Session 2: Key Challenges for Operation

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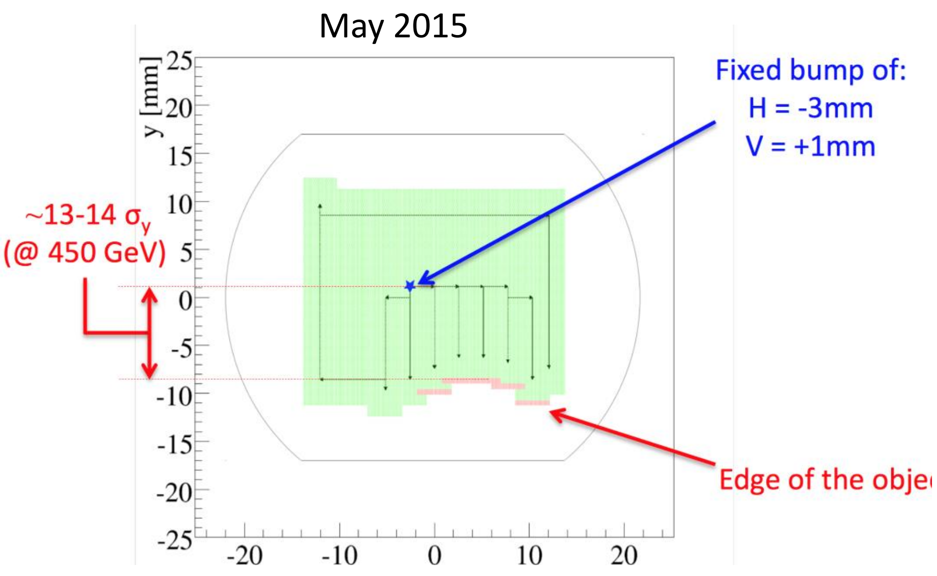
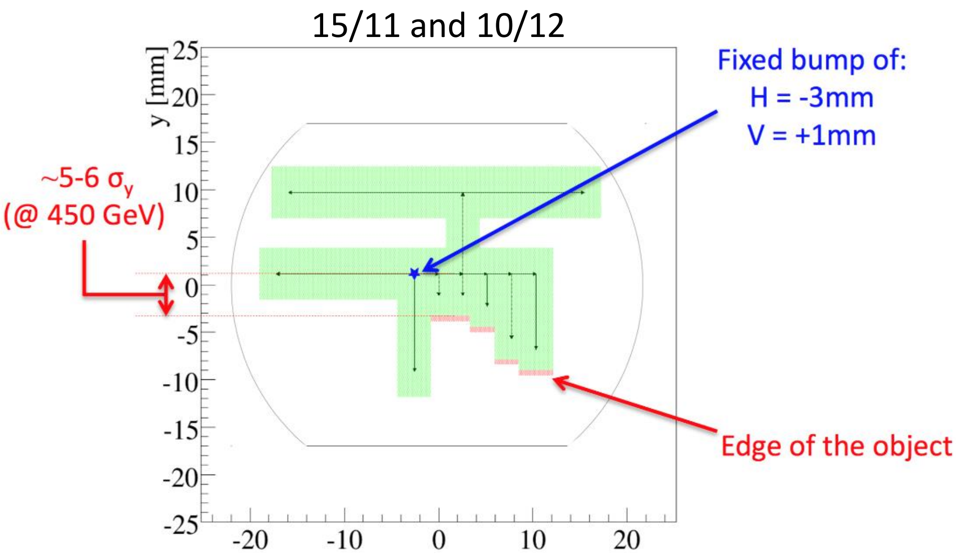
UFOs, ULO, BLMS	Bernhard Auchmann
Electron Cloud Effects	Giovanni Iadarola
Beam Induced Heating	Benoit Salvant
Instabilities, Impedance, Long-range Beam-beam	Kevin Li
SPS and SPS-to-LHC transfer	Verena Kain
Diagnostics	Federico Roncarolo

Big thanks to all the speakers for an excellent set of talks

ULO

- Aperture restriction deep in MB.C15R8.
- 3 ULO-induced quenches; BLM thresholds around 15R8 have been lowered so as to avoid quenches.
- **Vertical restriction not constant**; horizontal restriction stable.
- If the object moves further, there is room for increasing the orbit bump:
  - from currently H = -3 mm, V = 1 mm
  - we may increase to H = -6 mm, V = 3.5 mm
  - and reduce margin to 10 σ in both planes at 450 GeV in the nearby quad.



