LHC Beam Commissioning Status

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presently LARP Long Term Visitor @ CERN

With acknowledgement to the many CERN colleagues making up the LHC commissioning team, led by Mike Lamont.

Outline

- Introduction: The LHC Complex
- LHC Performance in 2010
- LHC planned Running & Improvements
- LHC Upgrades: Where to go
- Conclusion

The CERN Accelerator Complex

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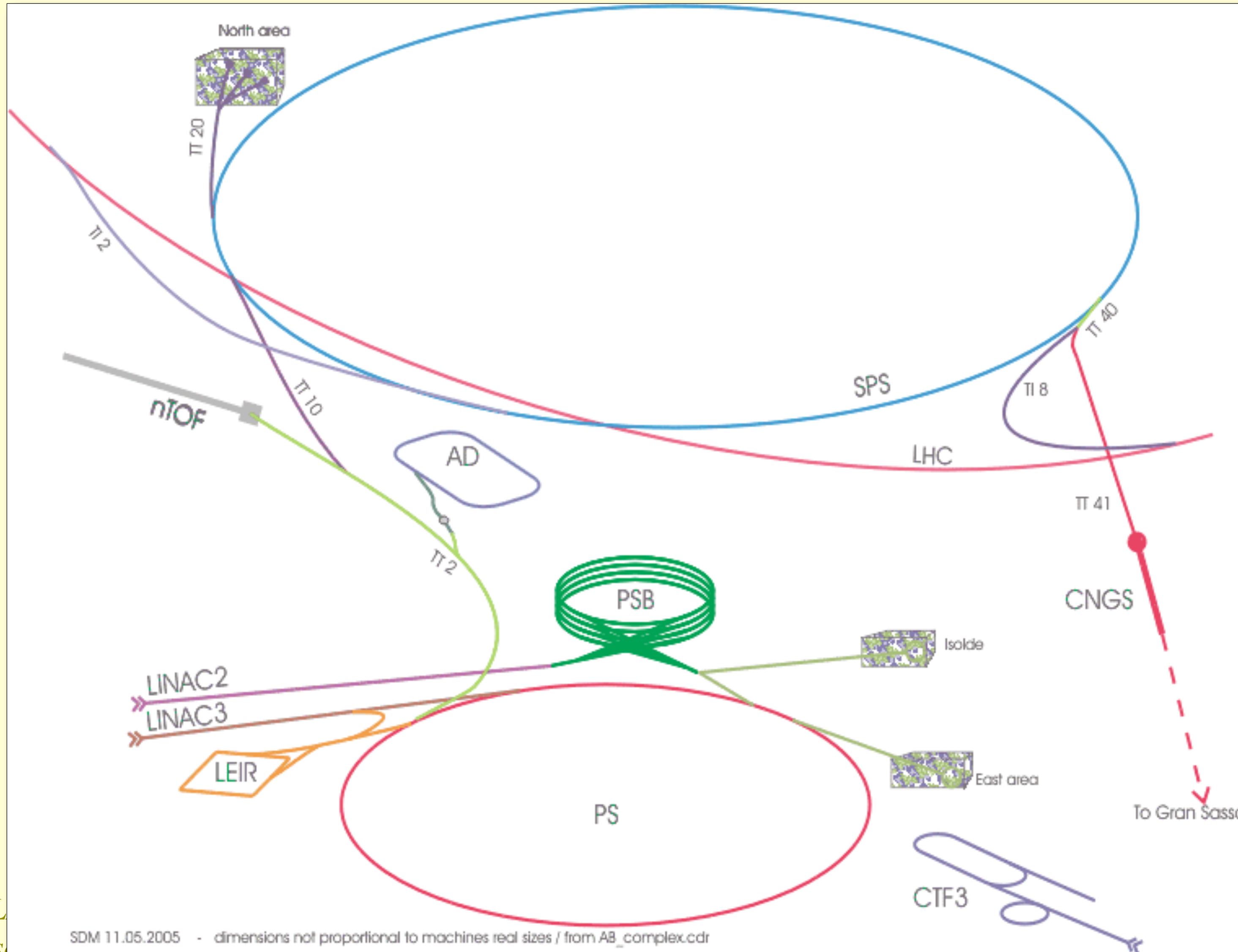

LARP

LHC Ring Layout

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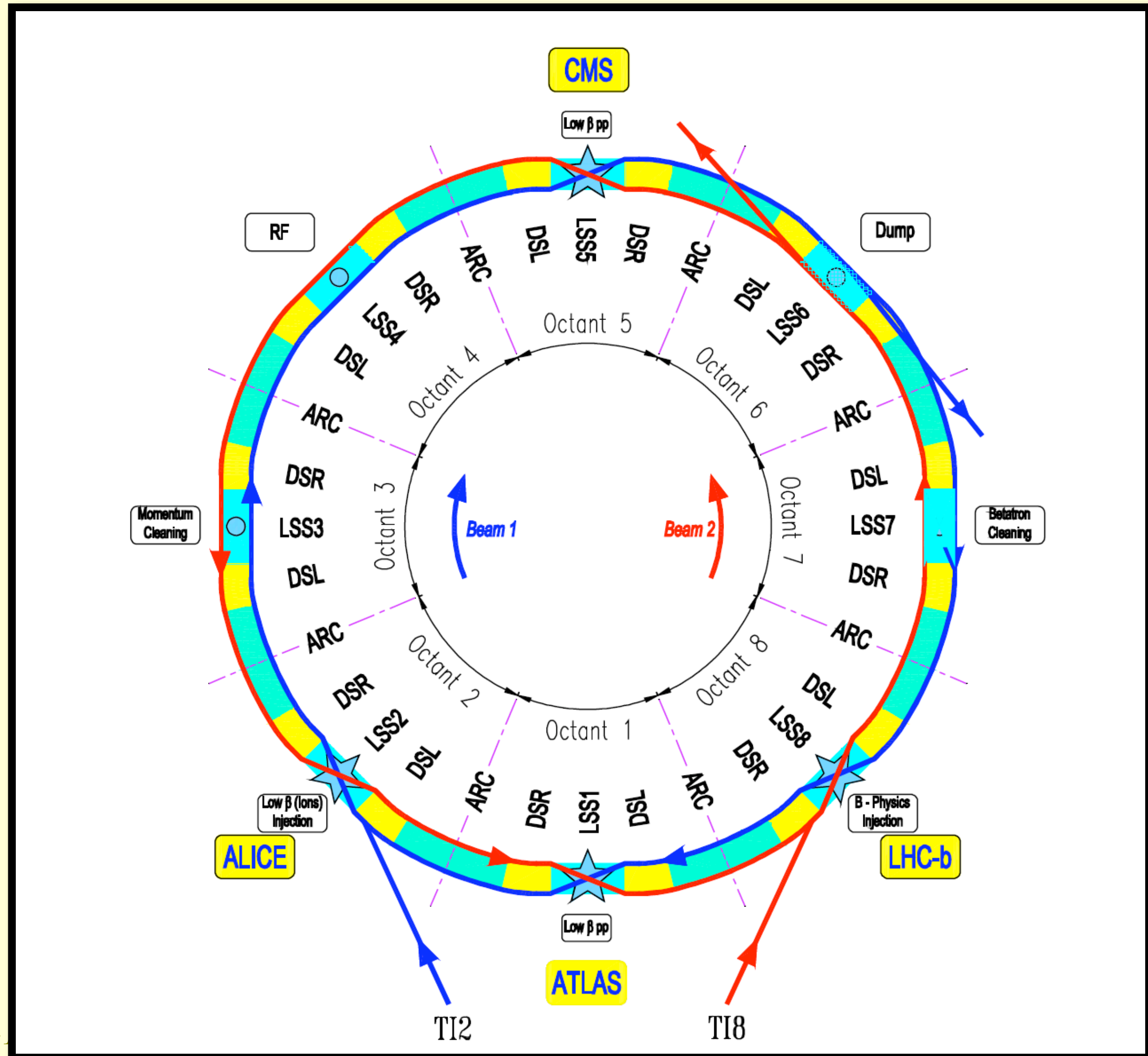


ALICE
4
2
LHC
PS
1
ATLAS
SPS
CMS
5
8
LHCb

The LHC Tunnel

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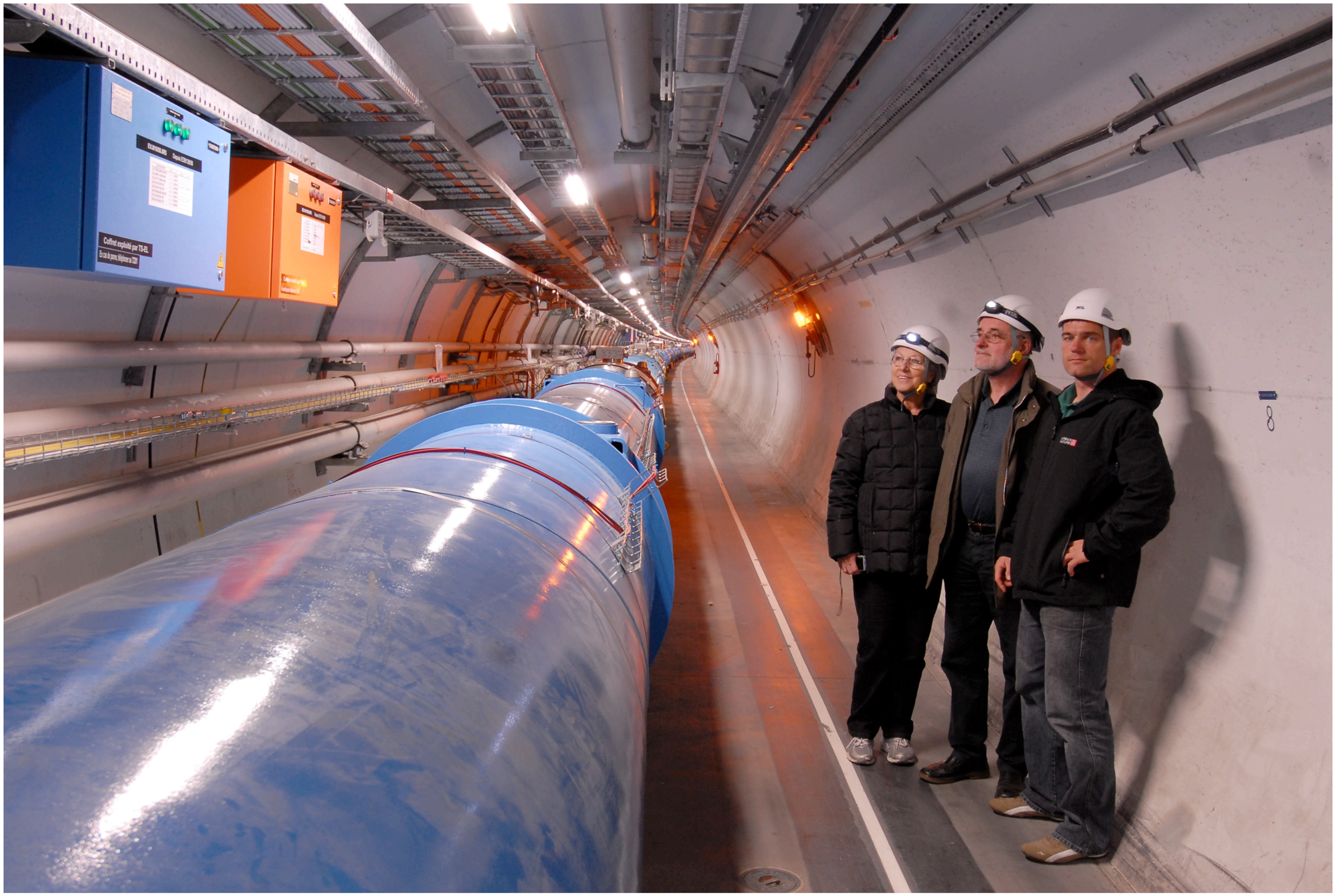
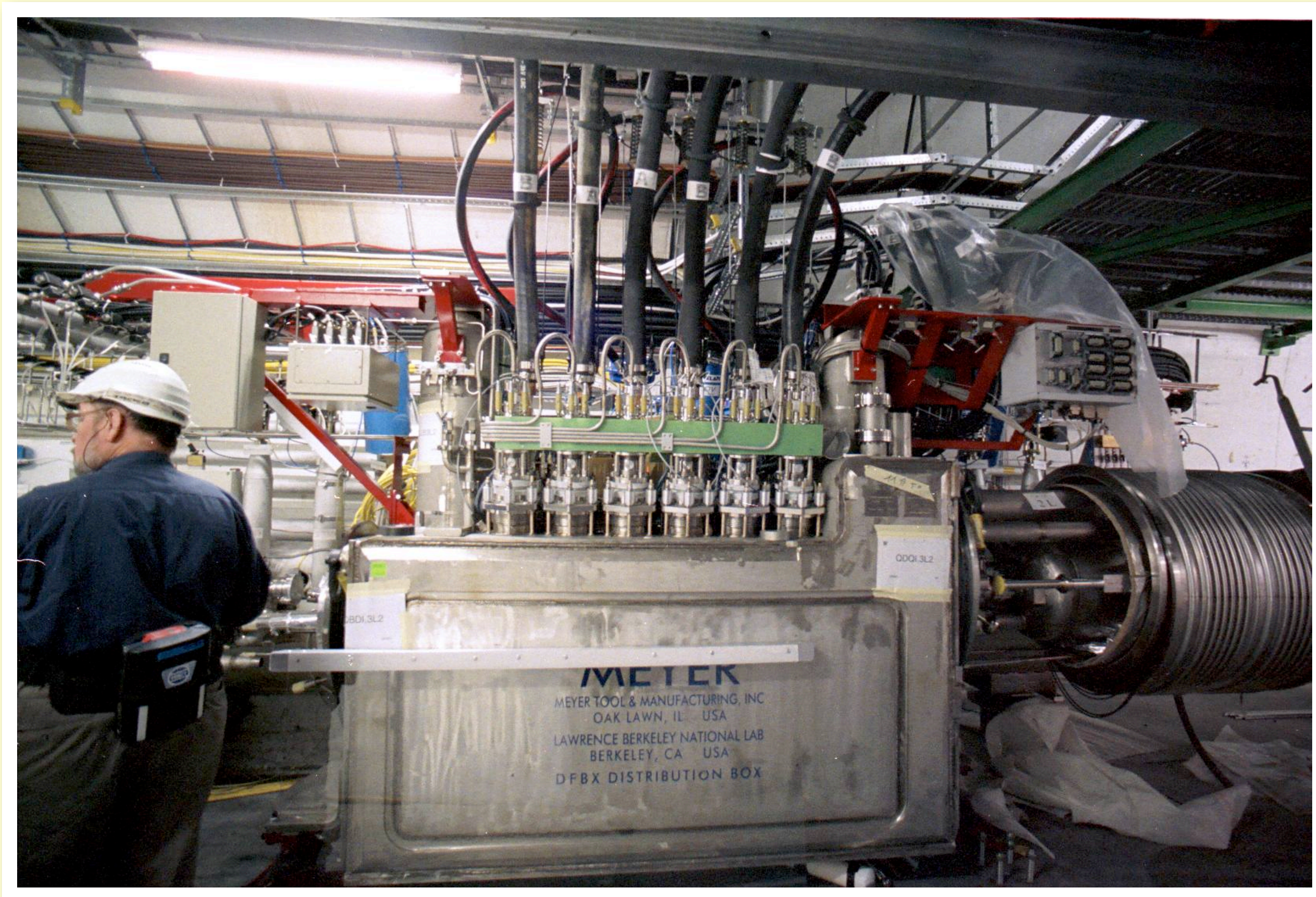


