



Chamonix 2011, 24. – 28.1.2011

## Session 5: “High Intensity: Present and Future”

R. Assmann & S. Redaelli

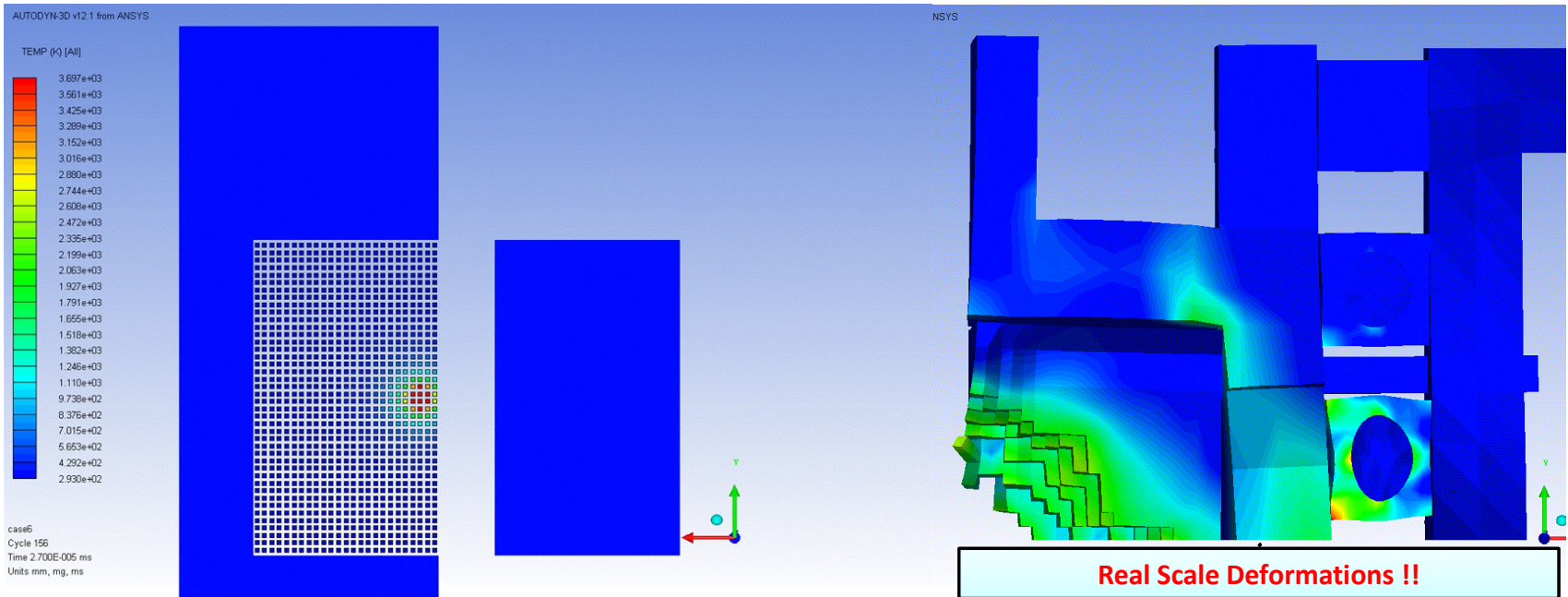
Thanks to Frank Z. for his notes...



# A. Bertarelli: "Limits for Beam-Induced Damage: Reckless or too Cautious?"

- State of the art tools to look at accidents.
- Conservative parameters and scenarios:
  - Up to 5 TeV, up to  $1.3 \times 10^{11}$  p per bunch, down to half nominal emittance.
  - Collimator setup with single bunch as listed above.
  - Asynchronous dump with wrong collimator hierarchy; all bunches impacting on same spot.
- Excellent news:
  - **Single bunch accident (most likely): Collimator need not be replaced.**
  - 2-4 bunch accidents (unlikely): Change collimator with spare.
  - 8 bunch accident (very unlikely): Severe: water leak into vacuum.
- Tests in HiRadMat to improve material models.
- Follow-up:
  - Realistic simulation for 2011 parameters → 1 month from FLUKA inputs.
  - Simulate onset of damage → damage threshold (emittance).
  - Can we get additional material properties from Los Alamos?

- **Case 7 (8 bunches at 5 TeV)** is the only studied case falling in Damage Level 3.
- High probability of **water leakage** due to very severe plastic deformations on pipes.
- Impressive **jaw damage** :
  - Extended eroded and deformed zone.
  - Projections of hot and fast solid tungsten bullets ( $T \approx 2000\text{K}$ ,  $V_{\text{max}} \approx 1 \text{ km/s}$ ) towards opposite jaw. Slower particles hit tank covers (at velocities just below ballistic limit).
  - Risk of “bonding” the two jaws due to the projected resolidified material.