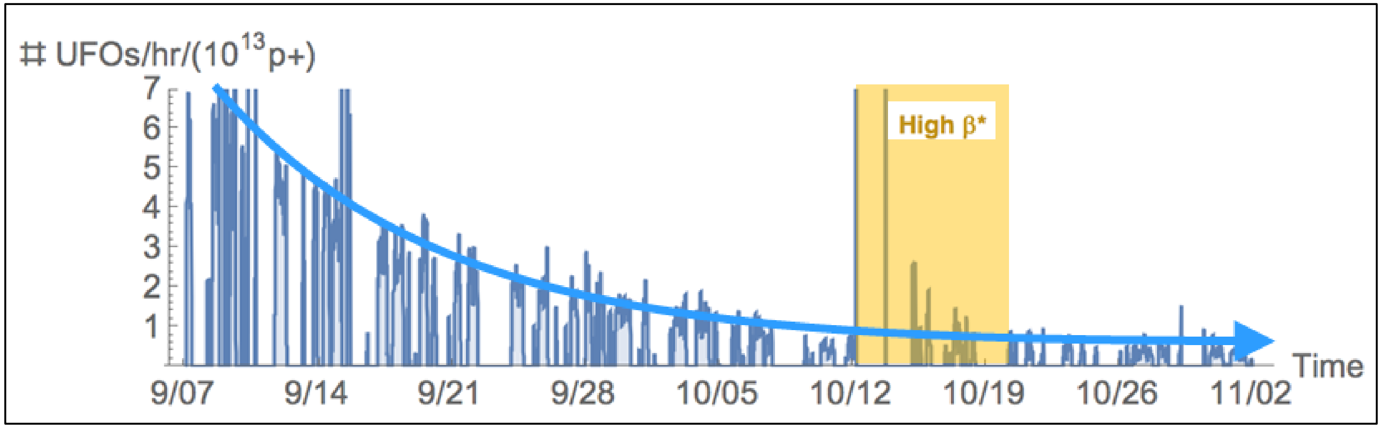


D. Mirarchi

Bernhard Auchmann

UFOs

An encouraging fall in normalized rates during 2015



UFO rates of ~10/h were stable over the last 3 weeks.

End of Conditioning?

BLMTWG proposes to continue to avoid dumping on UFOs as a strategy to maximize availability.

- increase the short Running Sums (RS 1-6) by another factor 2, while reducing the longer Running Sums to conservative values.
- In short: avoid dumping on UFOs all together as a strategy to maximize availability

Scrubbing - lessons to retain

- **Scrubbing** at 450 GeV allows to **mitigate e-cloud instabilities** and **beam degradation** occurring at low energy
- After this stage, relying on ADT and high Q' and octupoles, it is **possible to preserve good beam quality from injection to collision** in spite of the e-cloud still present in the machine → high heat load in the arcs
- **Parasitic scrubbing** accumulated during the physics run has **lowered the heat load** in the dipoles by roughly a factor two (in two months)

  → The **doses needed** to see an evolution at this stage are **very large**, practically incompatible with a dedicated scrubbing run

  → Possible **recipe for the future** (e.g. after LS2): relatively **short scrubbing at injection** to get the beam under control, then accumulate **further dose in parallel with physics** (but slower intensity ramp up)

Scrubbing - proposal for the 2016 start-up

- Arcs will be kept under vacuum → **scrubbing should be at least partially preserved** during the YETS
- Scrubbing **proposal for 2016**:
  - **4 days scrubbing run** should be reasonable to recover high intensities at 450 GeV (assuming setup for high intensity is done before, e.g. injection, ADT)
  - A few **"refresh" scrubbing fills during first 1-2 weeks of intensity ramp up** in physics (to avoid problems with deconditioning)
  - **During intensity ramp up**:
    - → As long as no limitation is encountered, try to **maximize electron dose** by using long trains (up to 288b. per injection) → **it will pay off later**
    - → If/when cryo limit is reached, move to **optimized filling scheme** to gain luminosity
    - → Use **physics fills to accumulate more scrubbing** for further intensity increase
- **Doublet test** to be performed when **SEY is sufficiently low** (e.g. at least after recovering the end-2015 situation) to check whether good beam quality can be preserved
    - → In case of positive outcome, **first scrubbing stores with doublets**

Giovanni Iadarola

Beam induced heating

- **Beam induced RF heating is not expected to be a limitation in 2016**
- New TDIs are expected and were measured to have a lower impedance than both 2015 TDIs.
  - The new solution should be more robust in case of coating issues
  - The new TDIs should not be a limitation in 2016

