CERN

Summary – what we discussed and learned (accelerator)

G. Sterbini

(starting from a personal perspective to trigger discussions)

Starting considerations

Improving the present **performance of the VdM scans** is very challenging and call for (even closer) collaboration between experiments and machine in a series of subjects.

Depending of the experiments**,** among the contributions to the systematic errors possibly related to the machine we have

- scan-to-scan variation,
- x-y non-factorization,
- orbit stability,
- beam current-calibration,
- beam-beam effect,
- …

In this context, the present understanding of the **luminosity and emittance evolution** can be improved by a closer collaboration with the experiment.

Uncertainties and combination

- Per-year uncertainty summary
  - Treating 2015+16 as one dataset
  - Absolute vdM calibration subtotal
  - +Contributions to to physics lumi.
  - Total uncertainties for individual years are 2.0-2.4%
    - Largest single uncertainty from calibration transfer
- Combination of years
  - Taking correlations into account
  - */+=fully/partially correlated
    - See talk of R. Hawkings tomorrow
- Total run 2 lumi: 139.0±2.4 fb^{-1}
  - Uncertainty **1.7%**, dominated by calibration transfer and then long-term stability

Data sample	2015+16	2017	2018	Comb.
Integrated luminosity (fb^{-1})	36.2	44.3	58.5	139.0
Total uncertainty (fb^{-1})	0.8	1.0	1.2	2.4
Uncertainty contributions (%):				
DCCT calibration†	0.2	0.2	0.2	0.1
FBCT bunch-by-bunch fractions	0.1	0.1	0.1	0.1
Ghost-charge correction*	0.0	0.0	0.0	0.0
Satellite correction†	0.0	0.0	0.0	0.0
Scan curve fit model†	0.5	0.4	0.5	0.4
Background subtraction	0.2	0.2	0.2	0.1
Orbit-drift correction	0.1	0.2	0.1	0.1
Beam position jitter†	0.3	0.3	0.2	0.2
Beam-beam effects*	0.3	0.3	0.2	0.3
Emittance growth correction*	0.2	0.2	0.2	0.2
Non-factorization effects*	0.4	0.2	0.5	0.4
Length-scale calibration	0.3	0.3	0.4	0.2
ID length scale*	0.1	0.1	0.1	0.1
Bunch-by-bunch σ_{vis} consistency	0.2	0.2	0.4	0.2
Scan-to-scan reproducibility	0.5	1.2	0.6	0.5
Reference specific luminosity	0.2	0.2	0.4	0.2
Subtotal for absolute vdM calibration	1.1	1.5	1.2	-
Calibration transfer†	1.6	1.3	1.3	1.3
Afterglow and beam-halo subtraction*	0.1	0.1	0.1	0.1
Long-term stability	0.7	1.3	0.8	0.6
Tracking efficiency time-dependence	0.6	0.0	0.0	0.2
Total uncertainty (%)	2.1	2.4	2.0	1.7

4th June 2019 Richard Hawkings 18

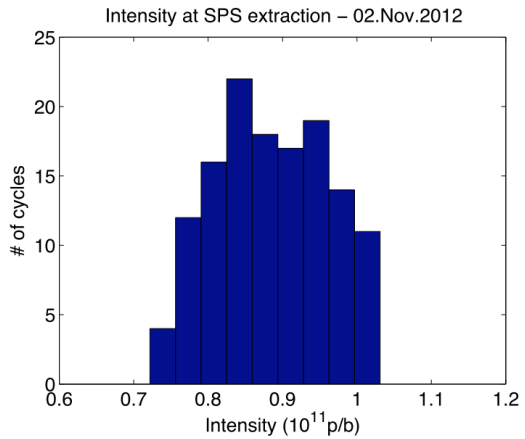
e.g., uncertain breakdown from R. Hawkings (ATLAS)

