilities

Light ion (Ar or O) pA / AA

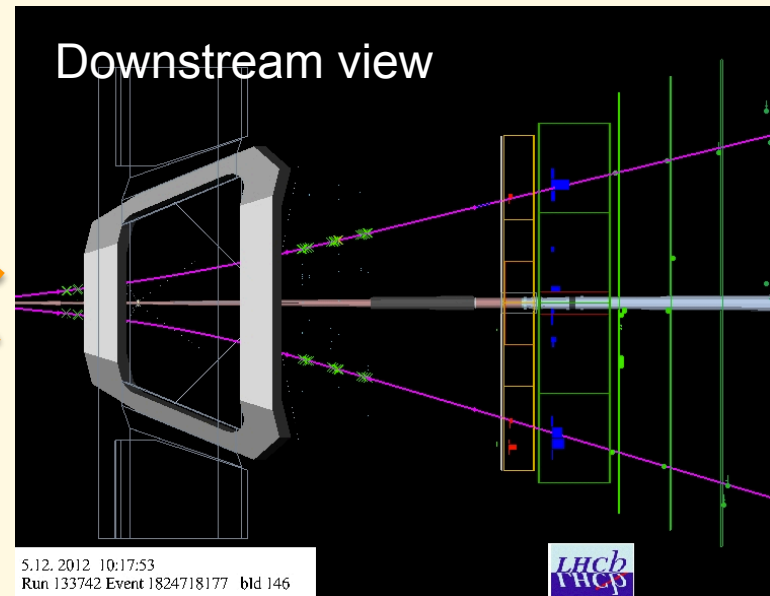
- ◆ Light ion running could be interesting to study
 - ◆ jet quenching (AA)
 - ◆ onset of “flow-like” effects (pA)
- ◆ Lower underlying event multiplicity reduces systematic error on measurements
- ◆ Potentially higher N_{coll} weighted luminosity achievable
 - possibly to be considered for schedule after LS2
priority will be defined based on the outcome of analysis of high statistics Pb-Pb and p-Pb from Run 2

Forward physics - LHCb

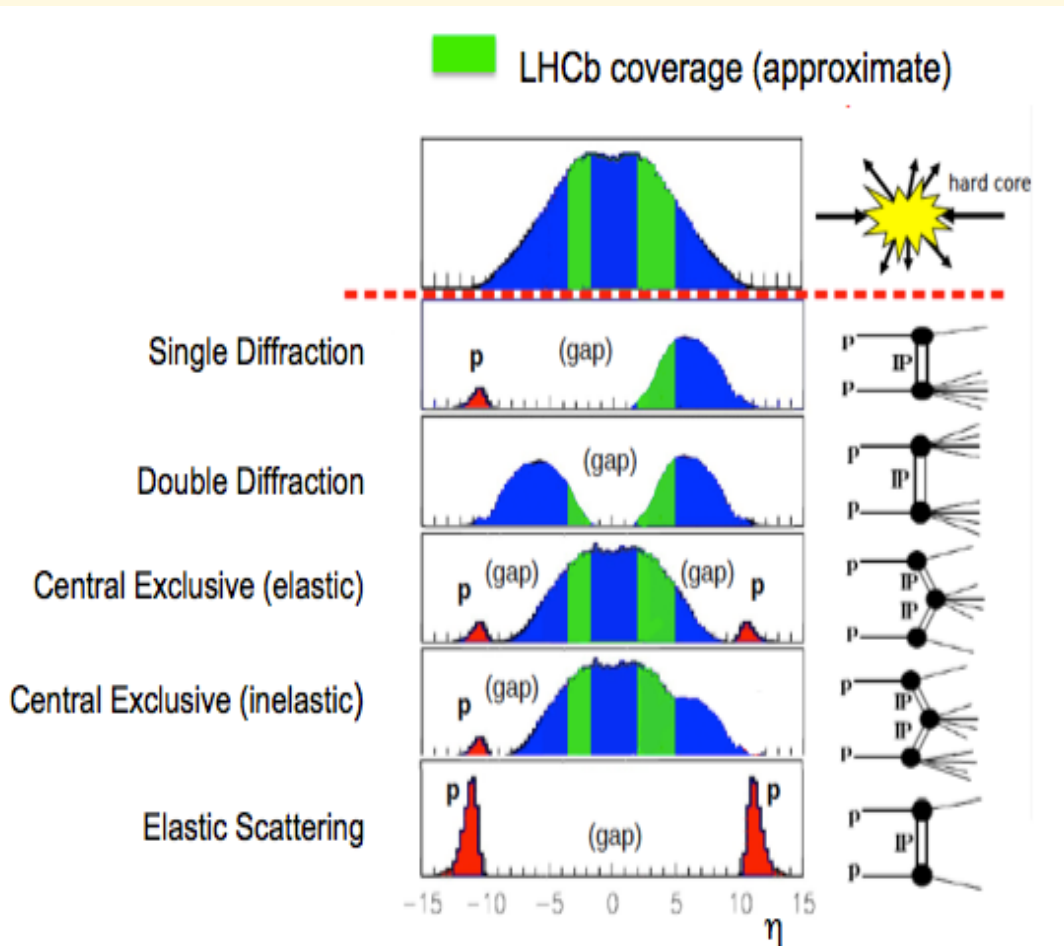
- LHCb forward physics programme in Run 1 & Run 2 focused on Central Exclusive Production – benefits from low pileup of standard LHCb operation
- For Run 2, installation of forward shower counters is planned to suppress inelastic background – HERSCHEL project
- The counters are compatible with routine operation and benefit from 40 MHz running ($\mu \sim 1$)