Distribution Box



Warm Section

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Rf in Tunnel

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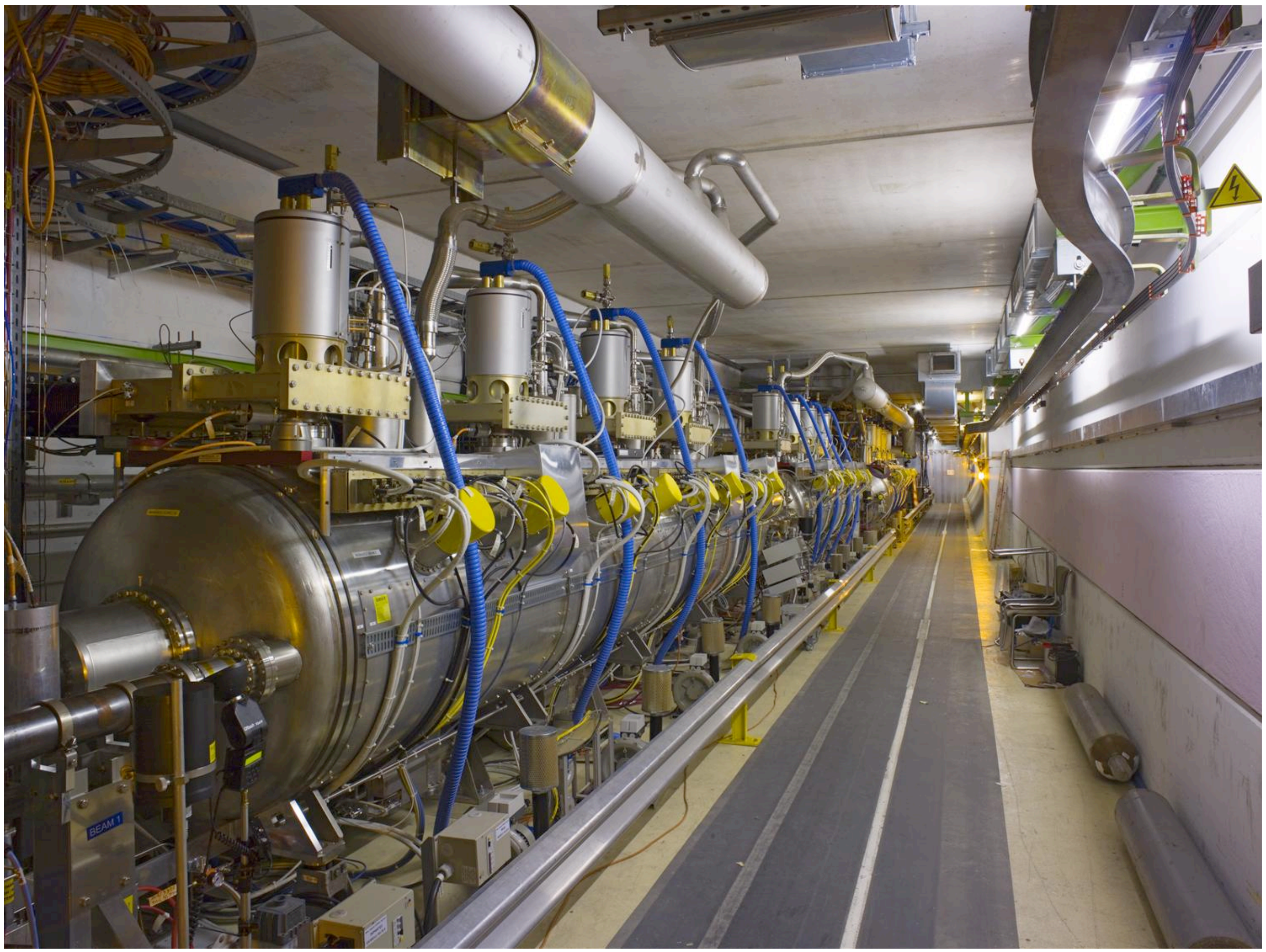
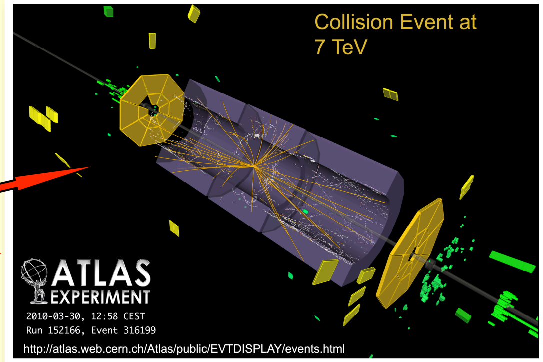
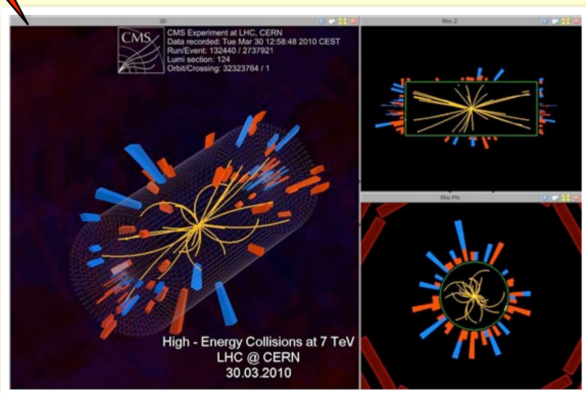


Beam Commissioning Main Steps

- Low intensity
  - Establish clean injection
  - Measure & correct optics
  - Establish Collisions @ 3.5 on 3.5 TeV
  - Commission ß squeeze at the IPs
    - commissioned to 2 m but for machine protection use 3.5 m for now
  - Establish beam-collimation setup
    - strict hierarchy of apertures



- Nominal bunch intensity (≈1.1×10^{11}, 1 bunch)
  - assess beam stability
    - commission dampers
  - assess beam-beam effect
  - Check collimation setup
- Multibunch collisions
  - redo all of the above
  - Check collimation setup



Parameters Achieved to Date

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- Energy: 3.5 on 3.5 TeV
- $\mathcal{L}_{peak} = 3.6\times10^{31}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- # bunches: 104 on 104
- E_{stored}: ≈10 MJ
- β^*: 3.5 m operational, 2 m in dedicated runs
- Beam emittance (norm): ≈ 3.5×10^{-6} m-r
  - growth of 2…3.5%/h seen
  - also have run near 2×10^{-6} m-r
- Luminosity life time: ≈ 20 h
  - … even for low-emittance (high ξ) fill
  - effect of beam size growth significant
- Beam-beam parameter: $\xi \approx 0.007$ (UW est.)

Luminosity

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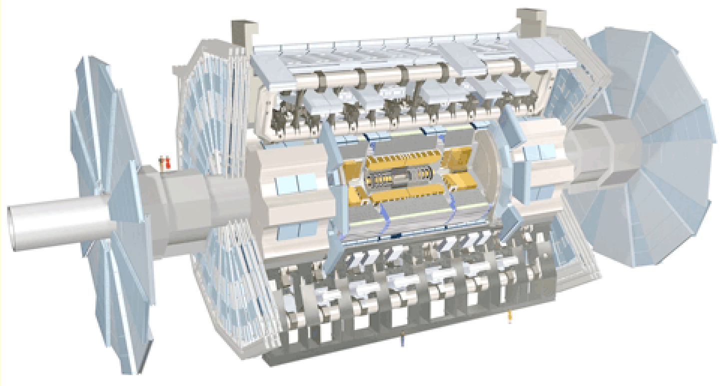