## Accident Simulations for TCT

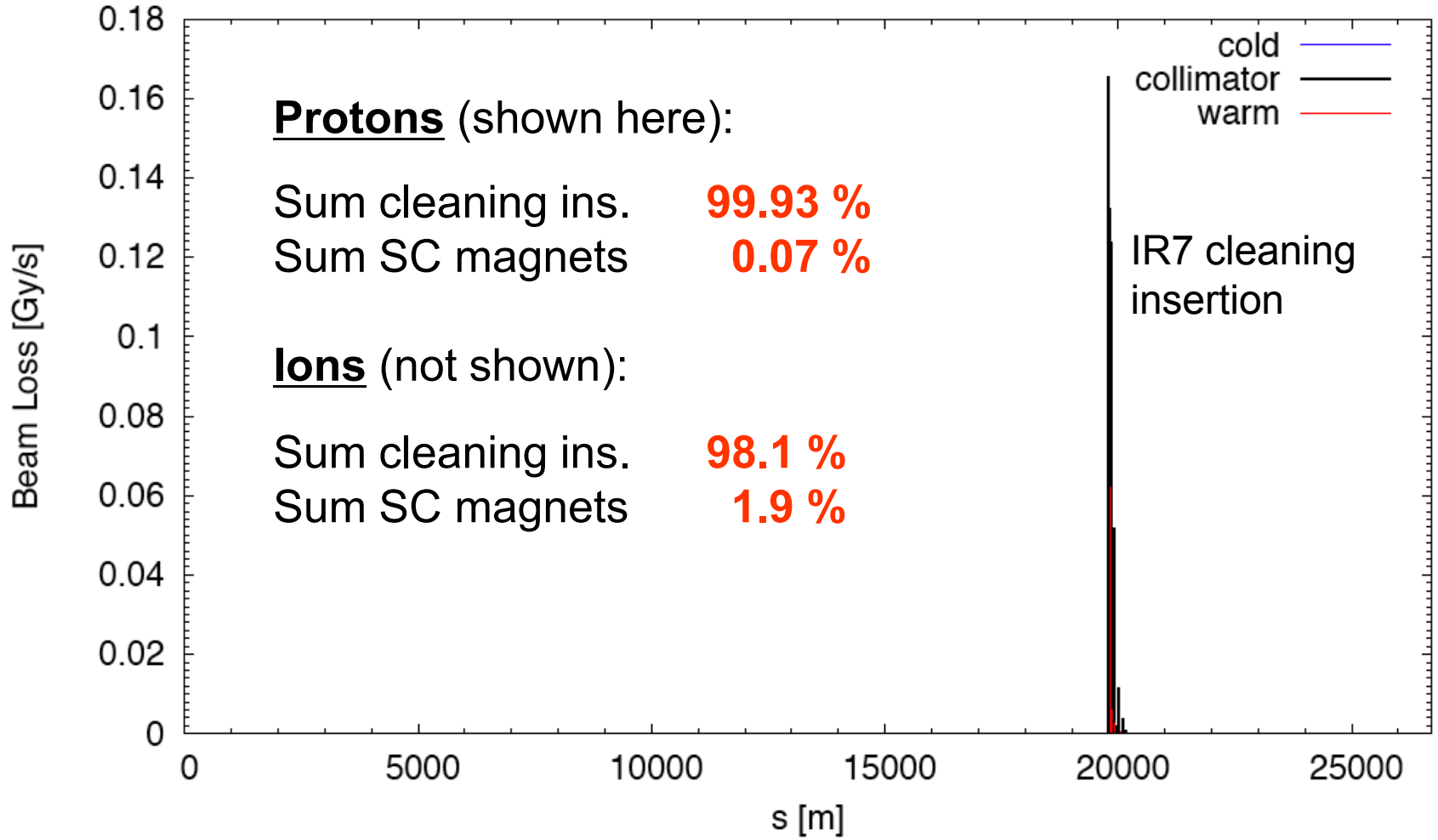


# R. Assmann: “LHC Collimation – Too Good or Too Bad?”

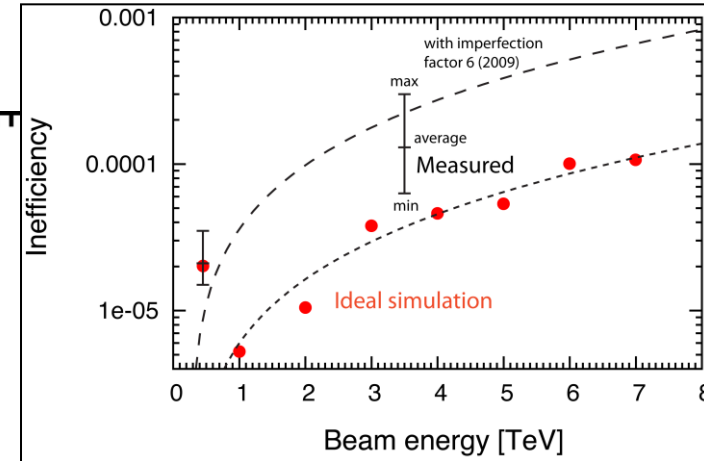
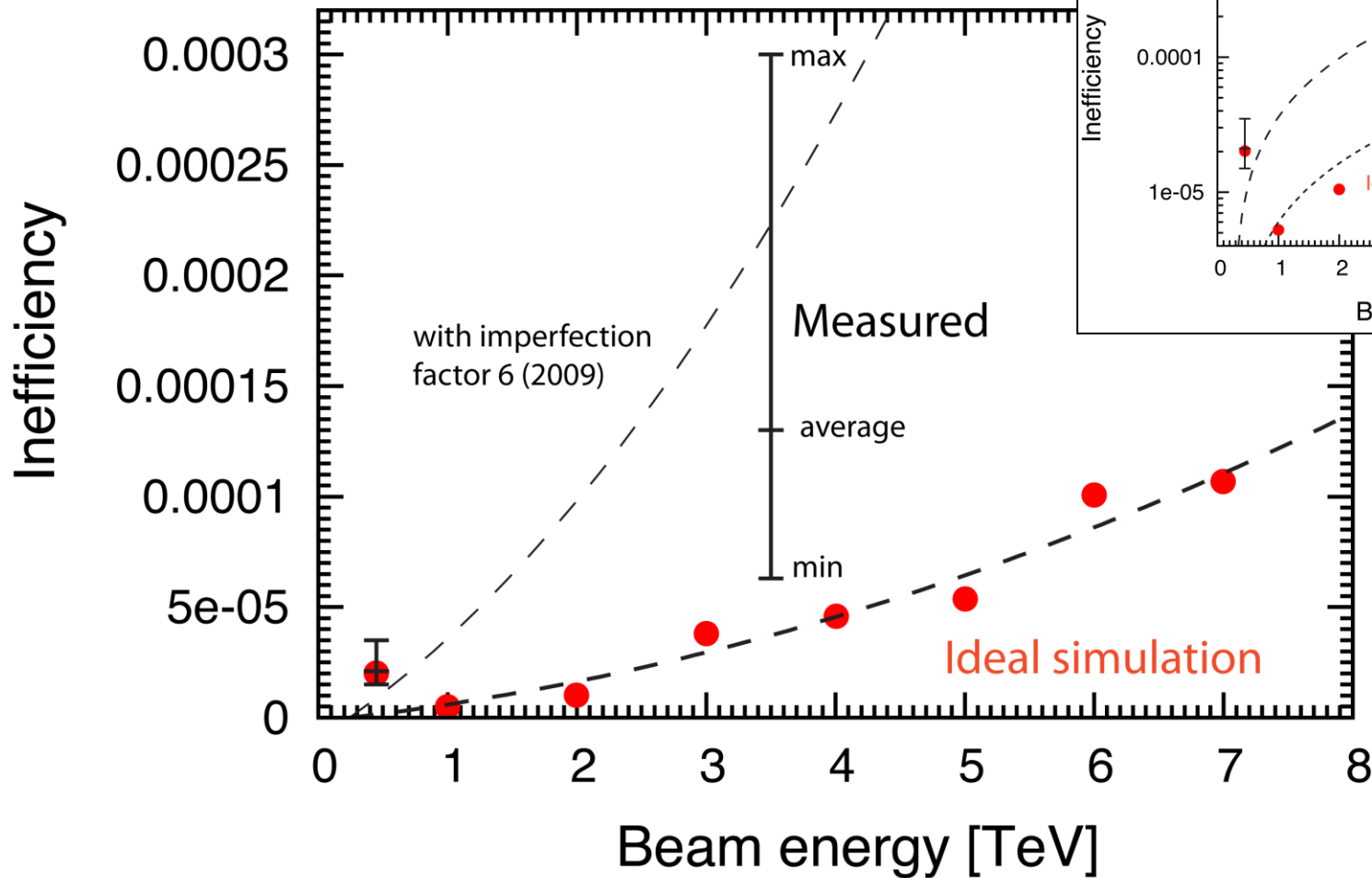
- Summarizing results R. Bruce, D. Wollmann, A. Masi et al (→ Evian)
- Results 2010 and parameters for 2011 (new collimator settings).
- **Collimation performance models confirmed (factor 2).**
- Good surprise: **6 times better beam lifetime than specified.**
- Collimation 2011:  $N_{\text{tot}}$  (p) no limit 3.5/4 TeV (within injector param.)
  - $N_p/\varepsilon \leq 3.4 \times 10^{20} \text{ m}^{-1}$
  - $T_{\text{setup}} \approx 94 - 114 \text{ h}$
  - $T_{\text{validity}} \approx 4 - 5 \text{ months}$
  - $T_{\text{uptime}} = 99.5 \%$
- Orbit & coll.:  $\beta^* \geq 1.6 \text{ m}$  (1.4 m @ 4 TeV)
- 2011 risk: 1/30,000 y for triplet, 1/300y for tertiary collimator.
- Limit for 7 TeV: now extrapolated to ~ 30% of nominal intensity.
  - Collimation upgrade to guarantee nominal intensity.