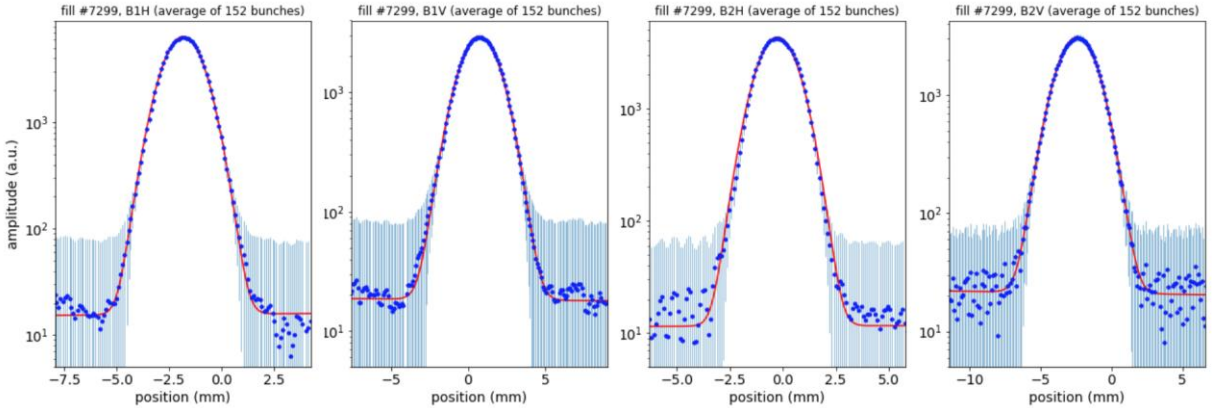
VdM Bunch from Injectors

H. Bartosik

- General consensus on improved quality of the beam form the Injector Chain after 2012, **but this did not solved the non-factorization.**
- For Run3, the strategy in the PSB may change due to the improved LINAC4 emittances, but clear commitment in producing the VdM beam during Run3 first year.

Single bunch beam parameters requested by LHC	
Intensity	0.7-0.9x10^{11} p/b
Transverse emittance (norm.)	≥ 2.5 µm
Transverse distribution	**Gaussian**





Optics for the VdM scan

Difficulties to measure the optics for VdM scan (β*=19/24 m, Q1 k-mod).

In principle an optics with β*=17 m can be easier to measure.

Can a β*=17 m optics be considered for VdM Run3?

H. Garcia Morales

2016 MD on vdM: β^* measurement

Uncertainties

- Magnet misalignment of 6 mm rms.
- Magnet strength error: $\Delta K/K = 10^{-3}$.
- Tune uncertainty: $\delta Q = 5.0 \cdot 10^{-5}$.

	Beam 1		Beam 2	
IP	β_x^*	β_y^*	β_x^*	β_y^*
IP1	17.4 ± 0.02	18.11 ± 0.02	17.73 ± 0.02	17.20 ± 0.02
IP5	33.06 ± 24.17	18.00 ± 3.7	16.21 ± 0.02	18.7 ± 1.4
IP8	21.52 ± 0.03	19.97 ± 0.03	26.35 ± 2	22 ± 12

- Reasonable for IP1.
- Very bad measurement for β_x^* in IP5 and β_y^* in IP8.

Protocol for the VdM scans

Beam displacement sequence controlled by experiment-provided files: pre-programmed scan are less error prone approach!

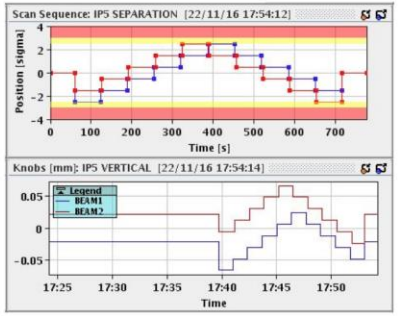
Clear non-factorization observed from the experiments...

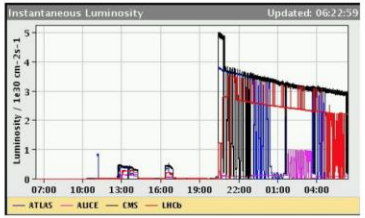
LHCb is performing a 2D scan aiming to relax the hypothesis of the x-y factorization. **Can a similar approach be considered in the other experiment?**

M. Holstettler

luminosity scans: VdM scans

- special fills for absolute lumi calibration
  - ~1-2 per year
- "parasitic" studies in physics
  - on request of the experiment
  - e.g. "mu-scan" to check linearity
  - little overhead for OP
- since late 2015: new scan protocol
  - beam displacement sequence controlled by experiment-provided files
  - allows for complex patterns
    - e.g. LSCs, "diagonal" scans
  - synchronization with the experiment through DIP