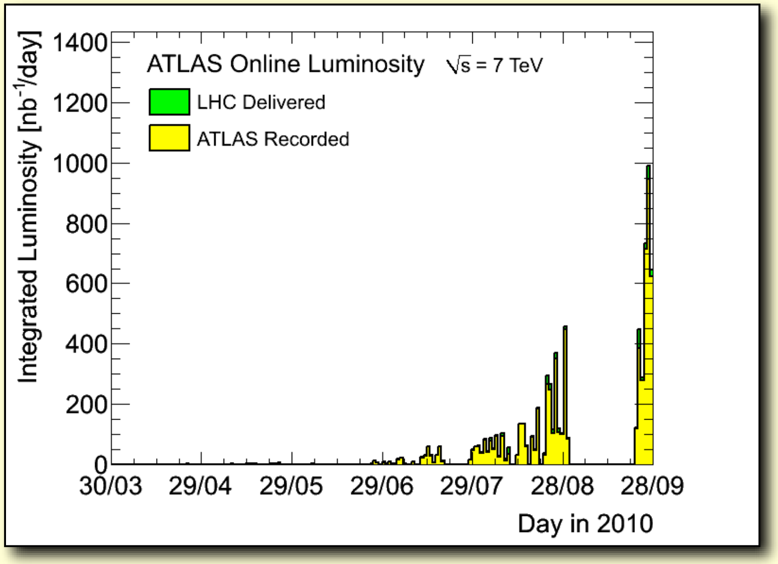

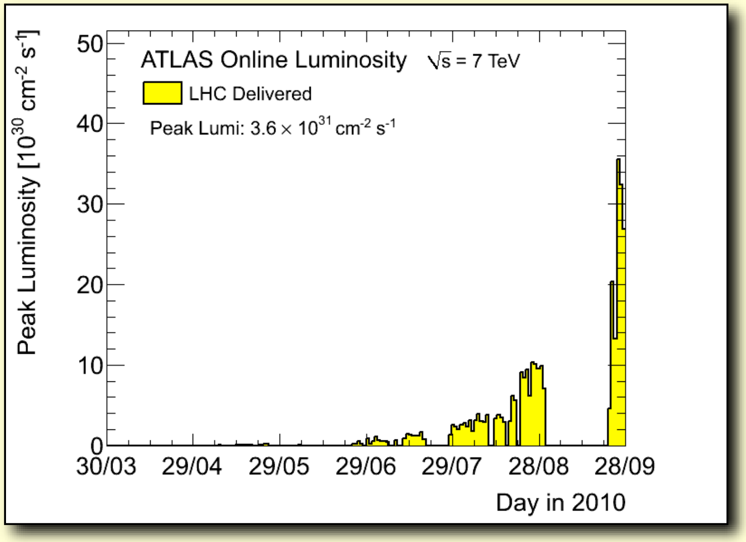

$\int Ldt$

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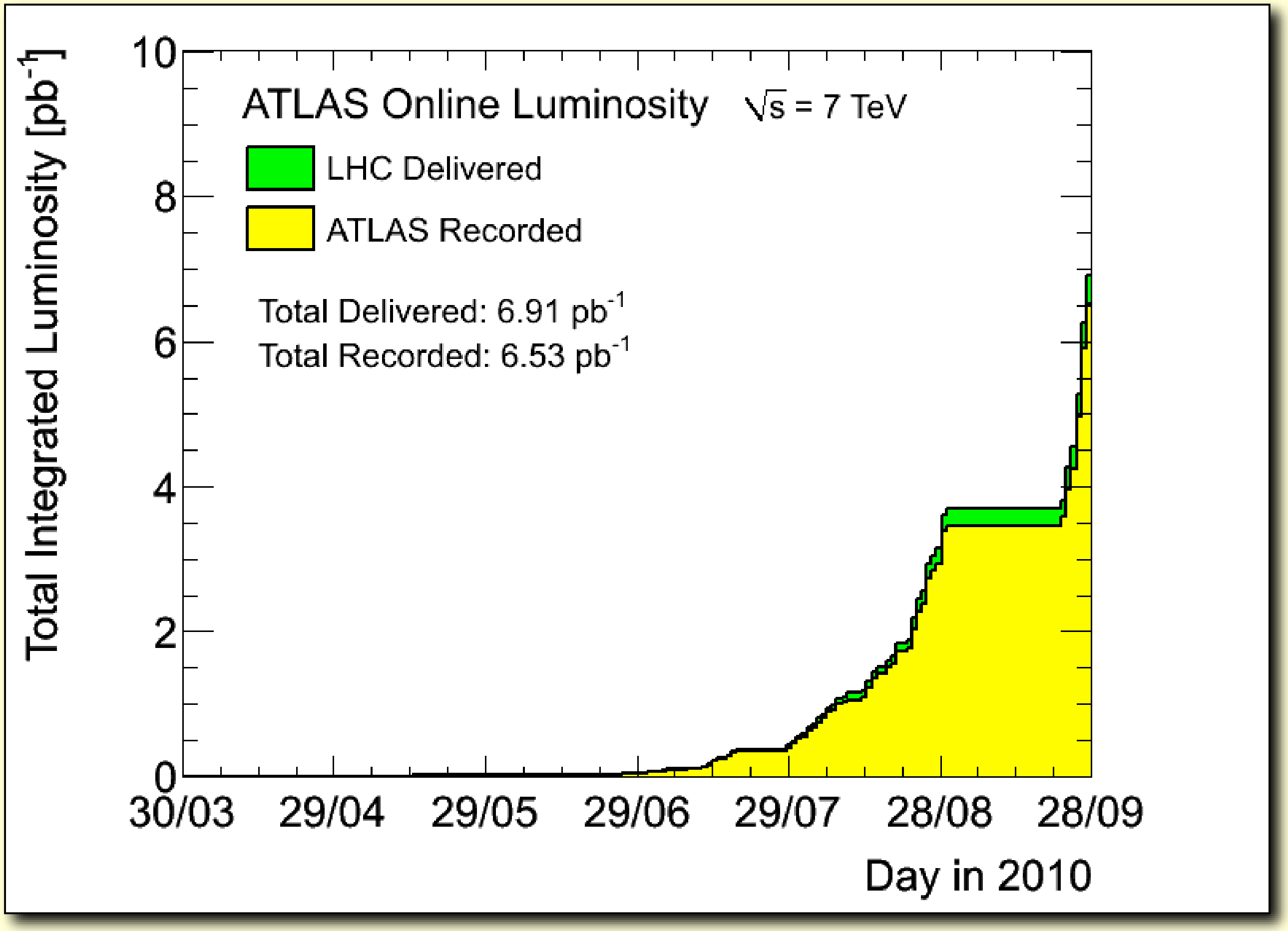

Beam-Beam Scan

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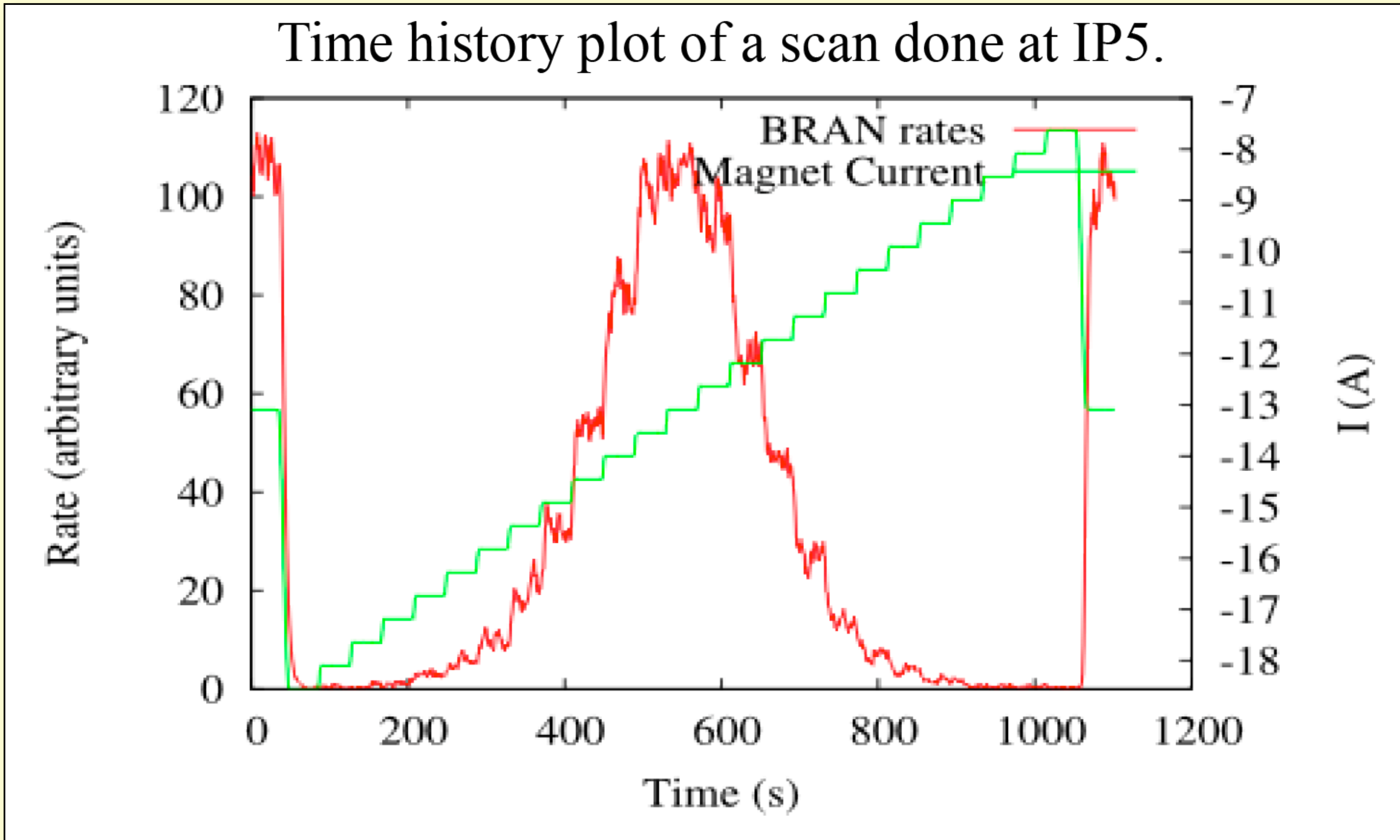

Luminosity Lifetime

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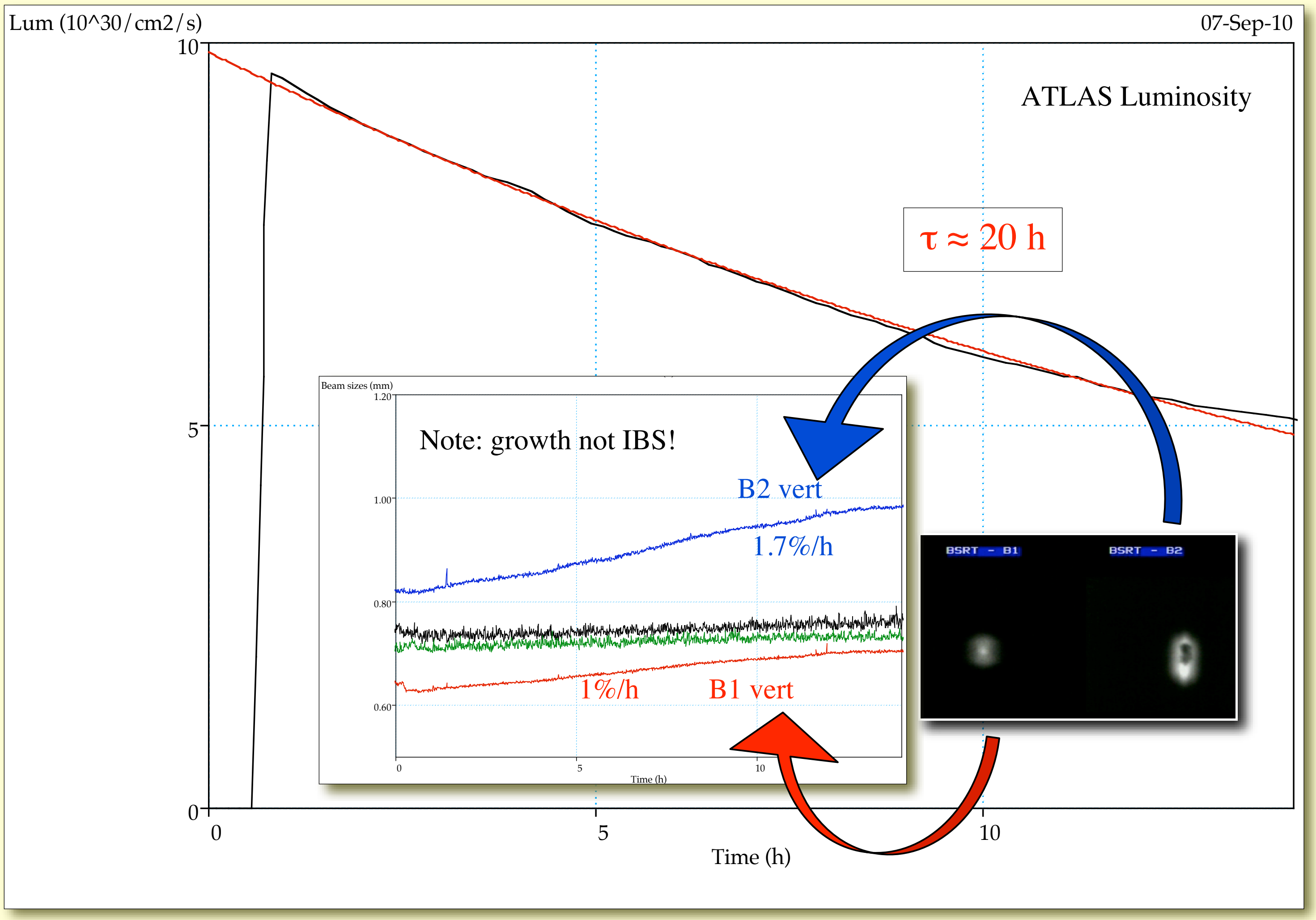