VELO RZ view,
 J/ψ Central Exclusive Production candidate

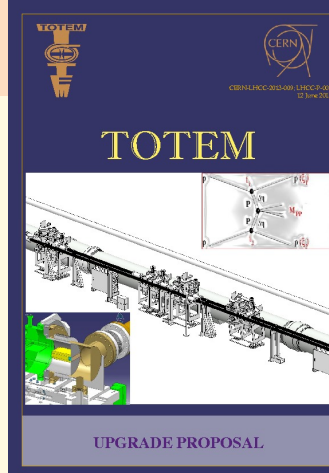


Forward physics - LHCb



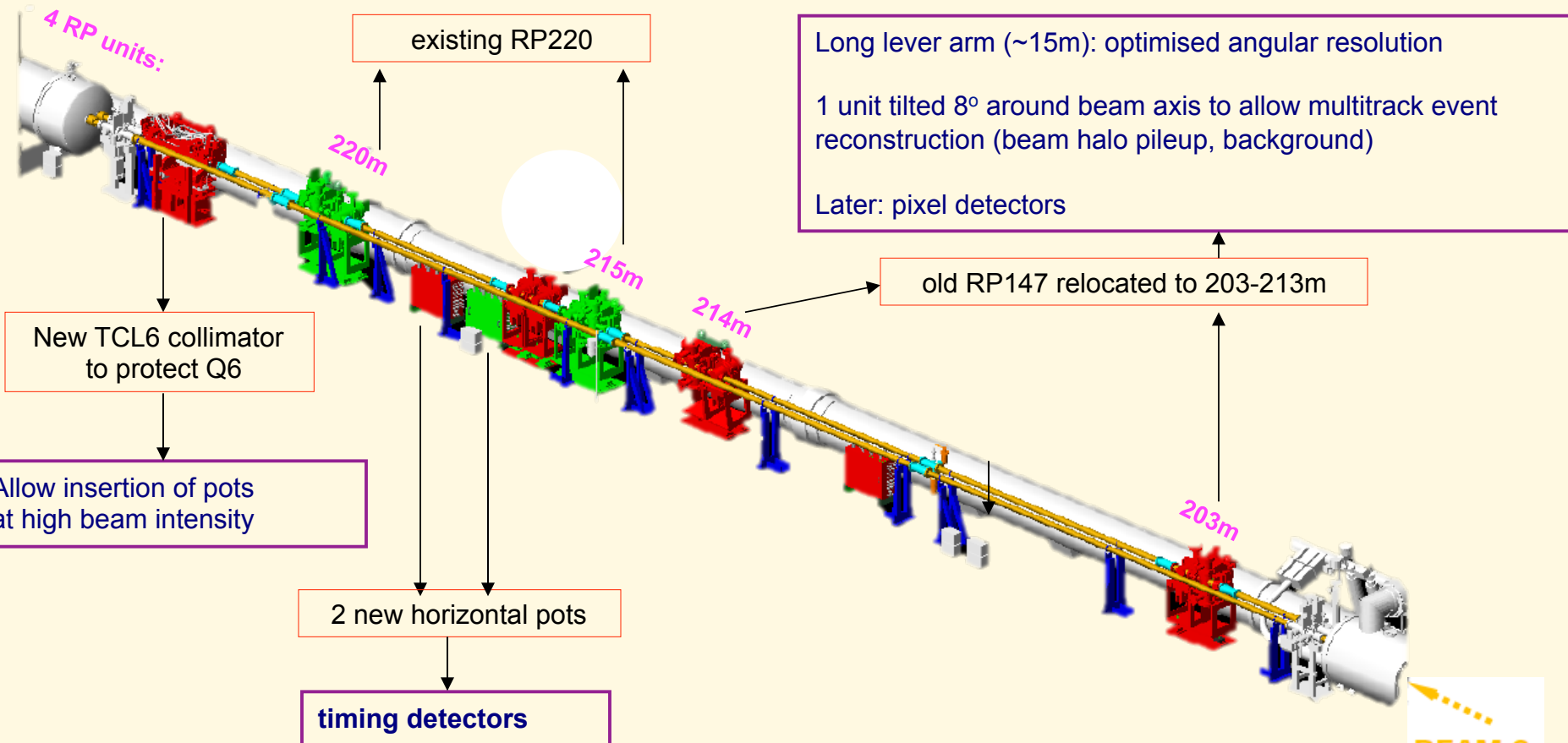
- Higher luminosity after LHCb upgrade (post LS2) would limit usefulness of FSCs
- Possibility of adding proton taggers in Roman pots under consideration
 $L \sim 1-2 \cdot 10^{33} \text{ cm}^{-2}\text{s}^{-1}$