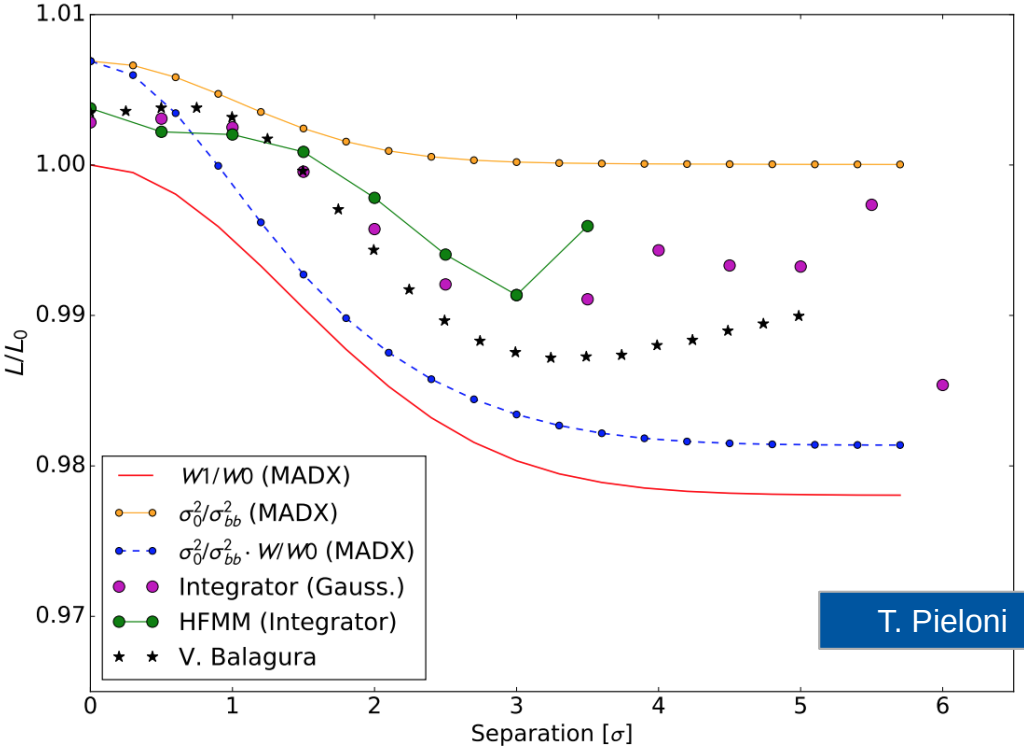




→ sessions 1 & 2

VdM BB simulations

- The linear approach used until now should be improved → **from single particle parameters to distributions**.
- To find optimal agreement between the COMBI/Balagura results.
- Find a parametrization to apply this correction in the VdM scan (complex BB schedule…)



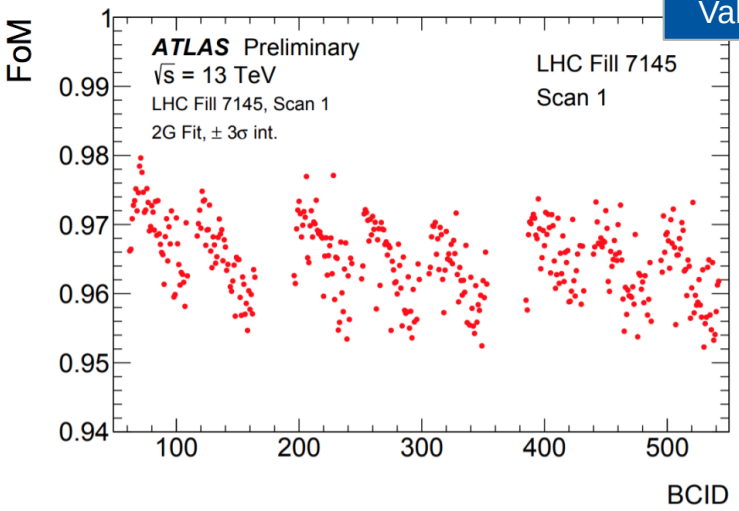
T. Pieloni

Effect along the train

- Patterns with trains emerged: are they related to BB?