Beam-beam Effect

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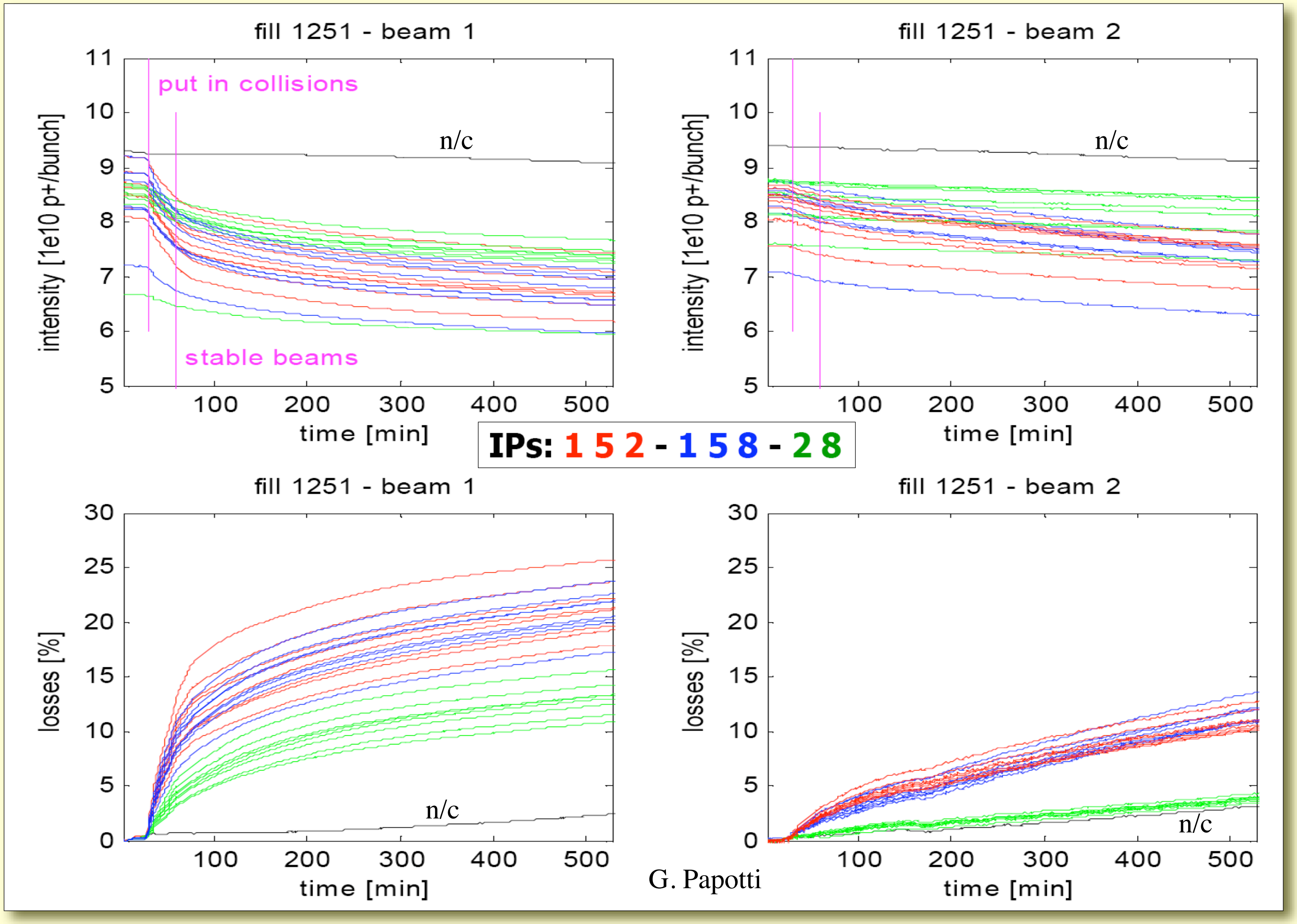

Beam-Beam…48-bunch fill

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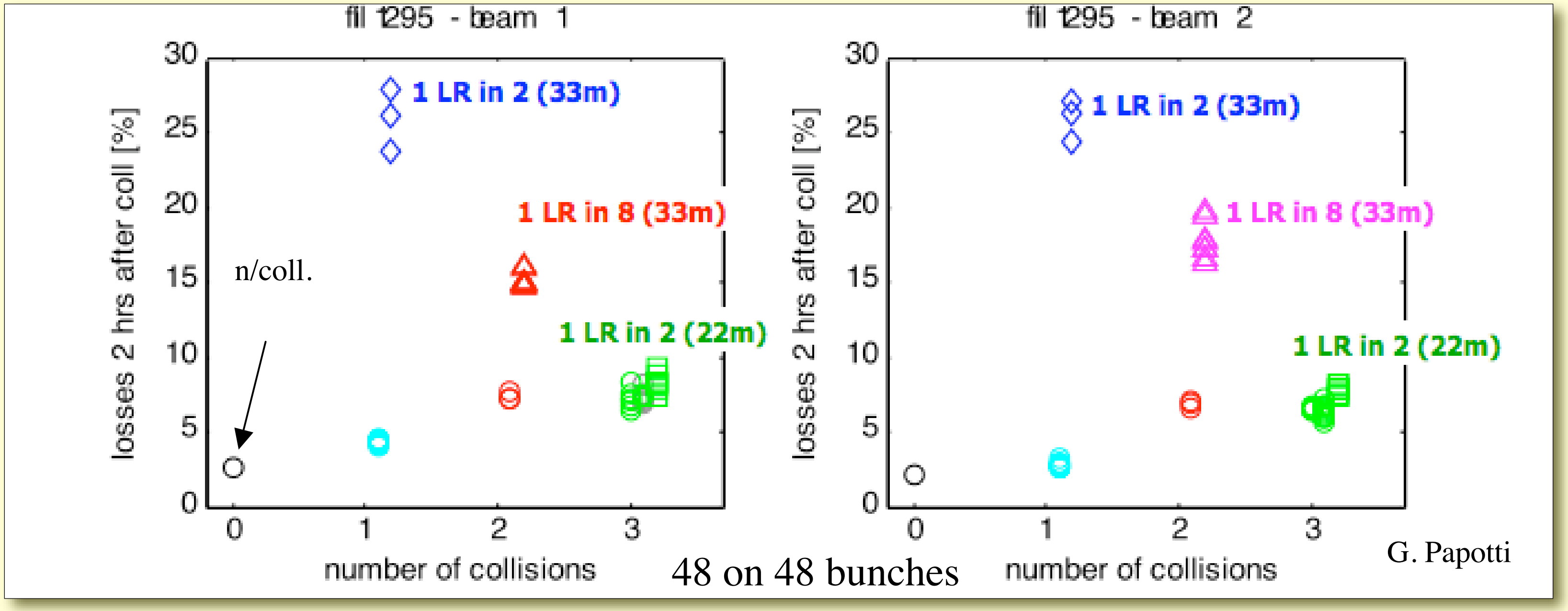
- $\xi \approx 0.003$ at these parameters
  - little problem for head-on collisions
  - parasitics are a different issue, though…
    - need crossing angle for larger # of bunches



Optics: Envelope Functions

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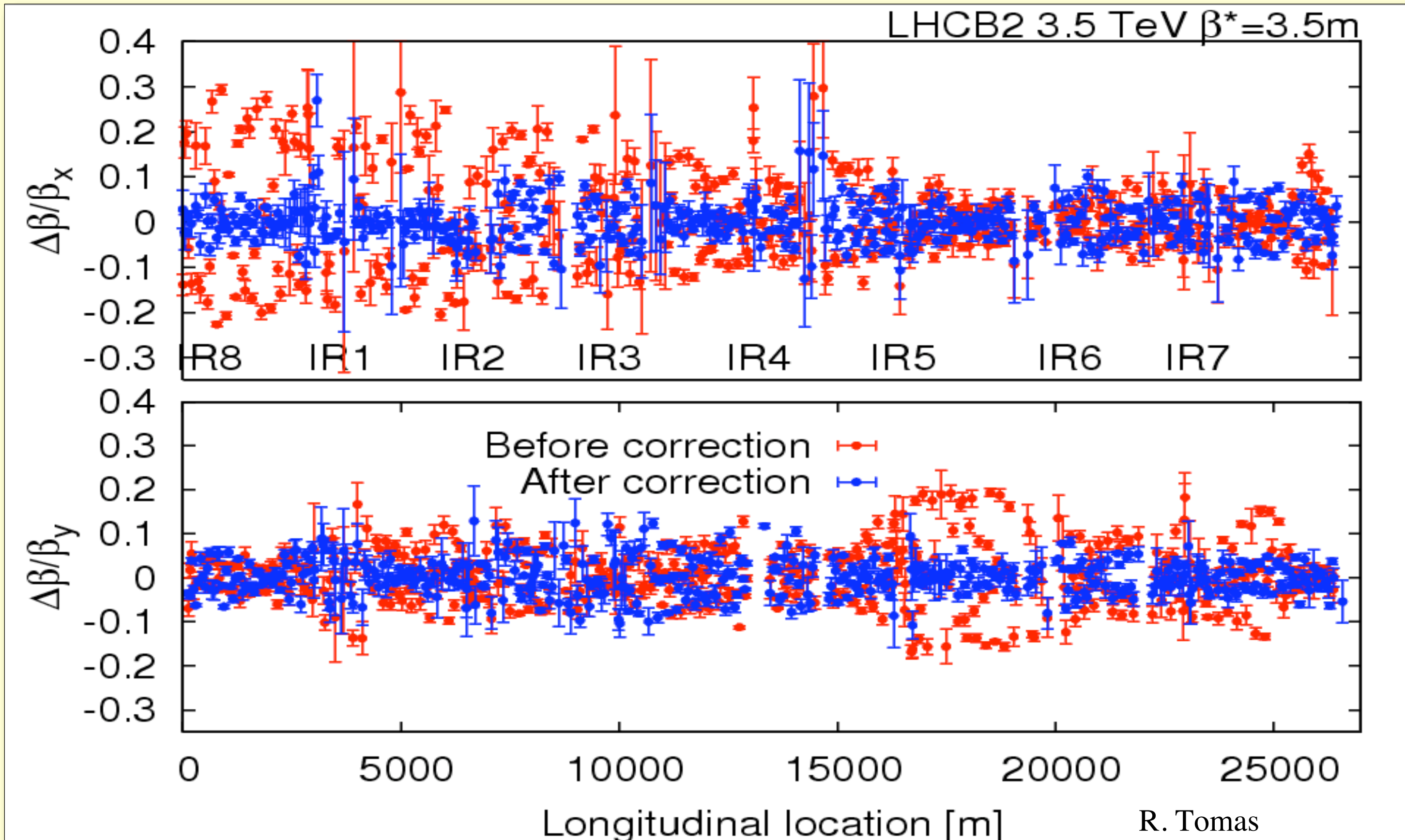
- $d\beta/\beta_{model} \leq 20\%$ (better than spec.)