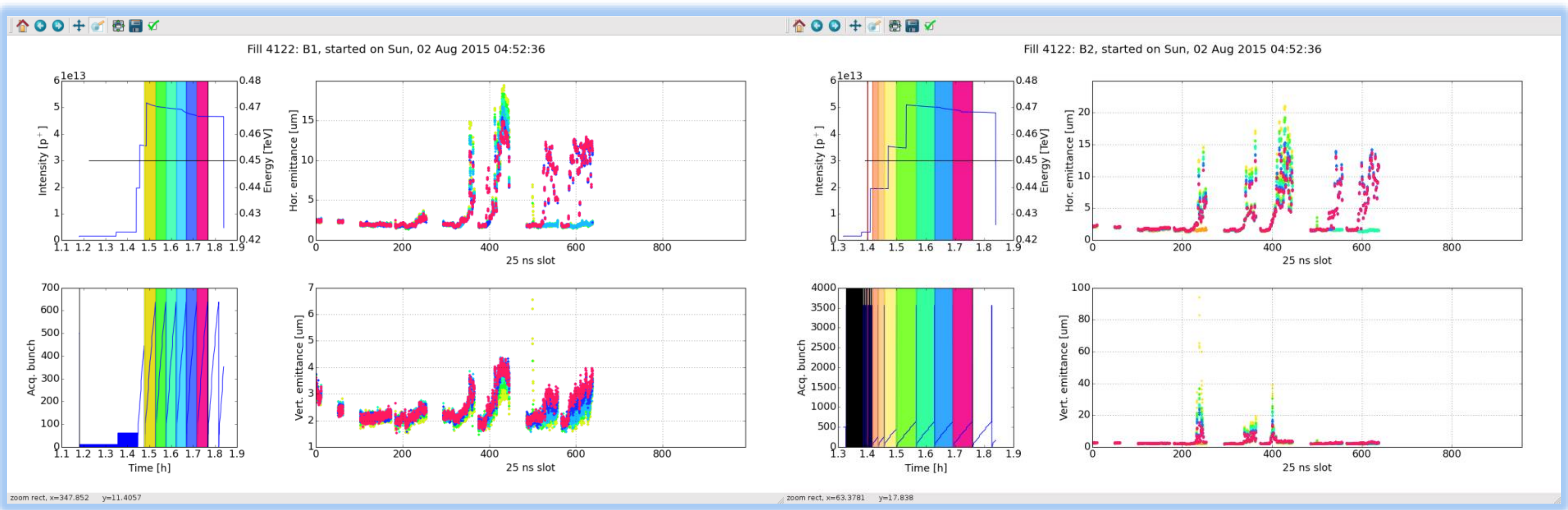
Recommendations

- Test and **validate impedance of the new TDIs** during commissioning.
- **Keep monitoring temperature, vacuum and beam spectra** to identify issues in close collaboration with MPP and equipment groups.
- Find a mitigation for the spurious temperature readings.
- In view of HL-LHC, **monitor power lost in MKIs, TDIs, beam screen and ALICE beam pipe** to assess the need for further modifications.
- **Test and validate bunch flattening** during intensity ramp up in case bunch length levelling is required by either heating or experiments.

Benoit Salvant

Instabilities 2015 Observations

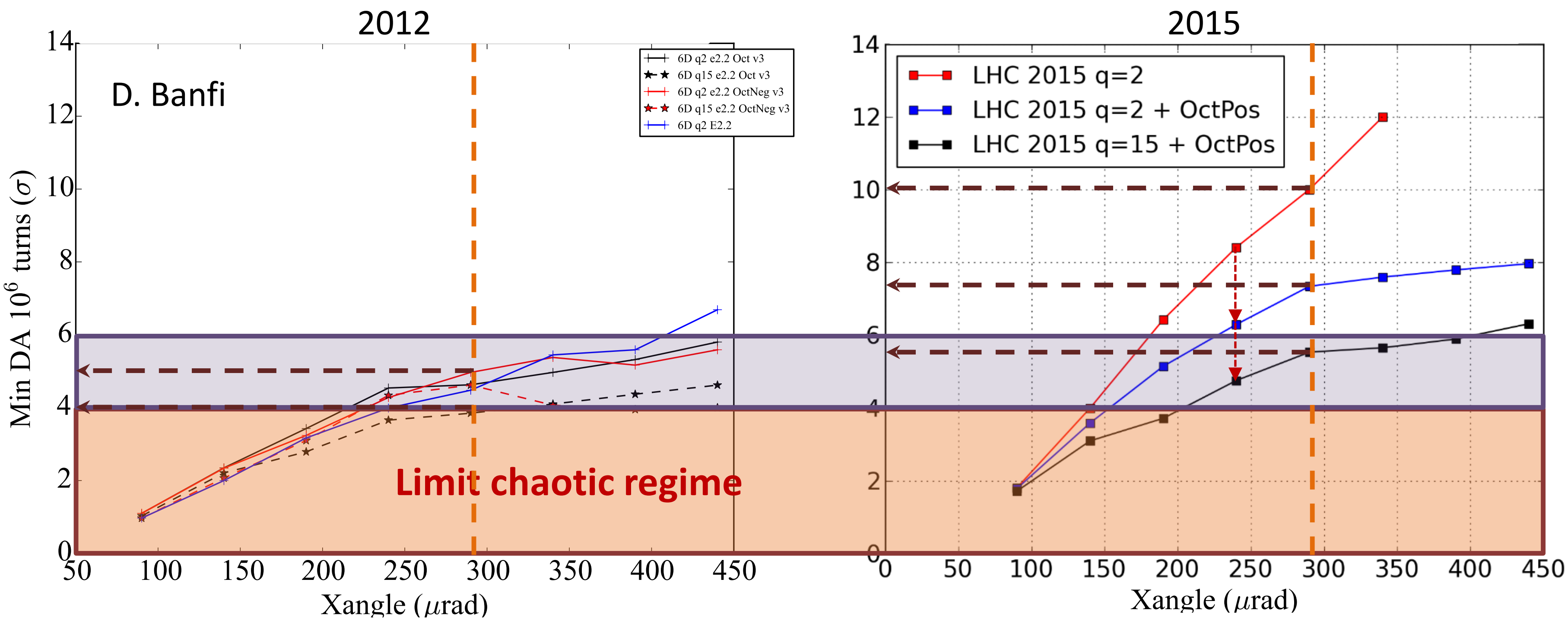
- Instabilities were mainly driven by electron cloud and its interplay with impedance, beam-beam, transverse damper
- Violent instabilities during initial stages of scrubbing – clear e-cloud signature
- Progressive optimization of machine settings (transverse damper, chromaticity & octupoles, working point) + conditioning and reduction of e-cloud



