Moving forward from these LumiDays Experiment Perspective

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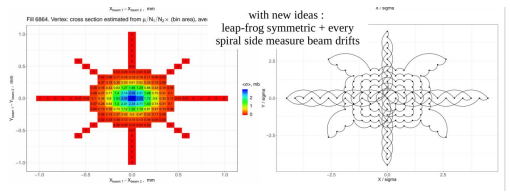
Experiments thank LHC Operations

Many BE/OP Developments in Run 2

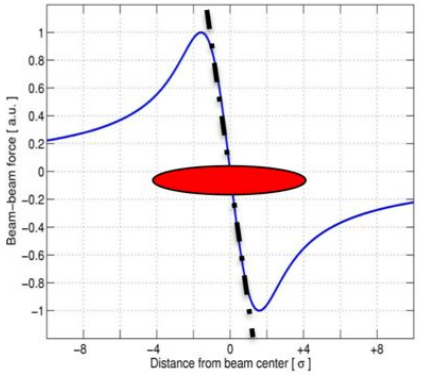
- vdM scan protocol has improved the reliability of vdM scans and the ability of the experiments to test various scan patterns
- Automation of emittance scan
- beta* and separation levelling to target luminosity

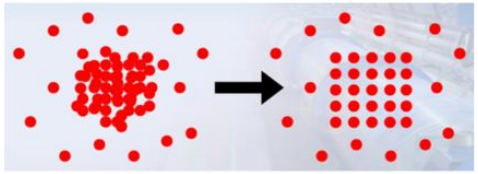


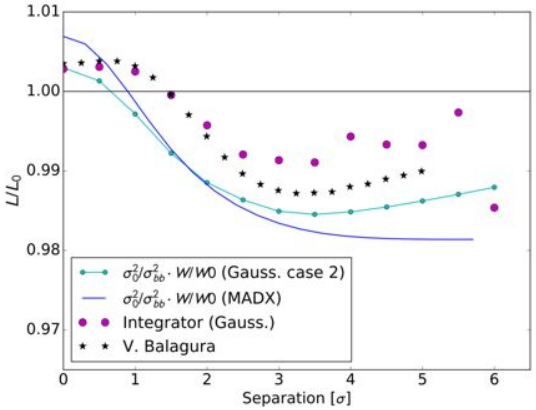
Thank all the work by Michi and his colleagues on the vdM scan protocol & exp handshakes & helping us benchmark LHC luminosity measurements

Beam-Beam !

- Deflections seem to be well understood
- Vladik's new approach to dynamic beta
- Tatiana checking corrections with multi-particle tracking code
  - Not all particles oscillate at small amplitudes as they sample different parts of the force
  - Effect depends on the amplitude of oscillation, this results in a tune shifts and "dynamic beta" change that depends on the particle amplitudes
- General agreement with Vladik's approach (sep< 2 sigma), details and uncertainties still under study







Tatiana: on-going work and outlook

- Improve integrator convergence for large separations
- Compare effects COMBI vs Balagura of beam size effects, overlap integrals, beam spectra.
- Multiple IP simulations and distribution impact from “HO” collisions in other IPs
- Build an effective parameterization (does it scale with ξ ?) that can be used by all experiments at all VdM scans
- Combined effects of long-range and head-on beam-beam effects (TRAIN and COMBI combined C. Rongrong EPFL student)
- Testing the effect in RUN III (X. Buffat and R. Tomas) ?

- Confirming the validity and details is clearly *critical* for the experiments
- Very grateful for work of Vladik and Tatiana
- Very grateful for the investment from CERN Beam Physics colleagues, this is a big issue for Experiments
- Tatiana & team have a detailed work program to validate the details and build into the COMBI code
- Experiments are committed to assist & validate both Vladik's and Tatiana's team's work
- Experiments will support Vladik to apply his methodology to Run-2 vdM optics parameters
  - We thank him for sharing code & kind offer to mentor us

Orbit Drift instrumentation

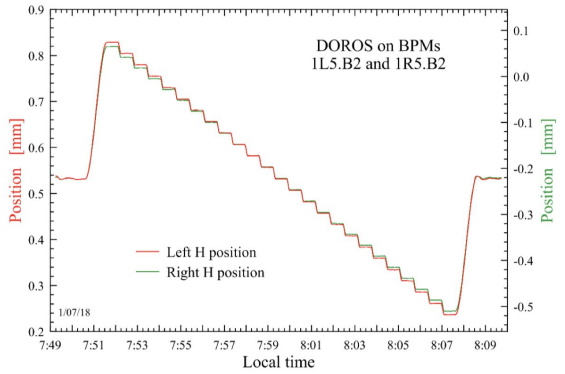
- Need Machine help to understand sources of orbit drift
- vdM orbit drift of 10um @ IP ~1% effect sig_vis and matters
- ARC BPMs, DOROS essential for the experiments
- Using an additional existing BPM close to the experiments, IP side of Q1 for IP1 and IP5 will help monitor orbit and x-angle stability at the experiments
  - BPM is “ARC-type” seeing both beams and equipped with ARC-type BPM electronics
    - In vdM the beam 1 and beam 2 will be separated in time @ BPM location. Resolution will probably be the same as DOROS. Accuracy different to DOROS (all controls to stabilize electronics not present).
    - Can see the relative drift of beam 1 wtr beam 2 with accuracy (because electronics systematics in common and cancel in the difference).
    - Same mechanical location as DOROS in IP1/2 different BPM type (stripline?)
  - This will be useful as an additional constraint on the IP stability
  - Experiments thank BE/BI for checking this in LS2