W Function (β chromaticity)

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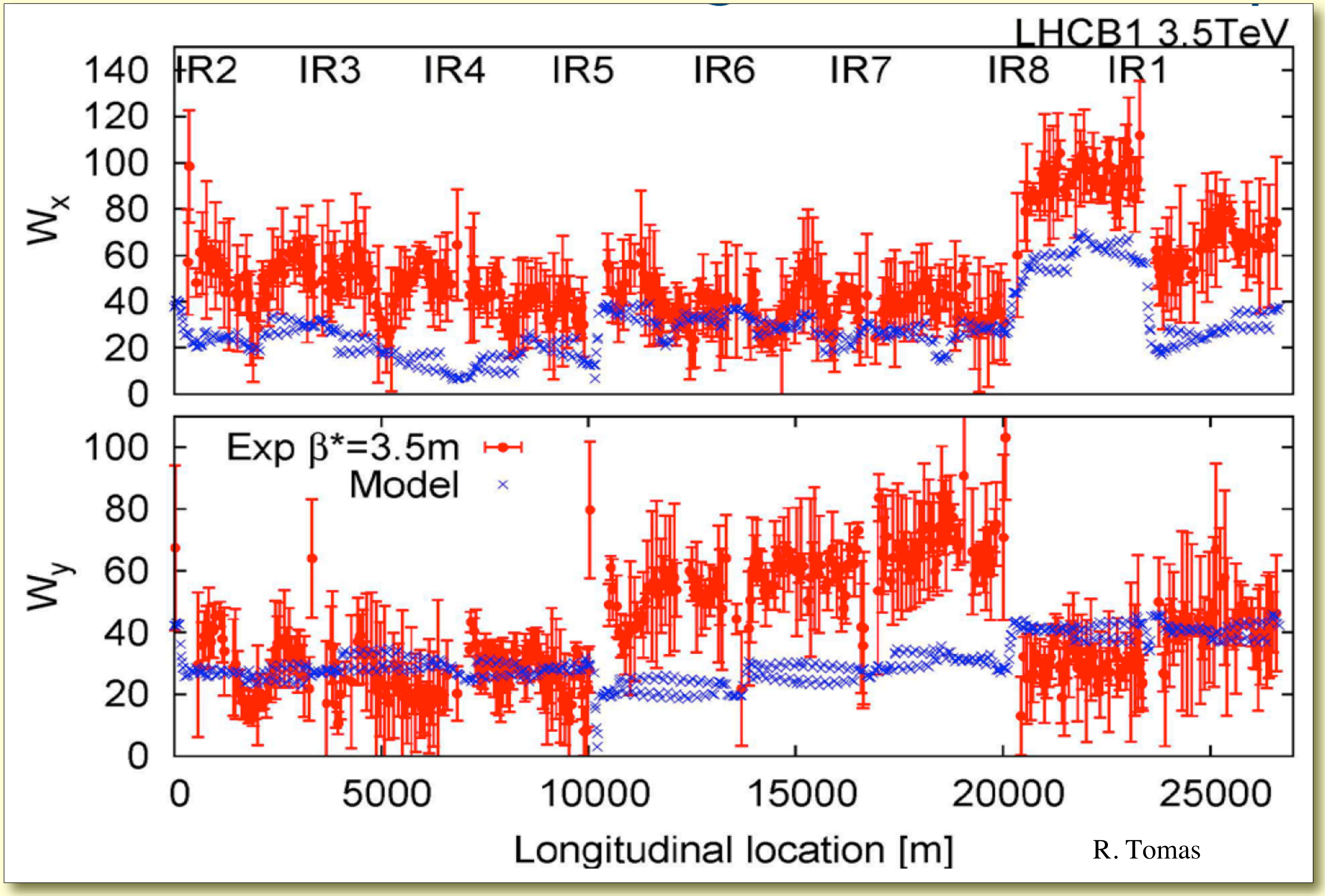

Beam Collimation

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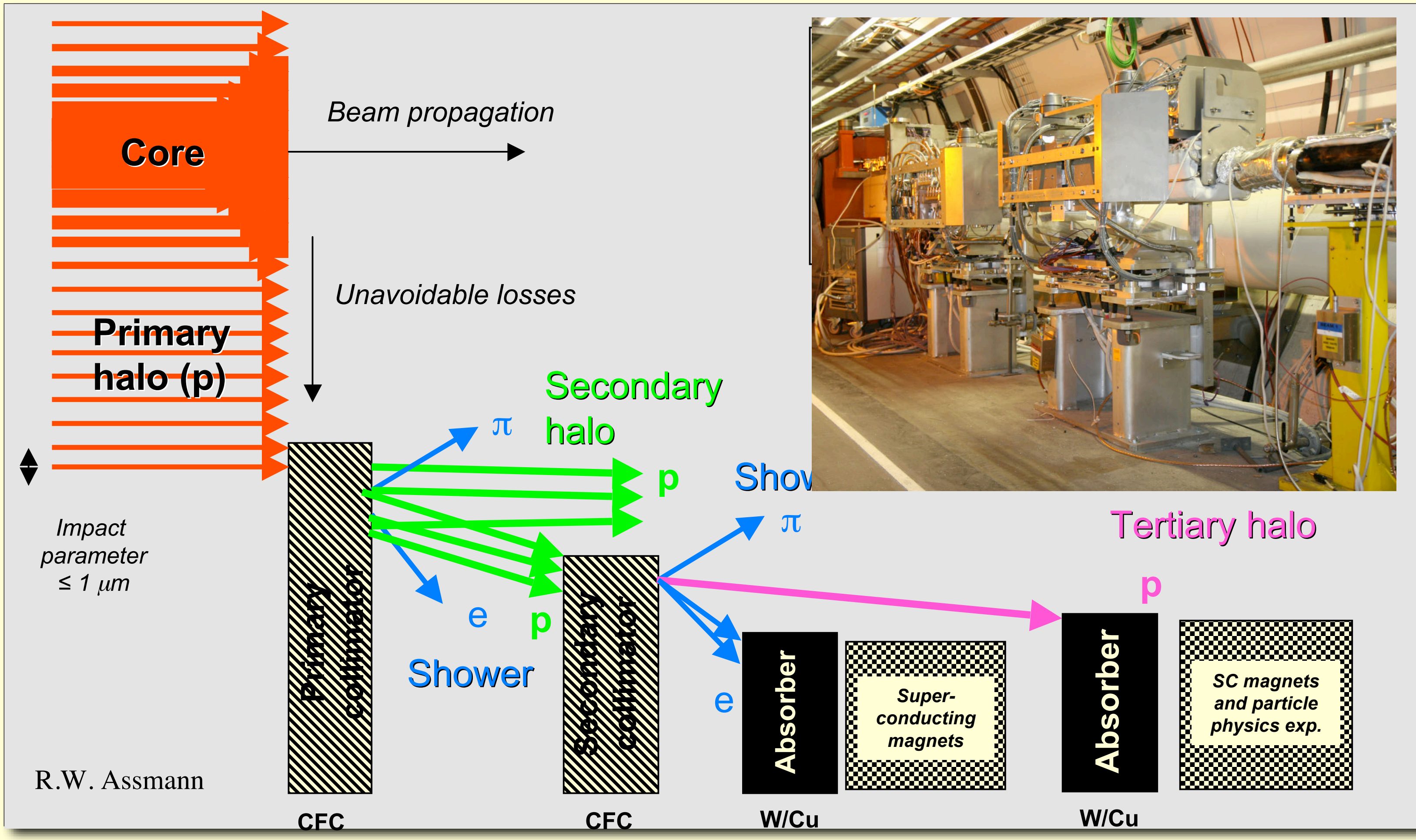
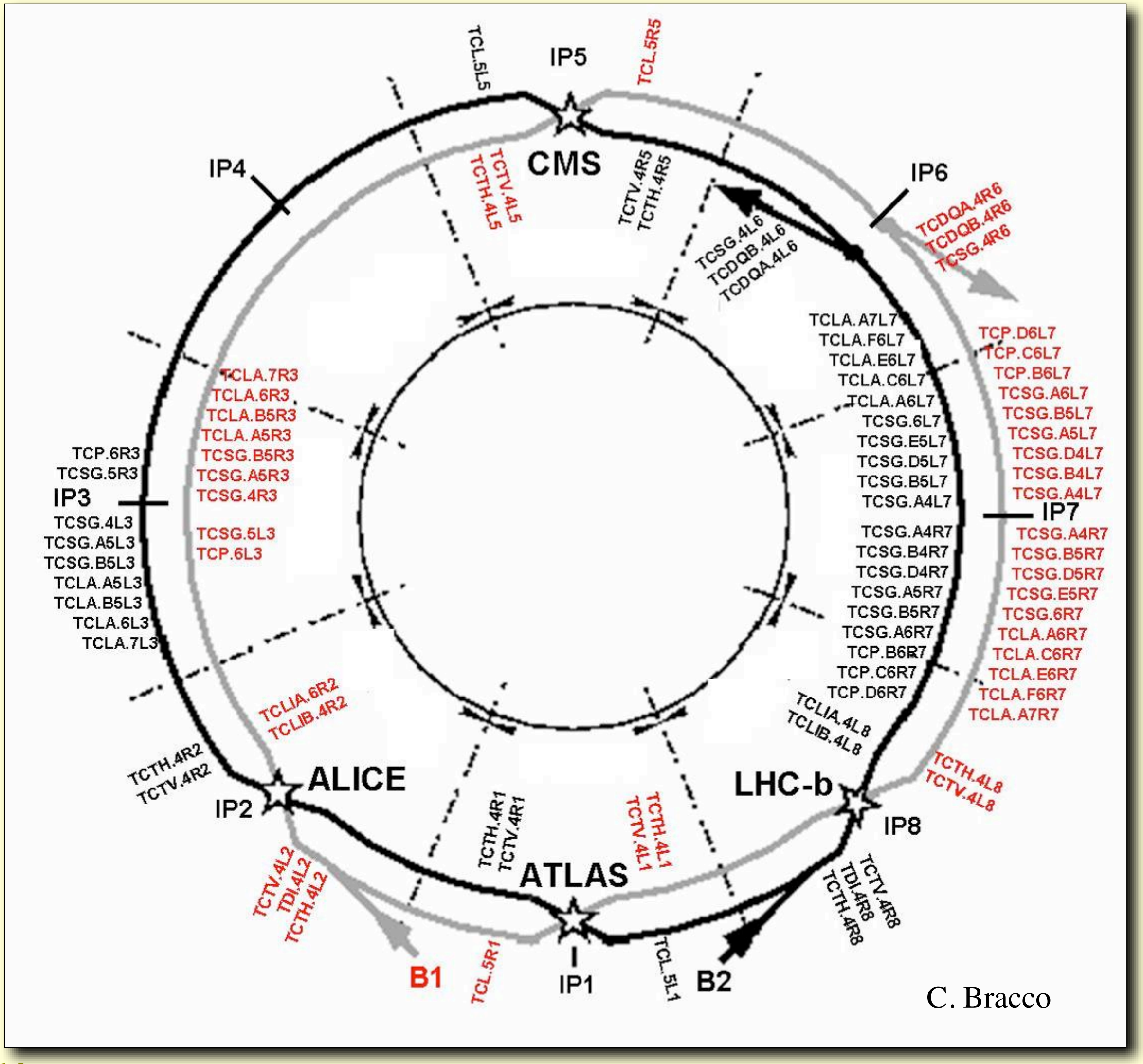


LARP



C. Bracco

Beam Loss Map in Collision

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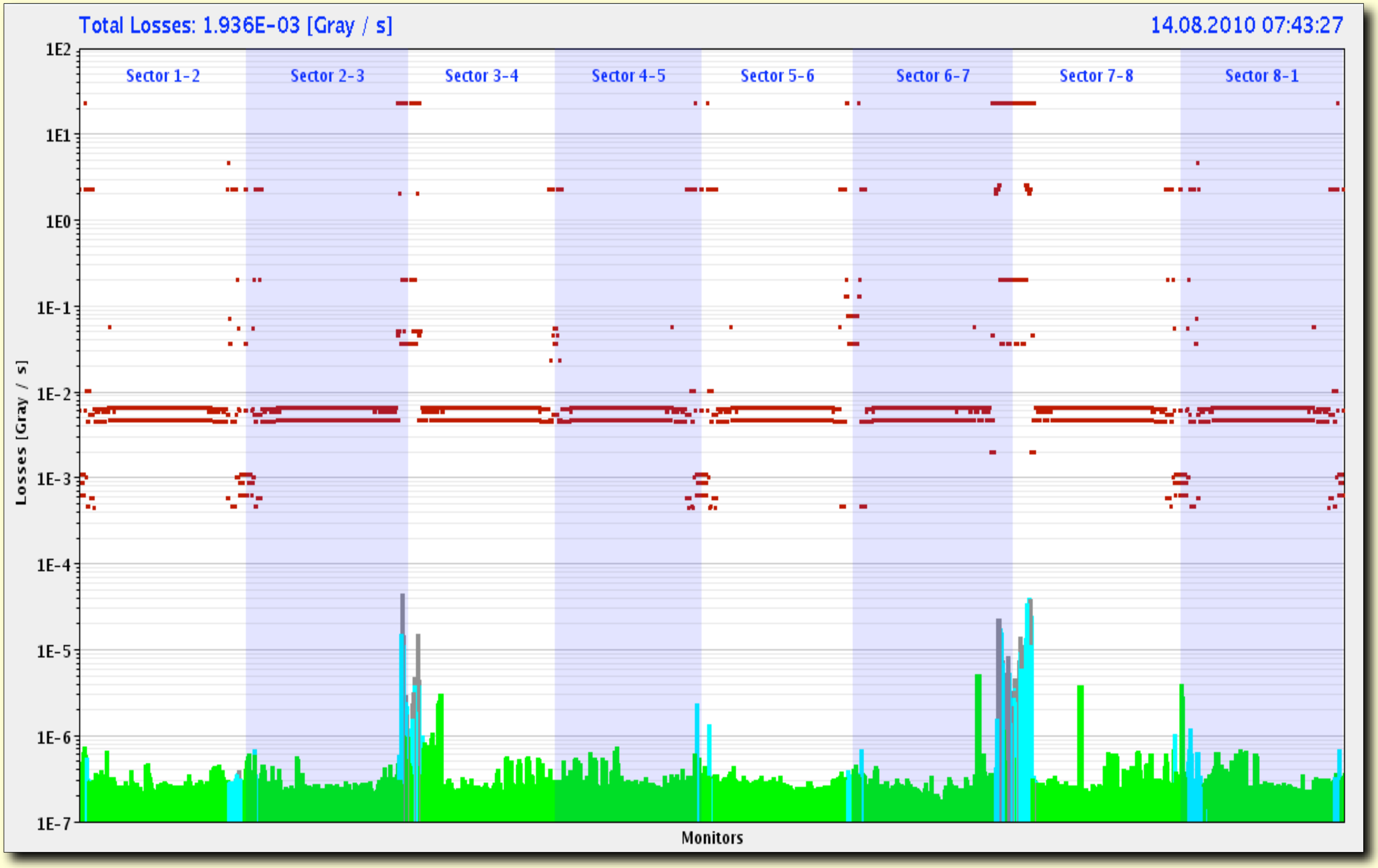