Kevin Li

Beam-beam – incoherent losses – 2012/2015

Plots taken from T. Pieloni Evian 2015



- Figure of merit: DA → 6 sigma criterion robust for commissioning phase
- Critical parameters: brightness, crossing angles, normalized separation
- **2012: 4 sigma DA vs. 2015: 6 sigma DA**

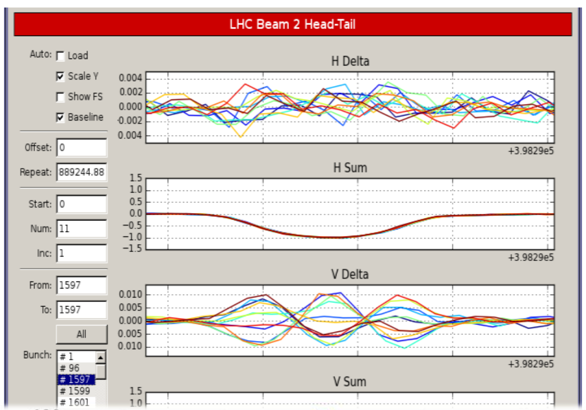
	2012	2015
beta*	60 cm	80 cm
intensity	1.6e11	1.2e11
emittance	2.2 um	3.75um
separation	10 sigma	11 sigma
bb parameter	0.0070/IP	0.0035/IP

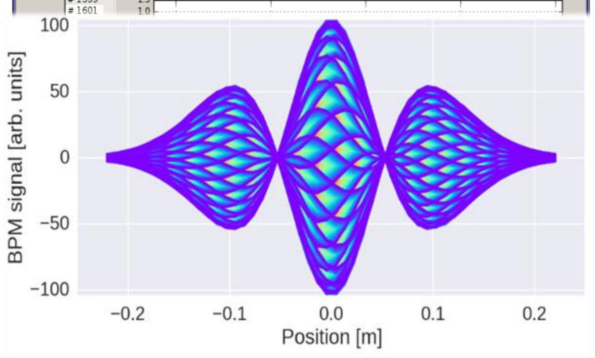
Kevin Li

New Diagnostics

HEADTAIL monitor:

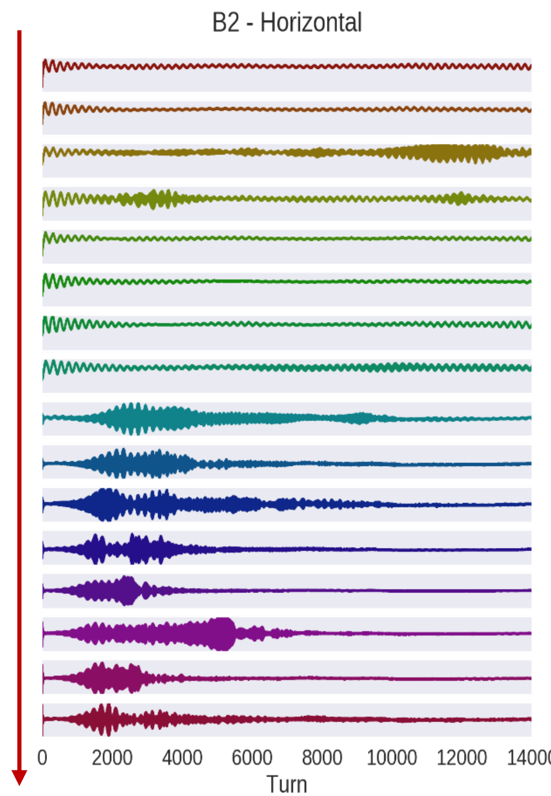
- detection of single/coupled bunch instabilities
- intra-bunch motion
- crucial for specification of wideband feedback systems



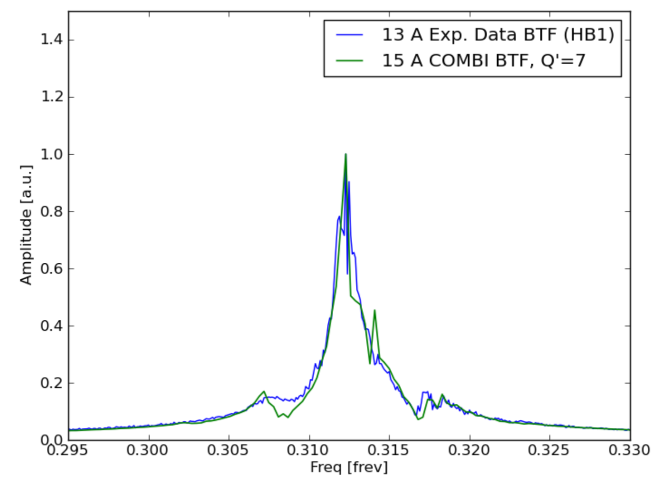


PyHEADTAIL simulation

ADT OBSBOX: up to 6 minutes of bunch-by-bunch – turn-by-turn data (Damping times, Rise times, Tunes)

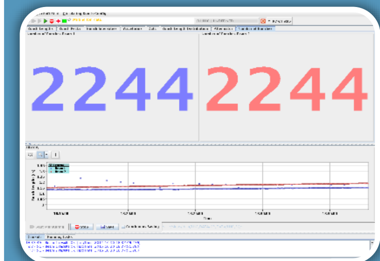


BTF: Investigate incoherent effects and deduce stability diagrams (ongoing work!)