# Measured Cleaning Efficiency (linear scale, overall sums)

betatron losses B1 3.5TeV ver ocorr stable beams (20101004, 162853)



# Compare Observation to Model from 2008



Model is OK!

- Probability of damage to TCT (conservative):
  - CAT 1: **Asynchr. dump + coll. setup** –  $P < 50 \text{ h} / 1,600 \text{ h}$  → 1 / 32 y
  - CAT 2: **Asynchronous dump + wrong setup:** → 1 / 300 y
- With news of “acceptable” damage: How much can we gain in  $\beta^*$  by accepting higher probability for CAT 2 failure?
  - We can gain by reducing tolerances (TCDQ → TCT) without impact on triplet protection (but higher probability that orbit out of tolerance).
  - Gain  $\sim 0.2 \text{ m}$  in  $\beta^*$  for every sigma in tolerances that we give up.
  - Proposed 2011 tolerance is 2.5 sigma → can gain max  $\sim 0.3 \text{ m}$ ... (going down to 1 sigma). **Maybe 1.3 m** at 3.5 TeV!?
  - Other gains from local IR aperture measurement, ...
  - **Detailed follow-up to be done.**
- Then in case of accident: minor damage but still unlikely.





# S. Redaelli: “Collimator Improvements 2011 and Upgrade 2012: What Do We Plan?”

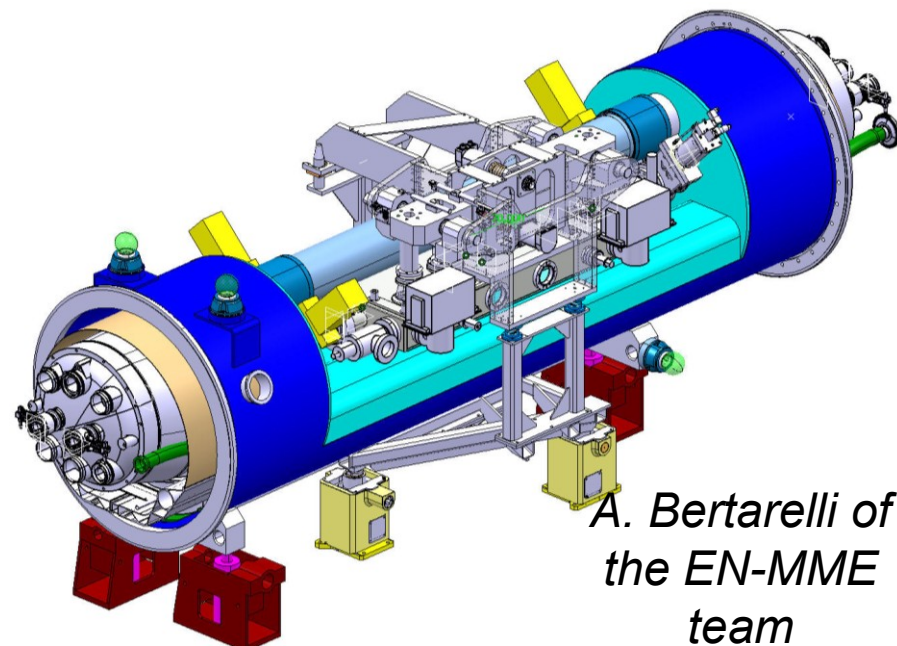
- Several improvements in 2010/11 christmas break:
  - close few unlikely loop-holes in MP logic
  - Semi-automatic collimator setup (less human errors and fewer fills req.)
- Collimation upgrade (phase 1) in IR3 in full preparation for installation in long shutdown:
  - Losses at predicted locations for protons and ions → need to protect DS magnets sooner or later.
  - Ensures that we can **reach nominal intensity** after long shutdown at 7 TeV
  - Implements **flexibility in loss location** → losses to IR3 if intensity limited by R2E in IR7 (to few %)… → impedance issue being followed up
- Collimators with integrated buttons:
  - Works very well with LHC prototype collimator in SPS
  - Can **reduce setup time from 100 h to a few minutes** (if all equipped).
  - No special fills, can follow operational changes, improves MP monitoring,  
…