Momentum-Space Beam Loss

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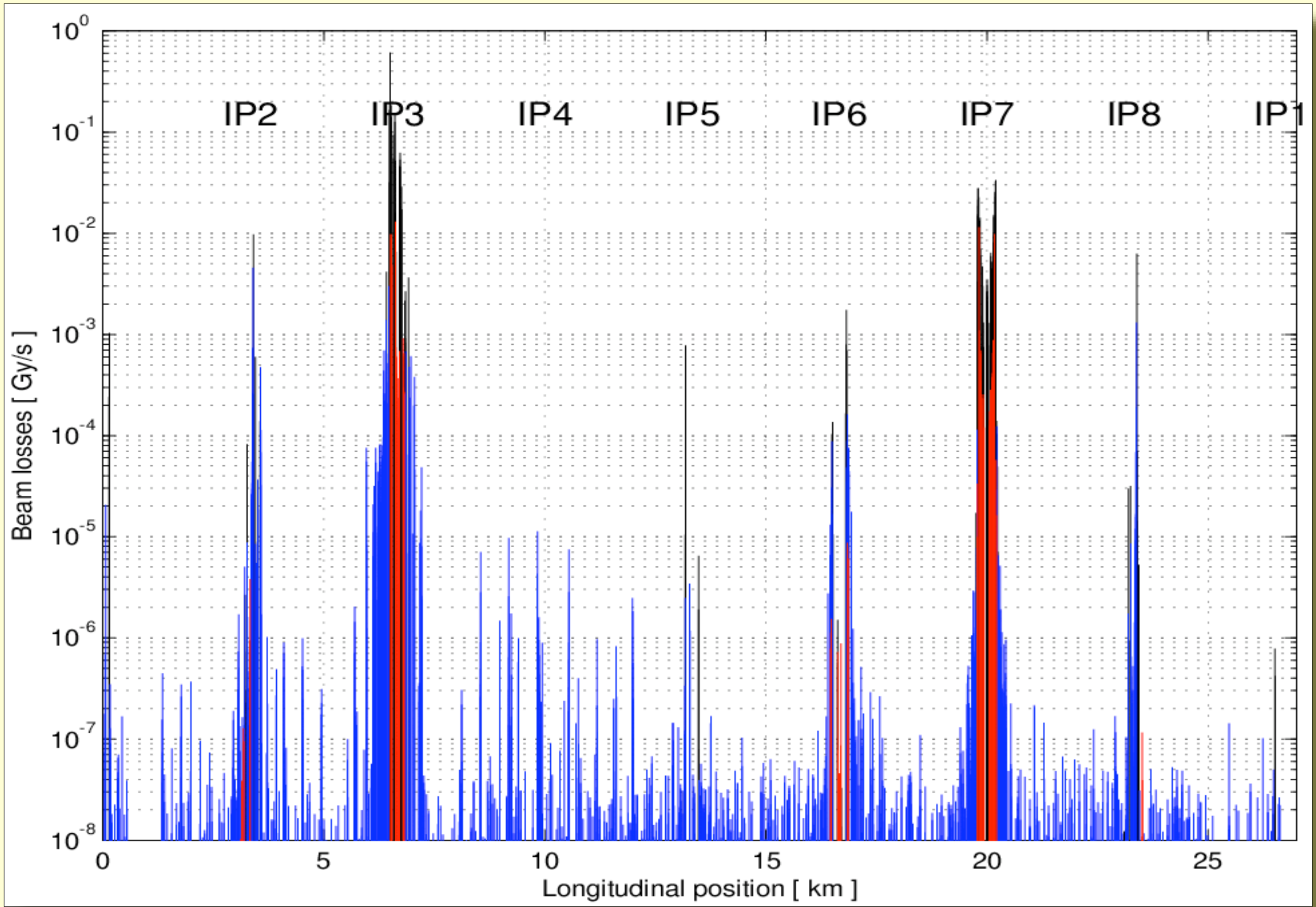

Intensity-Related Effects

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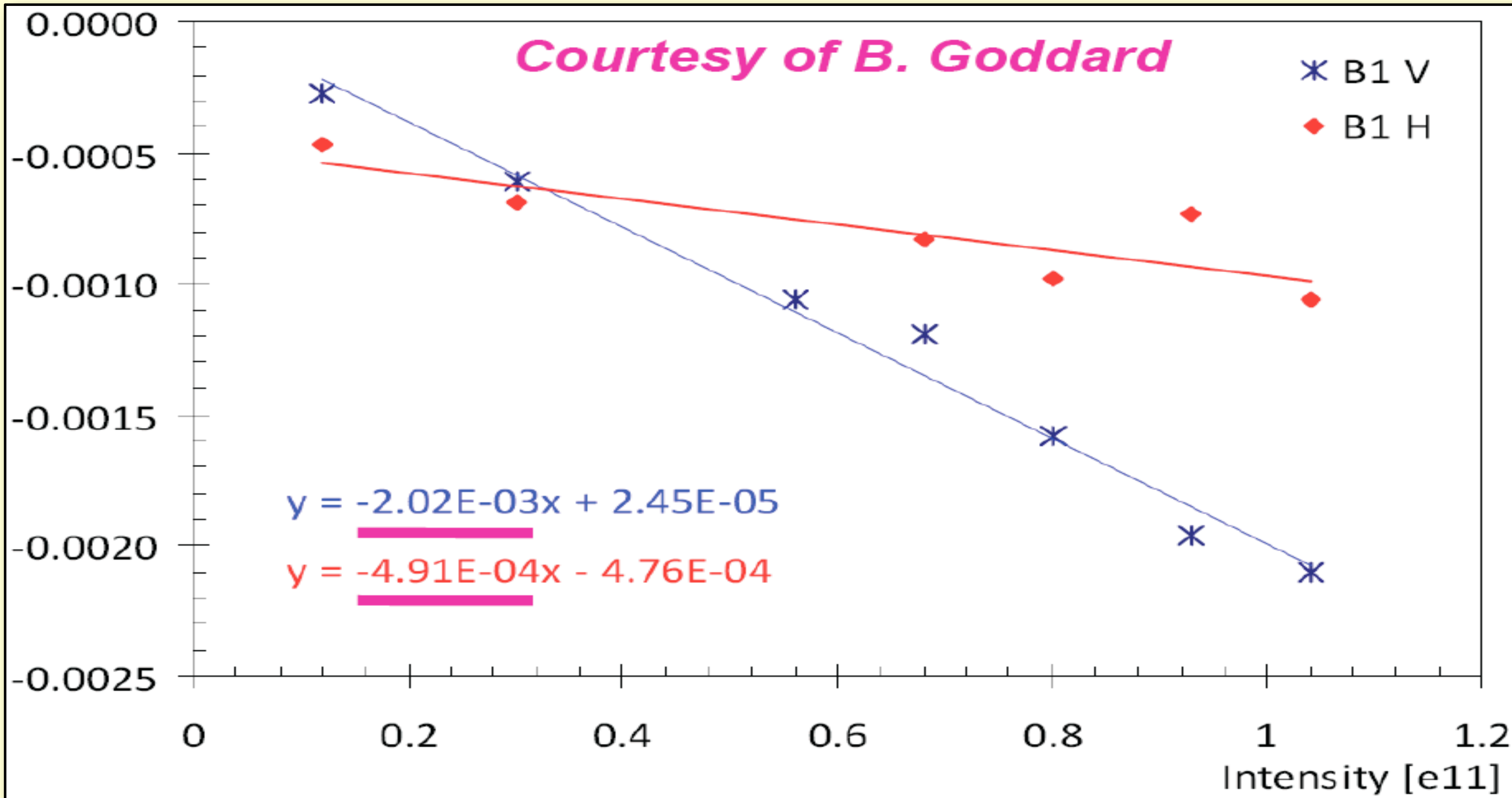
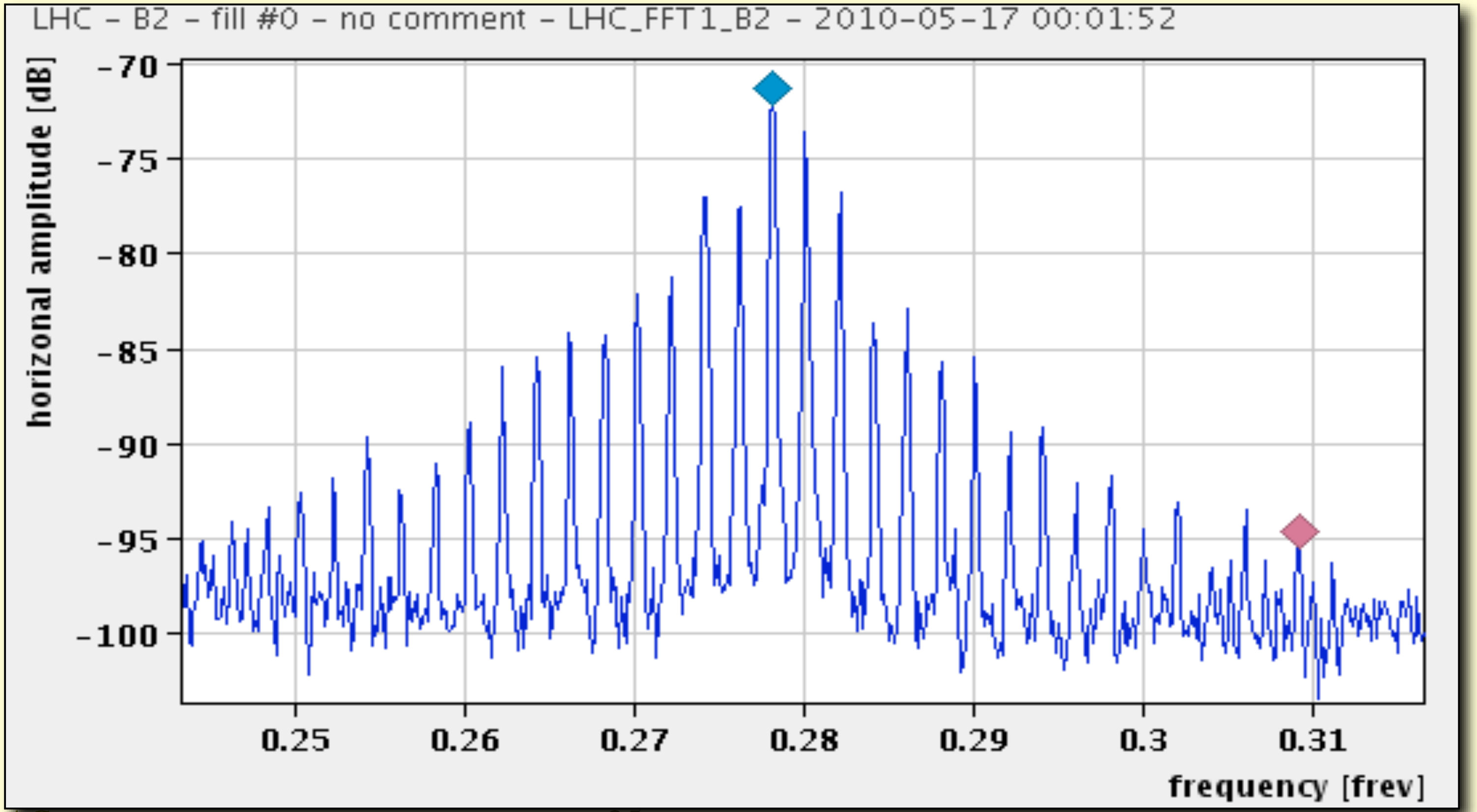
- Higher than expected tune shift with intensity
  - (high-frequency-) impedance… collimators?