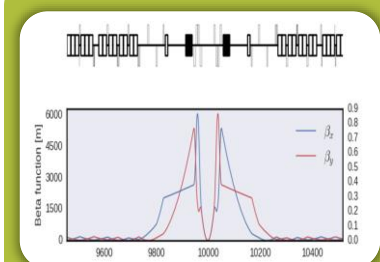
Important that this effort is supported

2016 Challenges and Strategy



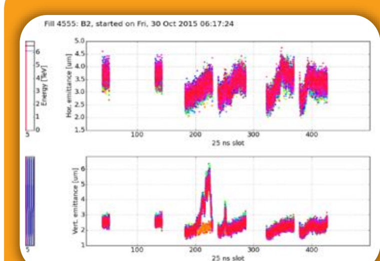
Running at 25 ns with large number of bunches and high total intensity

- Beam parameters envisaged:
  - Bunch number up to 2748 bunches
  - Intensity up to 1.2e11 protons per bunch
  - Bunch length down to 1.2 ns (starting from 1.35 ns with 1.3 ns in collision)
- Looming detrimental effect from e-cloud which makes the view, understanding and handling of beam stability a lot more involved



Optics (down to 40 cm beta*)

- Tight collimators (impedance: TCSG 8 σ → 7.5 σ)
- Reduced separation (beam-beam: 11 σ → 10 σ)
- Large beta functions in triplets (impedance, e-cloud and optics effects)



BCMS

- High brightness beams with reduced Landau damping potentially less stable
- High beam-beam parameter with strong head-on and less DA
- Increased sensitivity to e-cloud effects

Kevin Li

2016 Challenges and Strategy

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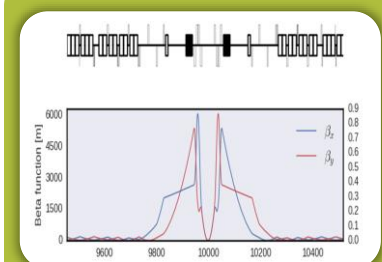

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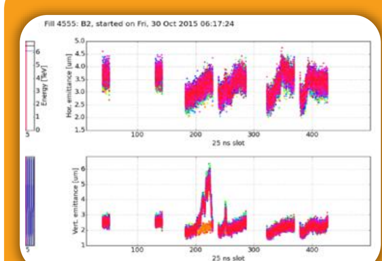


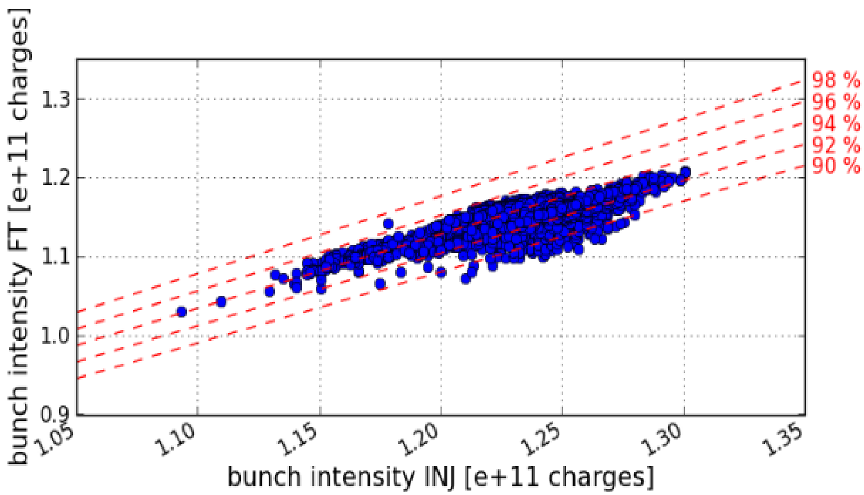
BCMS

- High b
- High b
- Increa

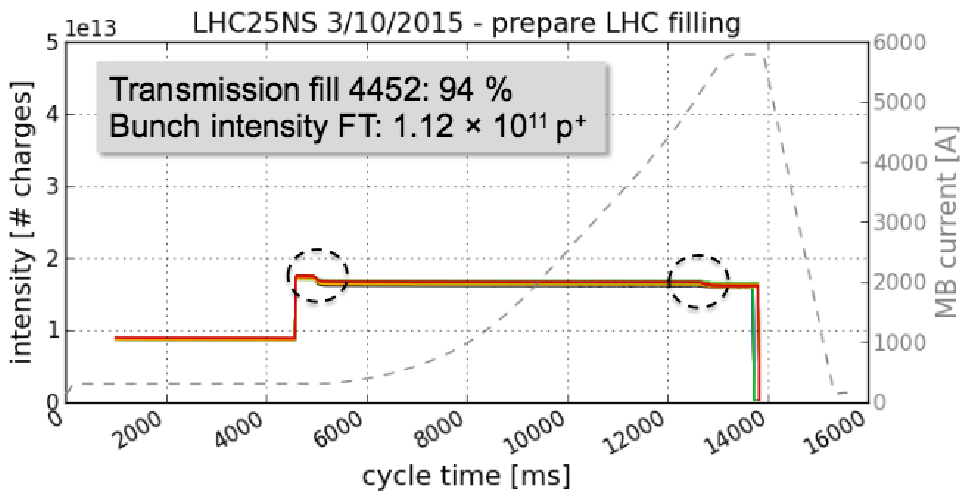
Ingredients for 2016 operation:

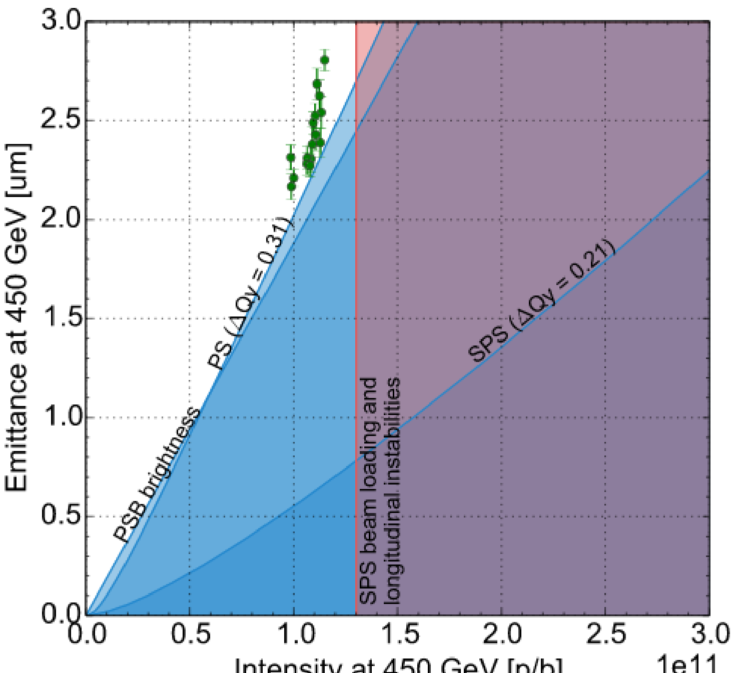
- Reliable diagnostics
- Good knowledge and control of the machine
- Main parameters (beam-beam separation, crossing angles, etc.) such the DA = 6 sigma
- Possibility of playing with: bunch length, emittance, tune, etc.

SPS: 144 25 ns Bunches



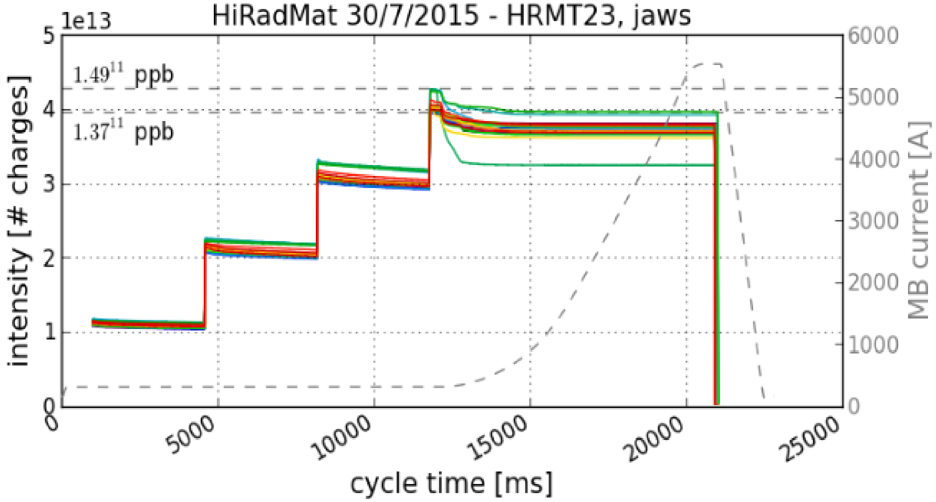
- **Nominal intensity 1.15e11 ppb in 2.5 μm emittance: 96% transmission**
- No intensity and brightness limitation but higher activation of the SPS (losses at the beginning of energy ramp and during scraping)
- Need continuous machine tuning to keep performance.