- Luminosity monitoring with emittance scans
  - Define figure of merit $FoM = \frac{\mathcal{L}_{spec,0}}{\mathcal{L}_{spec,beam}}$

Valerie Lang

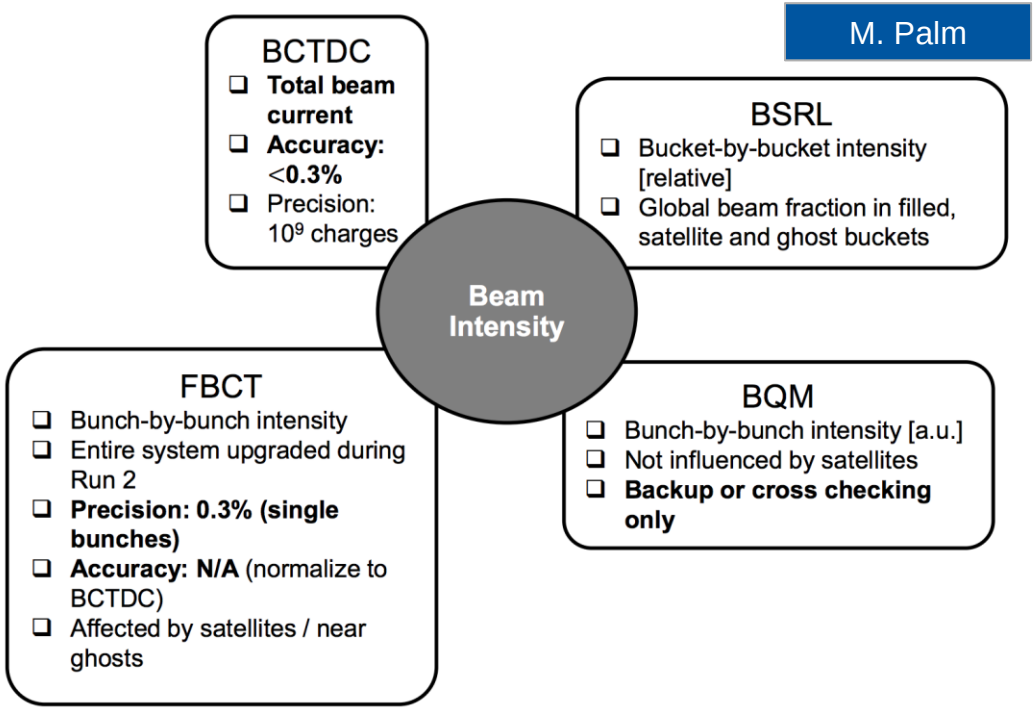


  - Observe bunch dependence and global downwards trend → Cause is not clear yet (also see next slide)

Instrument calibration and precision

- Important to track and document the performance of the beam instrumentation (legacy data).
- **Synergy with LHCb** for measuring the ghost bunches.
- **DOROS performance good for the (limited) intensity drop observed during the VdM scan**.