Intensity-Related Effects

- Coherent signal seen with multibunch beam
  - then cured with octupoles, no issue with trans. damper



Intensity-Related Effects

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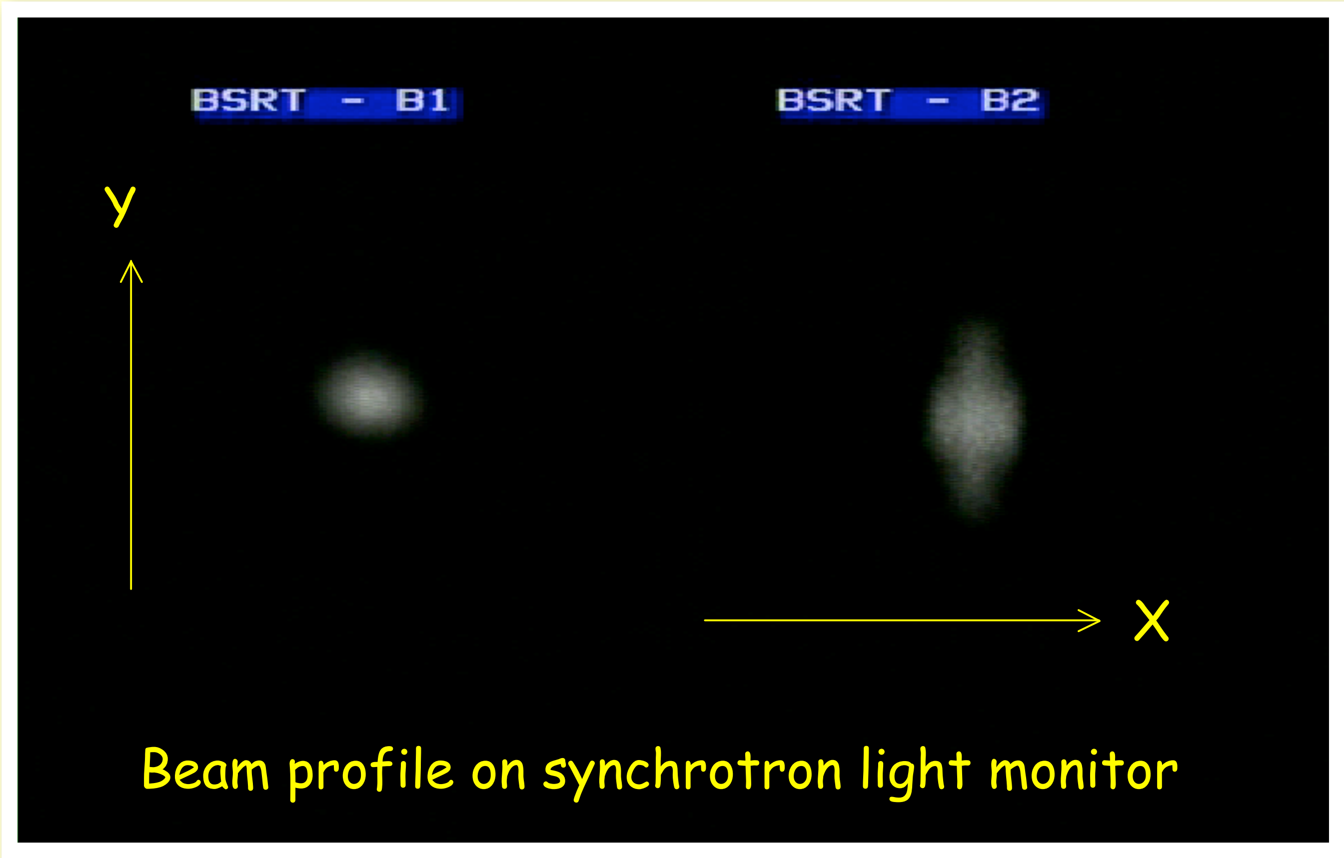
- "Saturn" instability



Transverse Damper Performance

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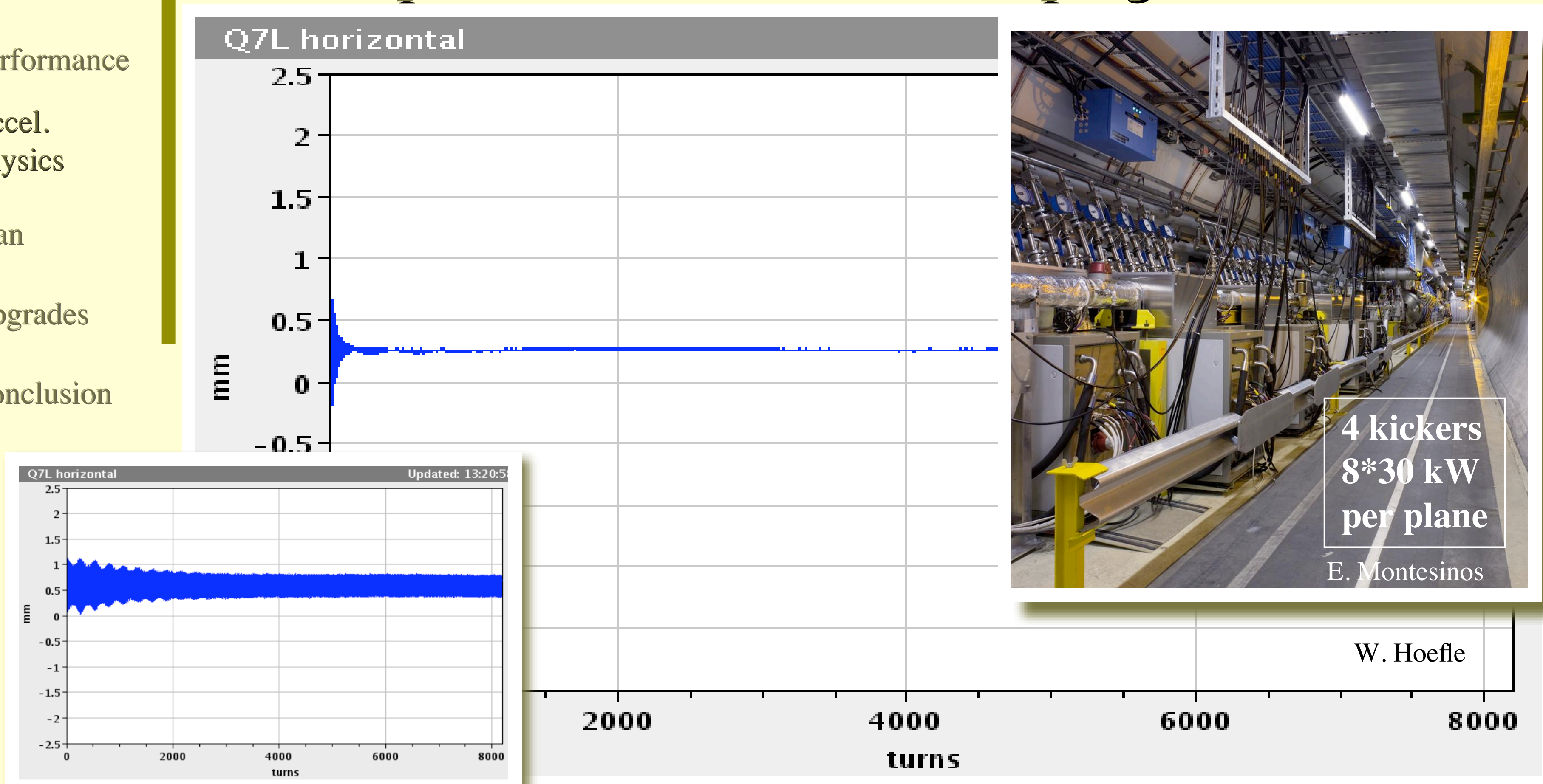
- Damps well… ≤ 20 turns damping time meas’t



Trans. Damper Effectiveness

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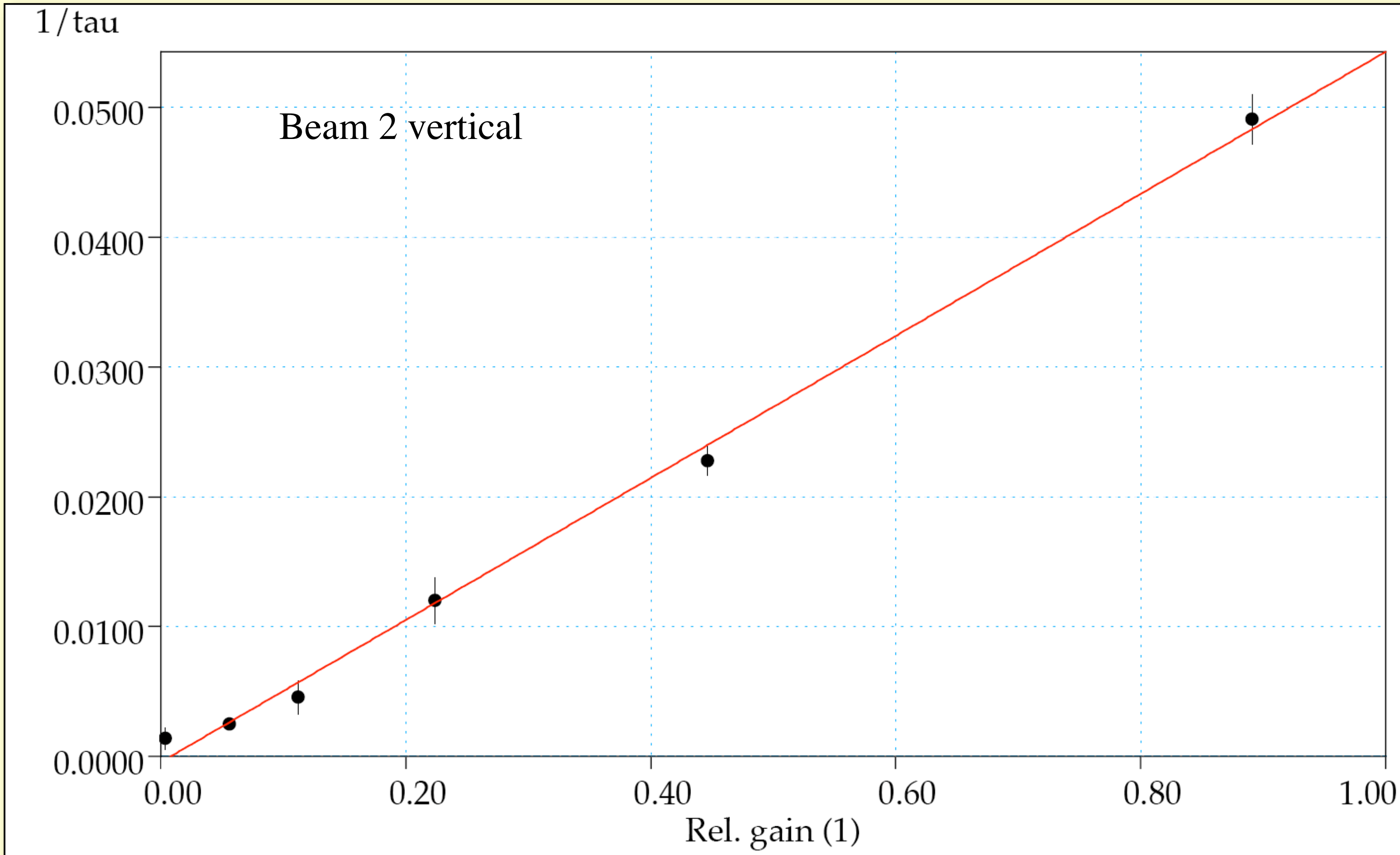