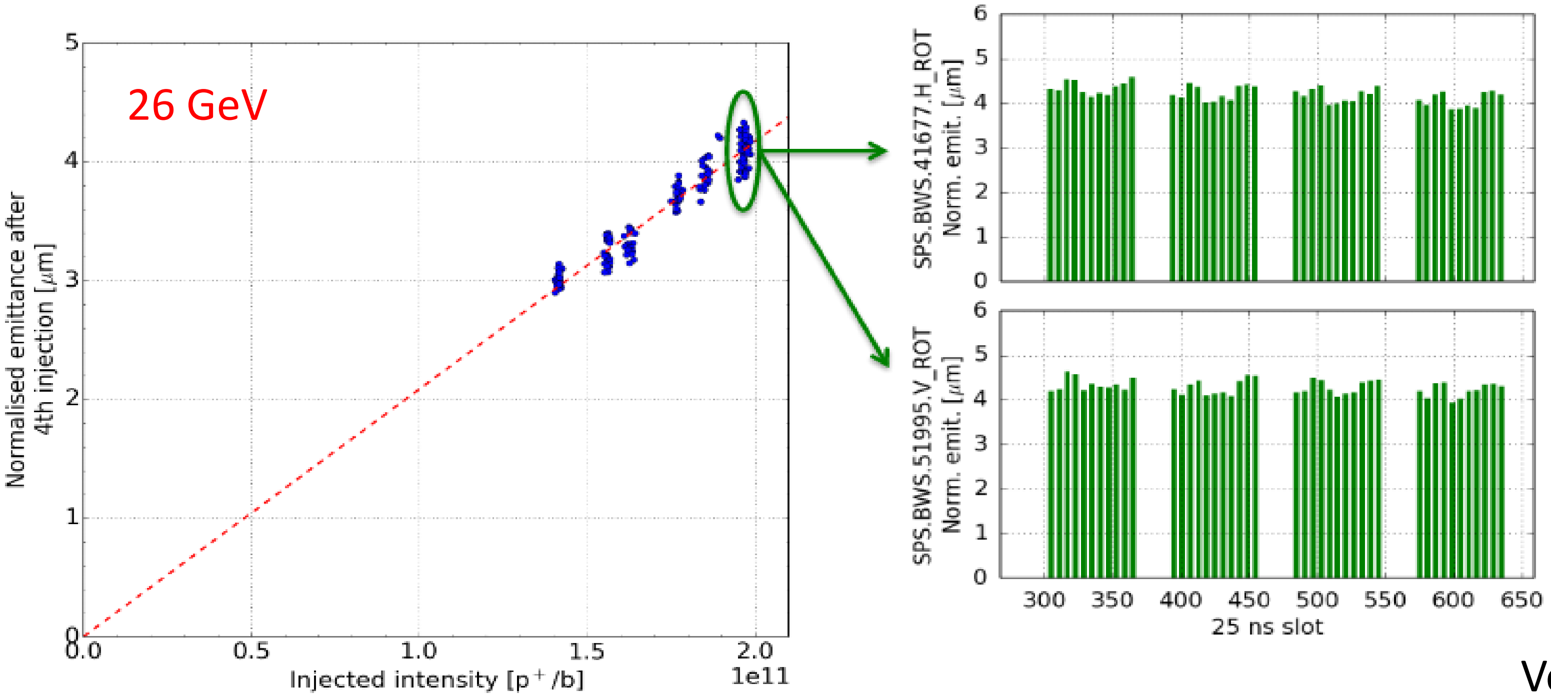


Verena Kain

SPS: 288 25 ns Bunches



- **Realistically aiming for 1.2e11 ppb in 2.6 μm emittance.**
- Operation more challenging and continuous tuning even more important.



Verena Kain

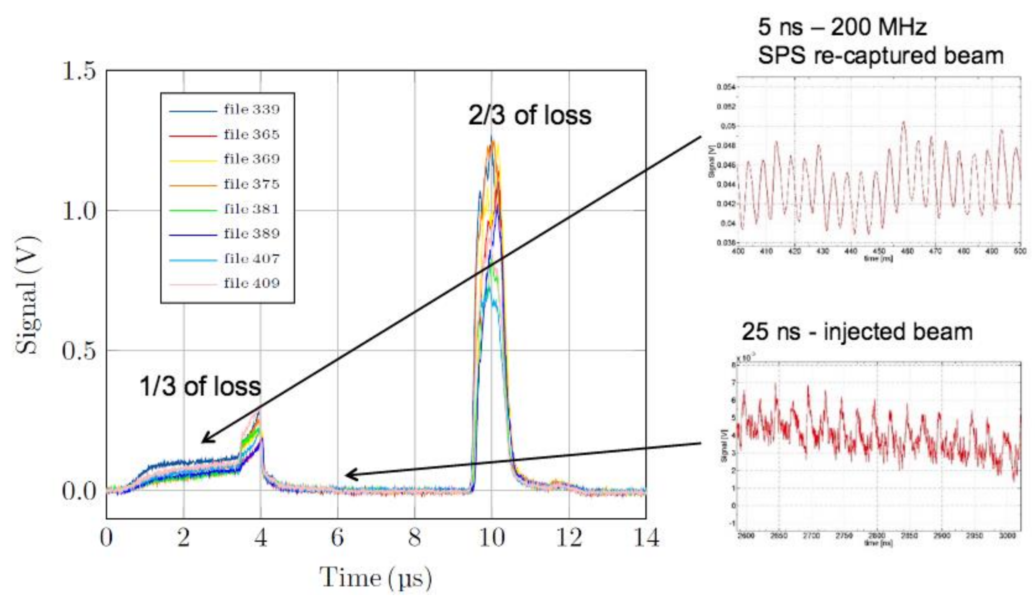
SPS and transfer: limitations and required improvements

- **Power limit on internal dump** TIDVG: 3.66 e13 p in 36 s

- **Impedance of injection kicker** MKP4 ➔ heating and outgassing

- **Emittance measurements with WS** at 450 GeV with 288 bunches not possible:
  - Above WS damage limit
  - BGI not operational
  - BSRT in non ideal location

- **Minimize uncaptured/re-captured beam** ➔ reduce losses on TDI



- **Improve TL stability**:
  - MSE source reduced by a factor of two
  - SPS orbit drift: investigations ongoing possible source (main dipole), test if possible correct the orbit with extraction bumpers