# IR3 collimation upgrade

## 1. Catch local losses in the dispersion suppressor (DS): two DS collimators per beam

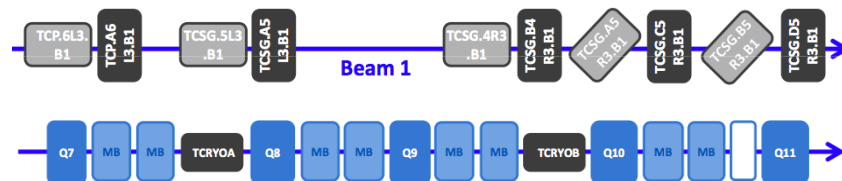
- Layout change of the DS: moving dipoles to create space;
- New design of warm collimators.



## 2. Combine momentum/betatron cleaning in IP3 by adding 5 vertical collimators per beam

- Standard technology of Phase I.
- Essentially using existing slots.
- New production chain for building the missing collimators.

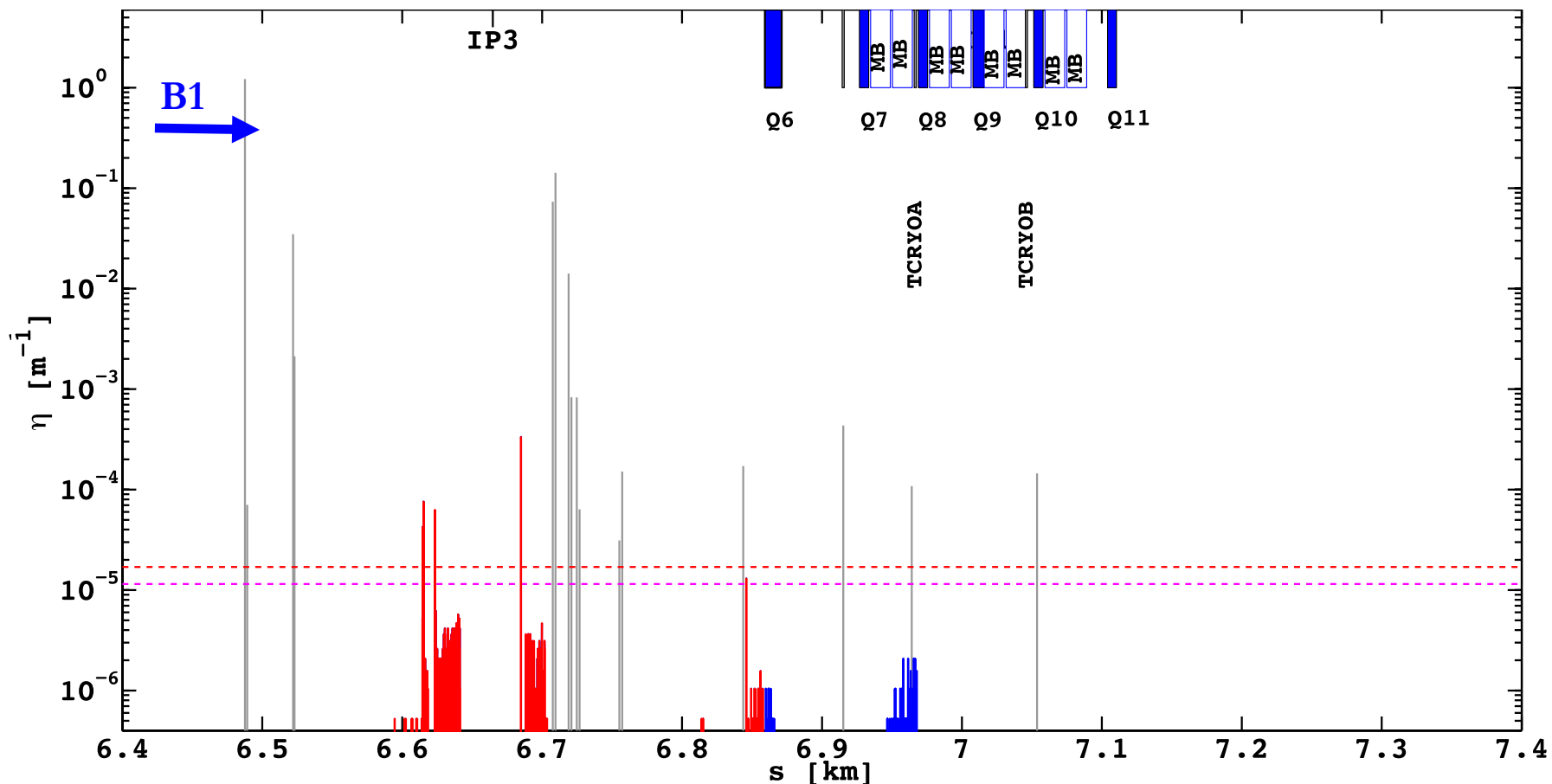
New IP3 schematic layout (by A. Rossi)