Orbit Drift instrumentation

- Can we confirm methodology …
  - is it valid to use DOROS during the scans?
    - For all Run 2 years?
  - To correct orbit drift for each scan step
    - (After averaging beam noise)
  - As opposed to an average of orbit drift from beginning to end of scan (as measured headon)

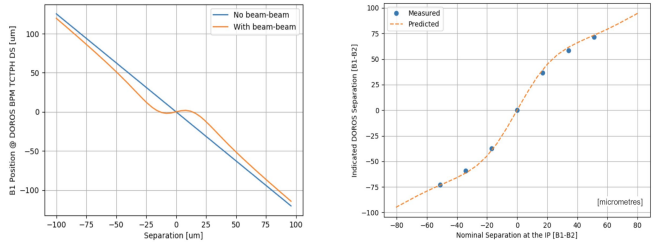
DOROS Performance excellent

- Perform Particularly well in vdM because residual nonlinearities due to bunch charge variation negligible (few % over many hrs)
  - Gain adjustment, unlikely in vdM fill but can give false orbit change and should be switched off for vdM for future
- Precision in the temperature stable lab 100 nm!
- Time per measurement point 10s seconds,
  - Orbit drift corrections within scan steps (~40-60 s) add value for experiments
- What is ultimate precision of orbit drift in a vdM fill?
  - Largest contribution to noise on DOROS measurement 2018 comes from the beam & not the instrumentation (Marek)
  - Impact of orbit drift contributions from the rest of the machine measured by ARC BPMS
    - ARC BPMs also Important and to understand systematics



BE/BI - invitation to experiments to communicate their performance requirements on orbit drift @ each IP

- Run 3 and HL-LHC



Measurements first reported as a DOROS non-linearity, later explained by beam-beam forces. Plots curtesy of M. Hostettler et al.