Transverse Damper

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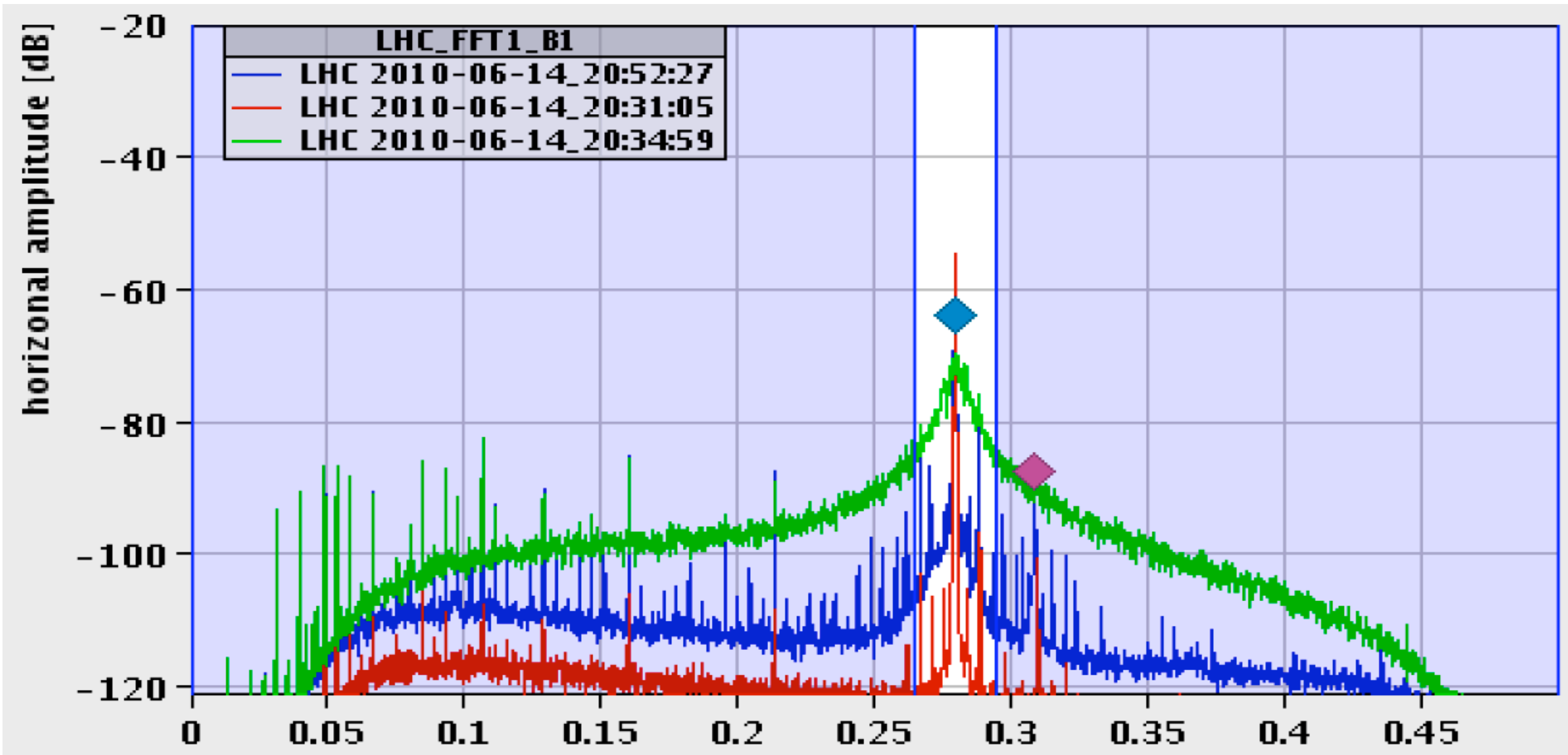
- …but tune spectrum shows increased noise…



R. Steinhagen, W. Hoefle

Spontaneous Beam Loss

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R.W. Assmann

??Dust Event??

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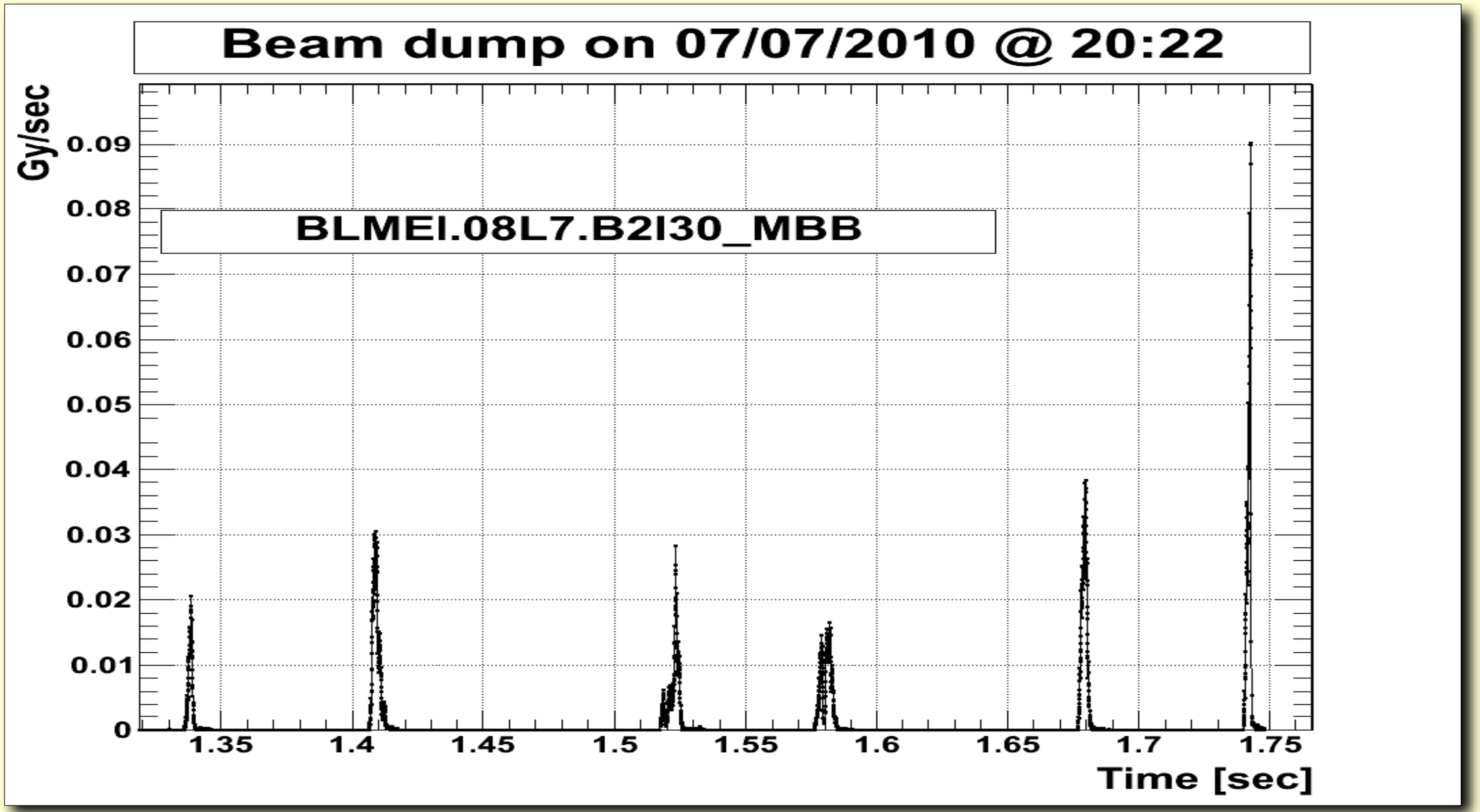
- Signature said to be consistent with dust particles ejected after ionization



Goals for 2010-2011

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2009			2010			2011		
Repair of Sector 34	1.18 TeV	nQPS 6kA	3.5 TeV $I_{safe} < I < 0.2\ I_{nom}$ $\beta^* \sim 2$ m	Ions		3.5 TeV $\sim 0.2\ I_{nom}$ $\beta^* \sim 2$ m	Ions	
No Beam	B		Beam			Beam		

Goal for 2011: 1 fb^{-1}/exp at 3.5 TeV/beam.

Large increase of L needed by the end of 2010

$L \approx 2 \times 10^{32} cm^{-2} s^{-1}$

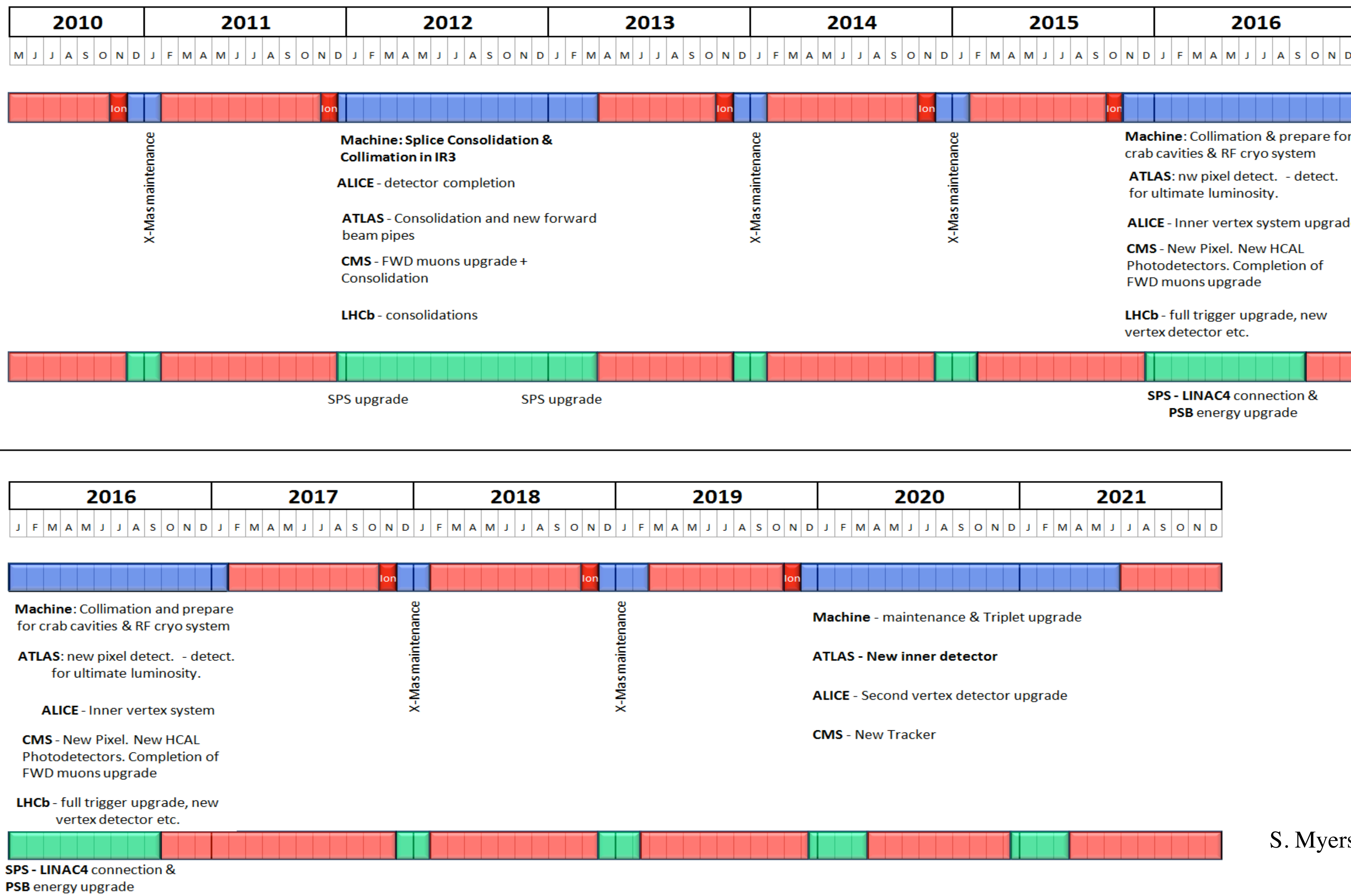
~ Tevatron Luminosity

~700 bunches of 8×10^{10} p/bunch

stored energy of ~ 30 MJ – >10% of nominal

Optics	$\beta^*_{inj.}$	$\beta^*_{coll.}$
IP1 / IP5	11 m	2 m
IP2+	10 m	3 m
IP8+	10 m	2 m
IP5-TOTEM	11 m	90 m

LHC Plan to 2021



S. Myers

Conclusion

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- The LHC is now the highest-energy operating collider in the world
- Initial beam commissioning has shown most systems to operate at or near design performance
  - no show-stoppers
- Highest stored beam energy (2.8 MJ)
  - need deliberation and due care
- delivered Luminosity has increased by an order of magnitude in the last 40 days.