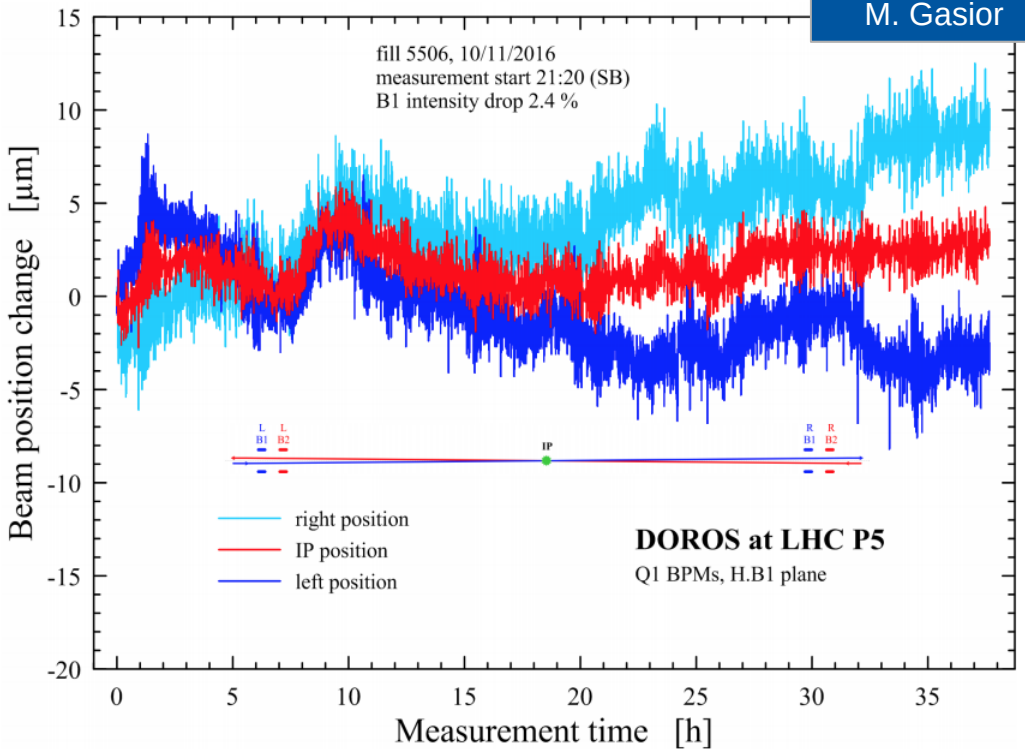
M. Palm



Instrument calibration and precision

- **Important to track and document the performance of the beam instrumentation**.
- Synergy with LHCb for measuring the ghost bunches (limit in the BSRL).
- DOROS performance very good for the (small) intensity drop observed during the VdM scan.

M. Gasior



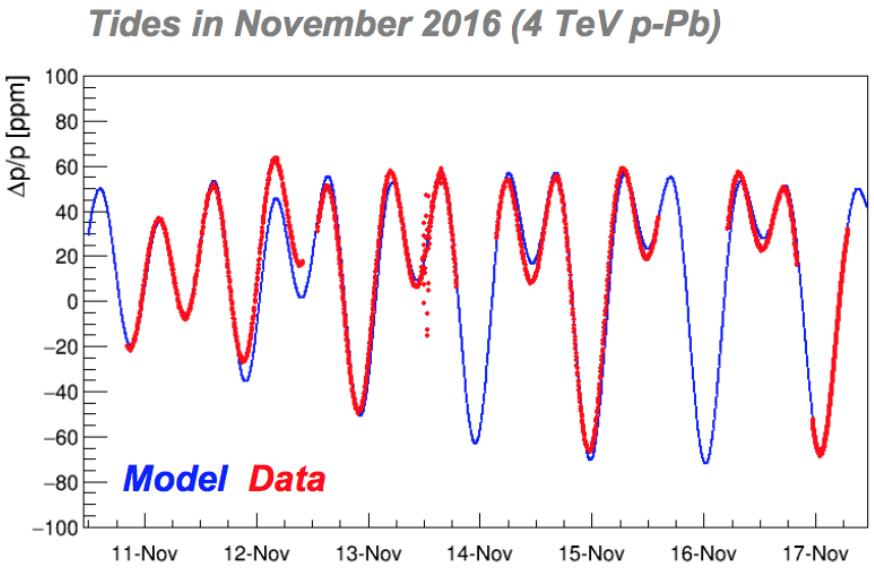
VdM scan and crossing angle

- **Currently unused, Q1 BPMs could be made available during VdM scans to quantify any drifts from zero crossing angle.**
- **Same BPM, same cables, same electronics are used to acquire both beams which eliminates many systematics.**

from R. Jones

Orbit stability and Corrector Hysteresis

- Orbit feedback is off during the VdM.
- Orbit drift has to be taken into account during the scan: **more automatic approach to monitor the orbit drift?**
- ATLAS observed hysteresis effect → systematic characterization during Run 3? can leap-frog scan help?