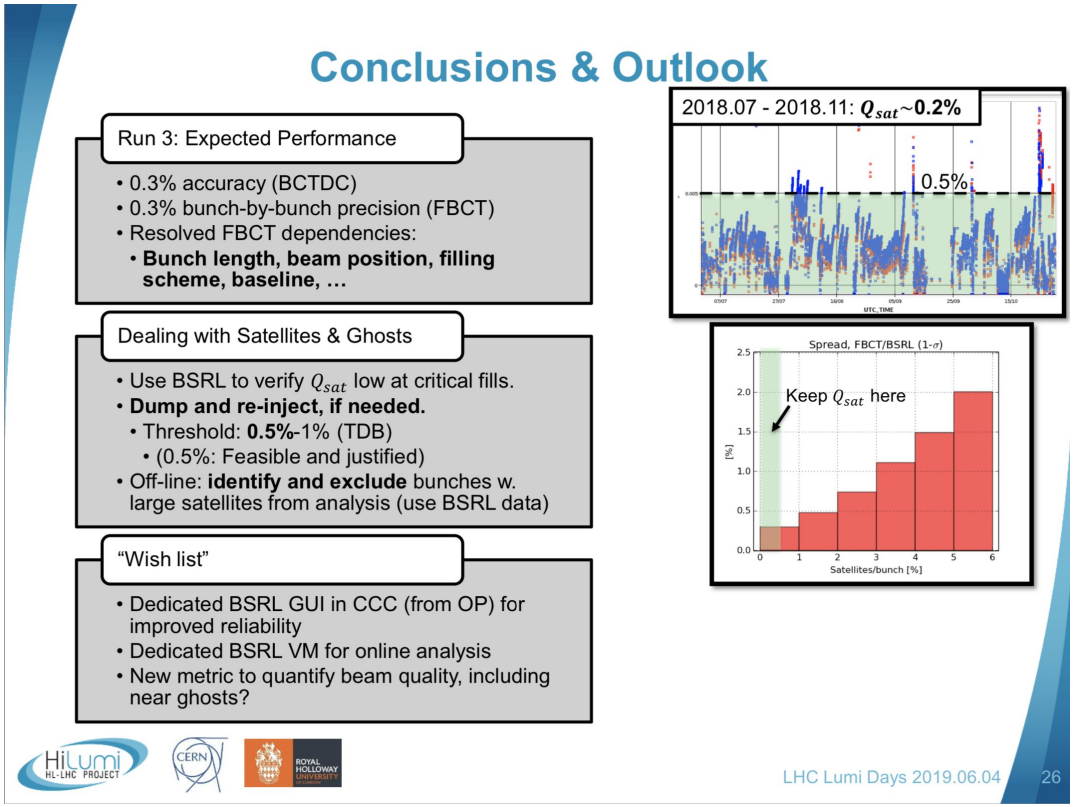
Considerations

- Best DOROS needed for systematics for orbit drift for legacy Run 2, 2015, 2016,2017,2018
- BE/BI raw data available to implement offline corrections (if there are any)
- IF no orbit drift - Cross calibration DOROS with inner tracker during Length Scale

Bunch Current measurements

DCCT and relative FBCT charge measurement is critical it enters directly into the normalization.

BSRL corrections for Satellite and ghosts important



Run 2

- ➔ **Resolved Even/Odd FBCT**
  - **Important input from ATLAS BPTX**
- ➔ **Understanding influence of FBCT baseline subtraction**
- ➔ **Work done in LS2 to resolve first bunch in train effect**

Run 3

- Accurate online FBCT increasingly important for luminosity stability and linearity measurement in nominal conditions
- BSRL to flag fills with poor satellites

Thank BE/BI colleagues for excellent instrumentation incl. Total charge measurement with DCCT.

Combining Years, Experiments, Scans...

As raised this morning, can we reach consensus on how we define some of our systematic components?

RMS, Error on mean, Full range, …

Can (should?) we combine measurements between experiments of non-factorisation in a given fill?

When we have only a handful of scans, and the variation between them is higher or lower in a given year, is it ok to treat the spread each year separately?

Planning Future vdM programs

- Many systematics studied in Run2 … approaching 1% lumi measurement
  - non/factorisation corrections important
    - To reduce (beam preparation) and to measure and to check across experiments
      - Cross checks of different methods within a single experiment
        - they all have different assumptions, strengths, weaknesses
        - Non-factorization effects have been measured to change within a fill
      - still-todo : year-to-year cross check non/factorization across experiments for all Run 2 vdM scans.
        - example shape info (e.g. correlation parameter) etc. exchanged could also help with cross-checks (also for Run 2)
        - Run 3 IP1/5 trigger on common BX?
      - Understanding the beam-beam correction on the beam spot shape is important
  - Scan to scan corrections & consistency
    - Beam beam corrections
    - orbit drift correction per scan step
    - per BX bunch charge measurement
    - Validate, as in 2018, no significant emittance dependence
- Experiments require vdM time to probe and measure all effects

Planning Future vdM programs

- Resolve the collective opinion on choice of Beta* for vdM
  - Is there really a significant gain to make to move from 19 to 17m?
    - How important an error on beta* is if beam-beam correction is reduced?
    - Check relative contribution vertex resolution & rates in detectors
    - How far away from L* needed ? (considering no alignment errors or beta beating included in simulation. Can Q2 be used to measure beta*?)
    - How much setup time for machine to validate a new optics?
- Run 3 -Beam quality from new injector chain
  - Quality of higher emittance bunches & prep of gaussian bunches
  - Factorizable bunches important for high precision vdM result
- Scan in both directions to check hysteresis effects?
  - Can be quite different in different IP’s
- What is the benefit from spending extra time in vdM fill preparation
  - “Verify the optics” (Xavier & Rogelio)
  - Update BE/BI instrument verification list (e.g. add. Turn off of DOROS automatic gain)
- Should we be programming more than one scan period per year?
  - With same beam parameters (separated in time) for stability of detector calibration
  - With different beam parameters or optics (close in time) for verification of beam-beam or non/factorization effects

Massi Files

We can (Can we?) improve the utility of the data we send to LHC colleagues.

If they are being used to study bunch by bunch effects then we can (with probably a more messy work flow on the experiment side) provide more correct data.

Is there a demand for beam spot (6d) distributions as well as mean/rms values - to allow analyses that need to investigate non-gaussian effects.

Again this is a substantial amount of work. Is there a demand?

If so how often in the fill?

Run2 to Run3 to HL-LHC

Most Physics measurements are no longer dominated by statistical precision but systematic uncertainties

- So the pressure to improve on the luminosity systematics will only increase
- Work required on both the hardware and the calibration systematics
- We cannot afford to sit on our Laurels (!)

LumiDays 2020 important to review “final” Run 2 offline luminosity performance, and plan for Run 3 (with perspectives for HL-LHC)