Details: Review of DS work, July 2010:

<http://indico.cern.ch/conferenceDisplay.py?confId=100156>

# Expected performance



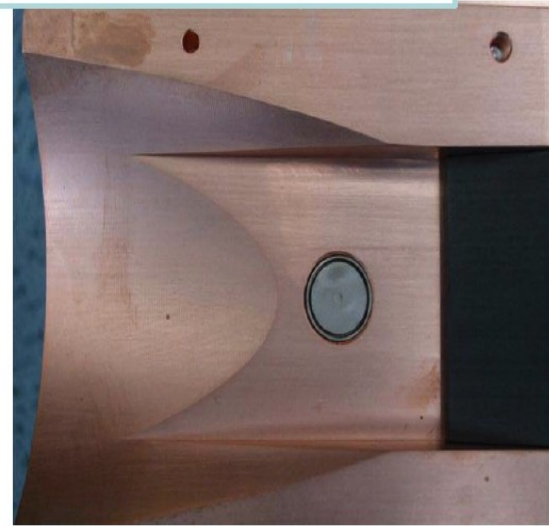
- Updated simulations by **D. Wollmann** and A. Rossi
- 7 TeV case, nominal parameters, perfect machine.
- Cleaning below quench limit for nominal and ultimate intensity.
- Simulations with imperfection are ongoing. Expect to be less sensitive.

Button 1 at upstream port on D side  
Distance from Jaw face: 10 mm

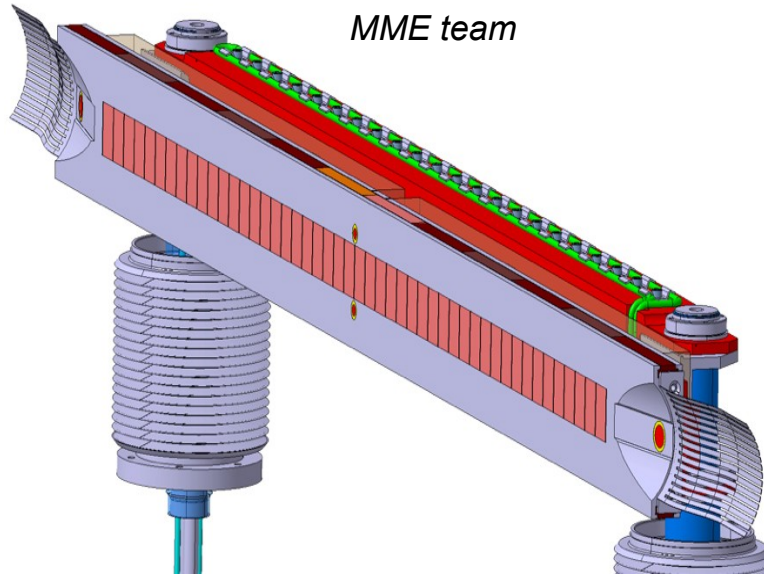
# BPM-integrated design

LHC prototype collimator (phase 2) in SPS installed.