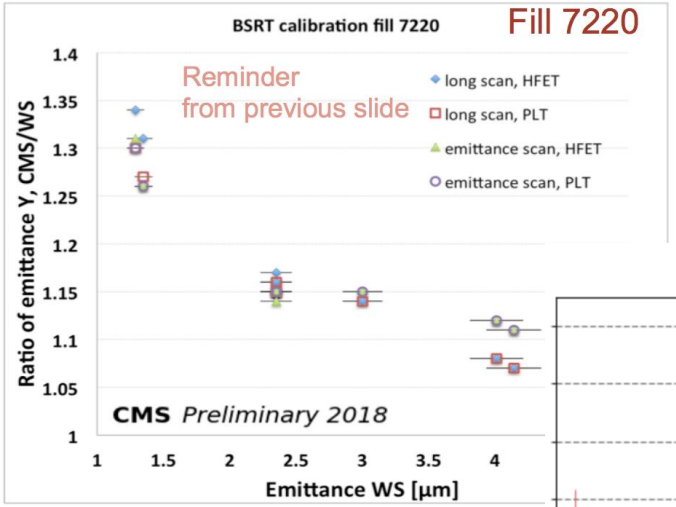
Emittance measurement

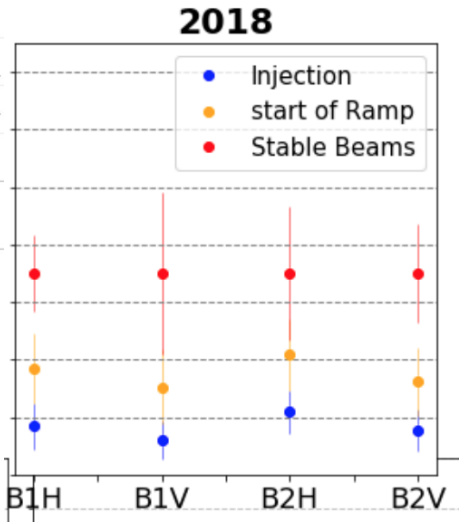
O. Karacheban

[Despite the efforts with WS and BSRT] “Emittance from luminosity not self consistent”.

Significant (and appreciated) efforts from CMS in the emittance scans.

Transverse and longitudinal emittance is a very important input for the luminosity model.



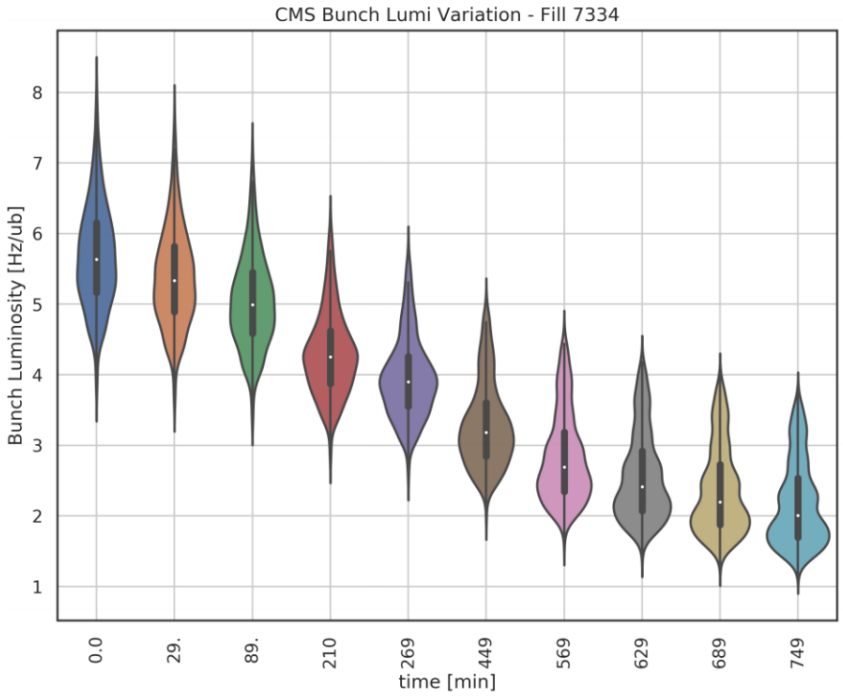


I. Efthymiopoulos

Bunch-by-bunch luminosity

I. Efthymiopoulos

- First results of the bunch-by-bunch fluctuation presented.
- It seems the effect is enhanced in 2018 with the BCMS beams, therefore the **interest to further understand it as may affect the machine/experiment performance in Run 3 or HL-LHC**.



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