TOTEM consolidation and upgrade

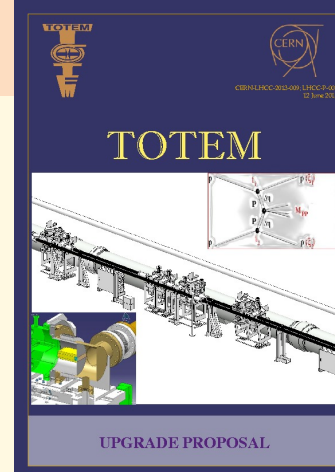


From LS1 to LS3:

- 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

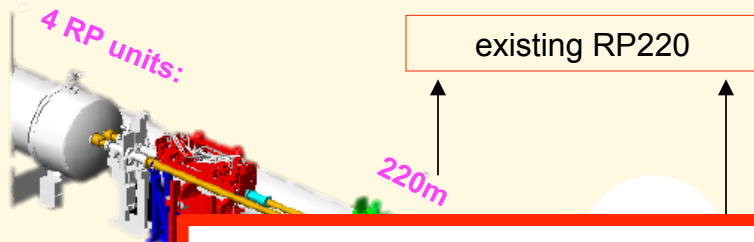


TOTEM consolidation and upgrade



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Long lever arm (~15m): optimised angular resolution

1 unit tilted 8° around beam axis to allow multitrack event reconstruction (beam halo pileup, background)

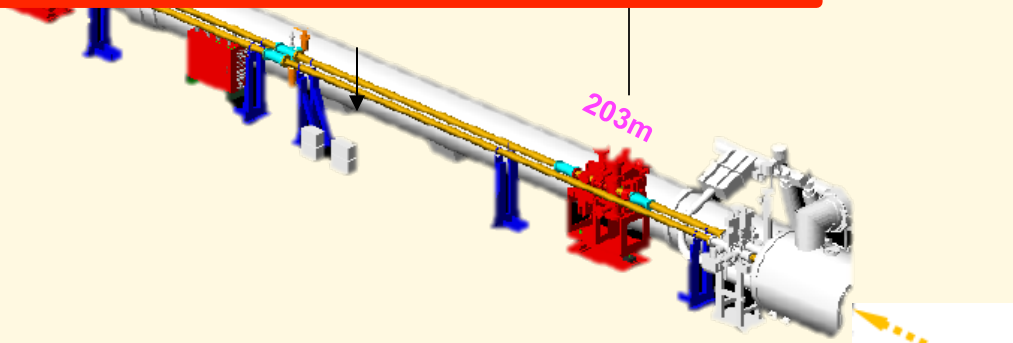
No additional running foreseen during HL-LHC

New TCL6 to prof

Allow insertion of pots at high beam intensity

2 new horizontal pots

timing detectors



Machine Needs for LS2

1. Upgrade of **SPS injection system**
2. Installation of **collimators** in dispersion suppression region around IRs to overcome heavy ion luminosity limit.
May also be needed in IR7.

Polarity Reversal in Spectrometers

- For complete control of systematics especially in very rare decay channels, LHCb will need roughly equal statistics for both spectrometer settings for all trigger configurations
~ bi-weekly
- ALICE will need infrequent polarity changes for control on space charge distortions at very high luminosity

Special Requests During HL-LHC - Summary

- covered the already planned / anticipated special requests:
 - special needs for pp operation
 - at other energies than top energy
 - at other luminosities than top luminosity
 - needs of detectors for forward physics
 - needs for polarity reversal of spectrometers
- need some flexibility in the planning of the machine operation for physics driven upcoming special needs