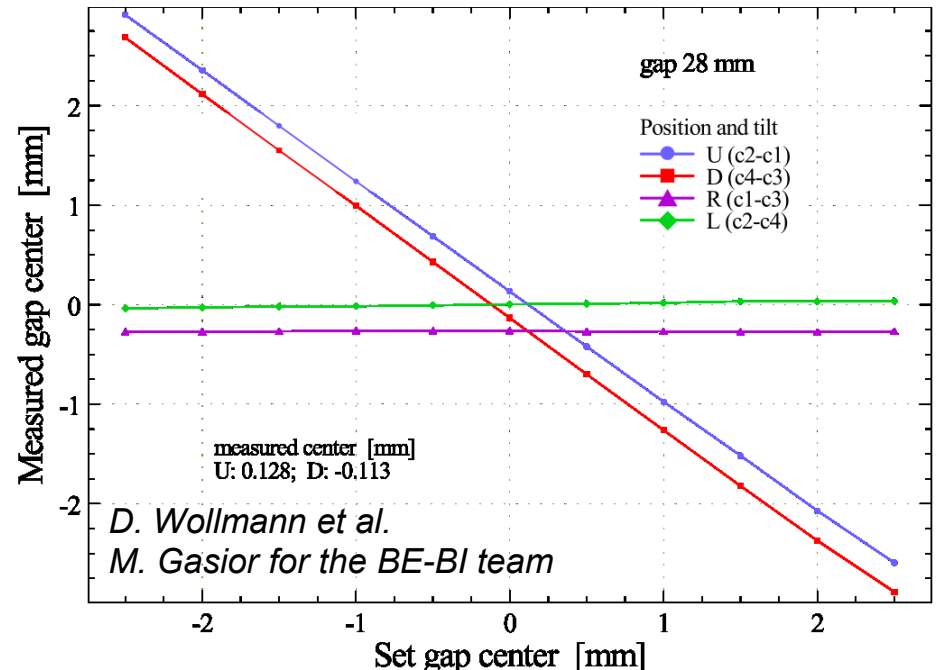
Measurements give excellent results!



A. Dalocchio for the MME team



## Shift of the collimator gap





# Questions & Follow-up (to SR + RWA)

- Do we really need to collimate losses in DS or can we live with it up to the second long shutdown?
  - 30% estimate has no safety margin and extrapolates based on 9 fills at 10% intensity, half beam energy, half emittance, ... → WATCH out!
  - Sooner or later we anyway need to protect DS's and why to accept a likely intensity limit up to ~2018?
  - Put all on table for prioritization with resources for first long shutdown.
- Can adv. collimators with buttons be ready for 1<sup>st</sup> long shutdown?
  - Gains in integrated luminosity (5-10%) and flexibility. Improves MP safety.
  - Resources for finalization of design and for prototyping critical.
- Investigate intermediate ways to speed up setup & verification.
- Stay on agreed plan: continue preparation of upgrade work for 2013, **review and final decision in June 2011**, follow-up in collimation project & departments

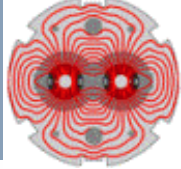


# M. Brugger: “Radiation to Electronics: Reality or Fata Morgana?”

- 2010 beam experience was used to benchmark R2E predictions.
  - Factor 3 improvement but no change in conclusion.
  - R2E remains a serious concern on the way towards design intensity → see next slide.
- Follow-up:
  - Prepare as much improvement as possible for 2011/12 shutdown.
  - Change B2 dispersion (IR7L): shorten region with cleaning losses into DS (ions).
  - Continue efforts to reduce uncertainty in equipment sensitivity.
  - Beam tests (quench test location + injection region) requested to improve radiation field calibration (2 shifts, 2 weeks preparation time + 8h installation).



# Failure Rates 2010/2011/2012++



- For 2010 we expected already some failures (estimate of July) **HIGH BUT OK**
- Adding **real operation, measured radiation levels and xSections**
- Refined estimate possible based on:



0.05fb<sup>-1</sup>

Xsect. rescaled

	2010 (from Meas.)		2010		2011		2012		nominal	
	SUM	MTBF [days]	SUM	MTBF [days]	SUM	MTBF [days]	SUM	MTBF [days]	SUM	MTBF [days]
immediate dump and access	20	18	2	150	98	4	166	2	2500	0.14
immediate dump	7	53	1	570	19	19	33	11	440	0.8
Scheduled access	11	33	2	220	35	10	60	6	740	0.5
Other	7	56	1	480	30	12	52	7	740	0.5

**R2E Mandate-> radiation induced MTBF <= 1 per week for Ultimate Intensities, losses and luminosities (a long way to go, even with uncertainties)**