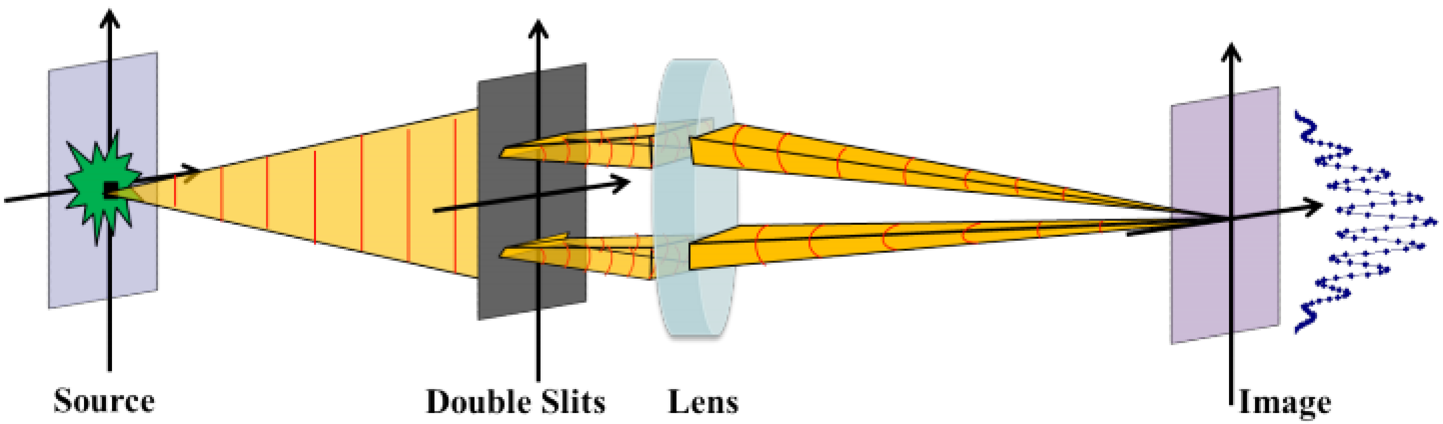
Verena Kain

LHC Diagnostics Overview

- Beam instrumentation improved after LS1
  - Better Performance and Reliability/Availability
  - Upgrades (e.g. feedbacks)
  - New implementations (e.g. DOROS, Instability Monitors)
- 2015 Run allowed identifying areas for further improvement
  - IBPMS
  - WS
  - BSRT
  - BCCM
  - …
- 2016 Run start of the transition towards LS2 consolidations and HL-LHC upgrades, e.g.:
  - Beam Halo
  - BGV
  - Schottky
  - Operational Diamond BLMs
  - …

Impressive set of novel developments

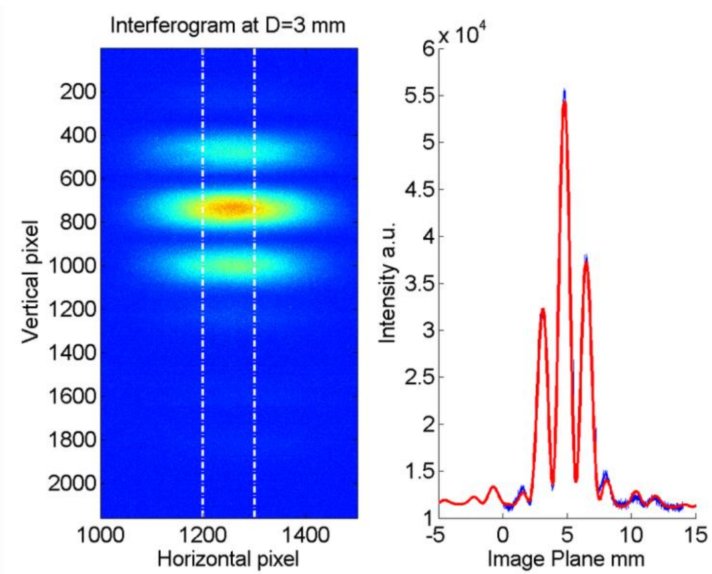
Sync. Light Interferometer (BSRI)



We Vary the slit Separation D → We observe the fringes “Visibility”

Interferometry tested on B1

- Beam size can be derived from visibility of fringes
- Method not affected by diffraction
- Results not fully understood in 2015 (comparison to WS)



Conclusions 1/3

- UFO rate has fallen encouragingly during 2015
  - Will lift BLM thresholds to avoid beam dumps
- ULO has moved vertically during 2015
  - Margins for increasing bump defined
- Electron cloud: lot learnt – good progress
  - Strategy for 2016 clearly defined
  - Look forward to supressing it in dipoles in 2016
- Beam induced heating should not be an issue
  - Keep monitoring closely
  - Prepare bunch length levelling

Conclusions 2/3

- Instabilities: main driver e-cloud in 2015
  - Proven mitigation in place
  - Diagnostics development is work-in-progress
- Impedance: understanding is fundamental to attempt to predict beam stability under change of machine configuration or beam parameters!
- Beam-beam - healthy situation – lower head-on, lower long-range
  - Good dynamic aperture even with high chromaticity, high octupoles, e-cloud

Conclusions 3/3

- SPS and SPS-to-LHC transfer
  - Better after a lot of work but constant attention still required
  - 25 ns: realistically aiming for 1.2e11 ppb in 2.6 um not much margin for improvement
- Diagnostics improved after LS1
  - 2015 reveal areas for further improvement!
  - Some very interesting novel developments (DOROS, diamond BLMs, interferometer, instability monitors…)

Looking good for 2016

All areas marked by impressive intellectual and experimental effort to fully understanding the issues. Backed up with MD and tool development.