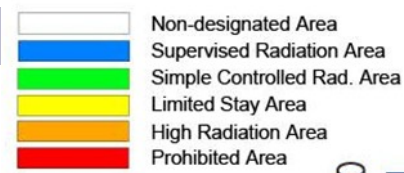


# S. Roesler: "Radiation Protection: How (radio)active are we going to be?"

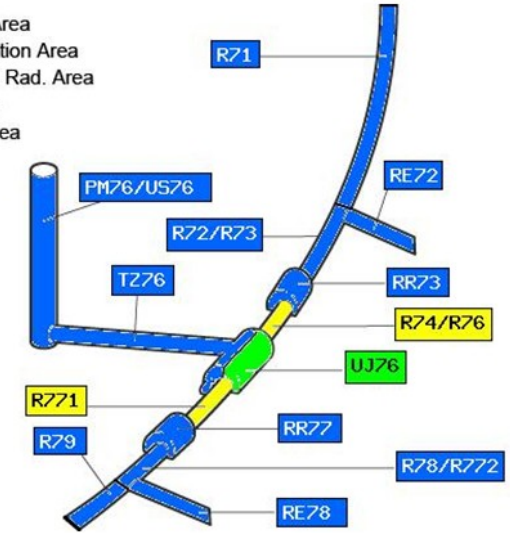
- Activation from 2010 beam run reviewed and all as expected.
- **RP OK for longer running and estimated performance from OP.**
  - 2011: factor 4-10 higher activation vs 2010
  - 2012: another factor 2
  - Air activation: to be ready for nominal intensities modifications to be implemented in next long shutdown.
  - OK for foreseen activities in the tunnel, whether long shutdown is 2011/12 or 2012/13.
- OK without remote handling up to 2016.
- Energies 3.5 TeV and 4 TeV OK.



# Future situation – IR7



Point 7



Dose equivalent rates ( $\mu\text{Sv/h}$ ) (about two months cooling)

IR7-Right	January 2011 (measurement)		January 2012 (Jan.2011 x fac.6.6)		January 2013 (Jan.2011 x fac.15)	
	Contact	Aisle	Contact	Aisle	Contact	Aisle
TCP.D6	10.0	1.2	66.0	8.0	150.0	18.0
TCP.C6	18.0	2.5	120.0	17.0	270.0	38.0
TCP.B6	31.0	3.1	205.0	21.0	465.0	47.0
TCAPA	70.0	3.0	460.0	20.0	1050.0	45.0
TCAPB	13.0	1.2	86.0	8.0	195.0	18.0
TCSG.A6	8.0	1.5	53.0	10.0	120.0	23.0
TCAPC	65.0	2.5	430.0	17.0	975.0	38.0

	Area classification	Dose limit	Ambient dose equivalent rate	
			At permant workplaces	In low-occupancy areas
	Non-designated Area	1 mSv / y	$< 0.5 \mu\text{Sv h}^{-1}$	$< 2.5 \mu\text{Sv h}^{-1}$
	Supervised Radiation Area	6 mSv / y	$< 3 \mu\text{Sv h}^{-1}$	$< 15 \mu\text{Sv h}^{-1}$
Controlled Radiation Area	Simple Controlled Radiation Area	20 mSv / y	$< 10 \mu\text{Sv h}^{-1}$	$< 50 \mu\text{Sv h}^{-1}$
	Limited Stay Area			$< 2 \text{ mSv h}^{-1}$
	High Radiation Area			$< 100 \text{ mSv h}^{-1}$
	Prohibited Area			$> 100 \text{ mSv h}^{-1}$



- RF performance in 2010 was fine:
  - Affected by klystron trips.
  - Uncaptured beam below spec (1% vs 5%) but issues for injection.
  - Noise on the loops analyzed.
- **2011 RF parameters defined and ready** for commissioning.
  - No RF issue for higher intensities nor 3.5 TeV and 4 TeV.
  - No RF issue for various bunch spacings expected.
- Follow-up:
  - Dedicated time required for higher voltage commissioning in 2011.
  - Above half nominal: Interlock strategy for RF trips (cavity, klystron, ...) to be decided but probably require beam dump.

# Longitudinal parameters 2011

- SPS beam (same as in 2010)
  - 1.5 ns,  $4\sigma$  length
- Capture
  - 3.5-4 MV
    - To be tried: Higher capture voltage. Consequence on capture loss? MD time needed
- Ramping
  - Linear voltage rise to 14 MV through the ramp
  - Emittance blow-up to 1.2 ns
    - To be tried: blow-up to 1 ns (bunch length 250 ps  $\sigma_t$  as in design report)
- Physics: Fixed 14 MV @ 3.5 TeV
  - In 2010 with 1.2 ns, 8 MV we had 1.6 eVs bunch emittance in a 3.7 eVs bucket
  - In 2011 with 1 ns, 14 MV, we have 1.5 eVs bunch emittance in a 4.9 eVs bucket



Thank you for your attention...