BLM for Collimation Issues and Measures

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LHC Collimation WG

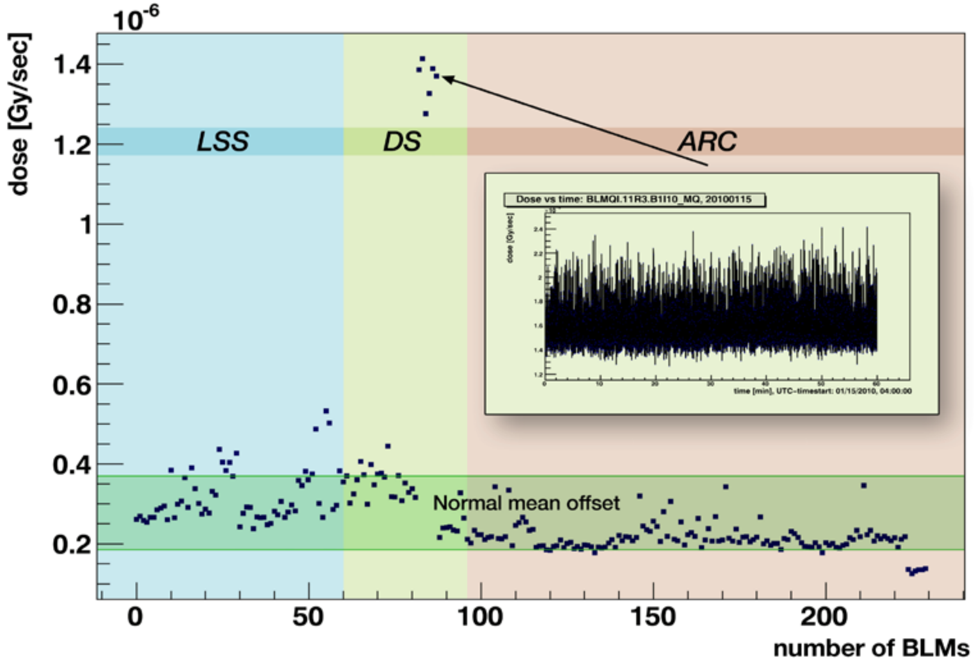
15. Feb. 2010

Noise and Offset

- ❑ Important for availability (false dumps)
- ❑ Onset of problem detected early by about daily checks on offset and noise for each channel, cause can be identified (cable noise, card problem, ...)
- ❑ Cables had been exchanged (up to 800 m), noise reduction: **factor 2**
- ❑ Next shut-down: install single pair shielded cables, noise reduction: > **factor 5**
- ❑ Development of kGy radiation hard ASIC readout (PhD Giuseppe Venturini, ≈4 years): avoid long cables

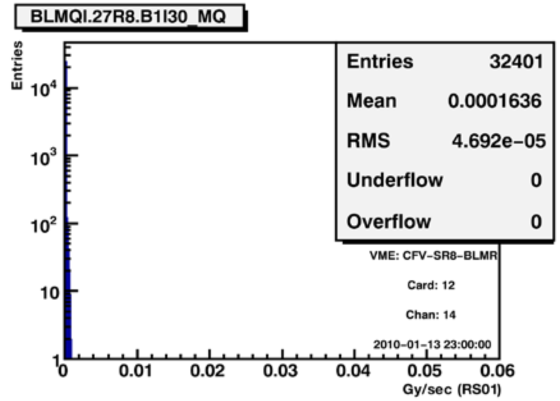
Example mean offset level right of IP3

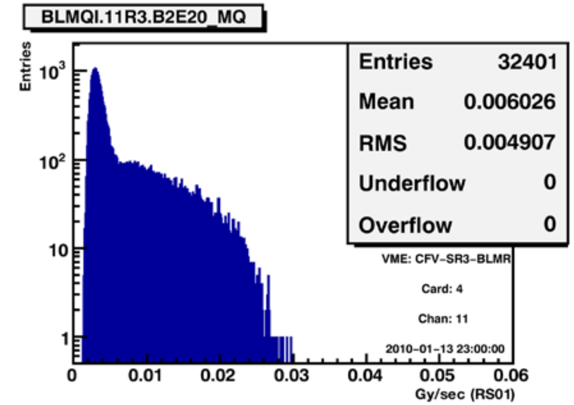
- Some bad channels in the DS have been repaired
- Long cables in LSS and DS lead to higher fluctuations



Noise and Offset

Noise single channel frequency distribution over 9 hours, low noise - short cable (left), high noise - long cable (right)

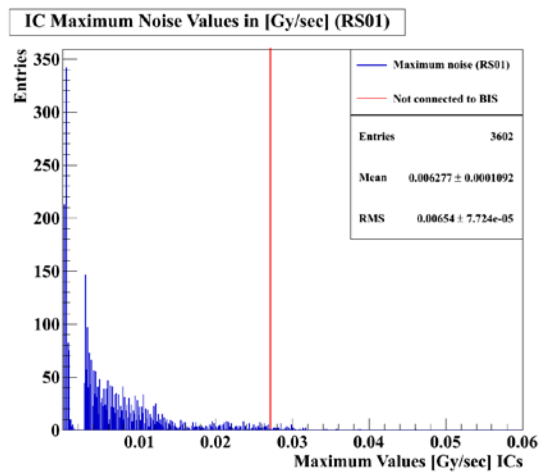


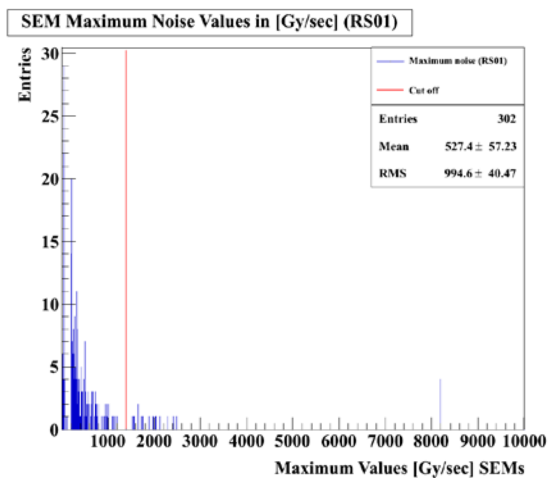


Max. noise frequency distribution, Ionization Chambers (IC) - left, Secondary Emission Monitors (SEM) - right

SEMs have a higher percentage of high noise

Max. noise above red line → channel will be repaired





≈3600 IC

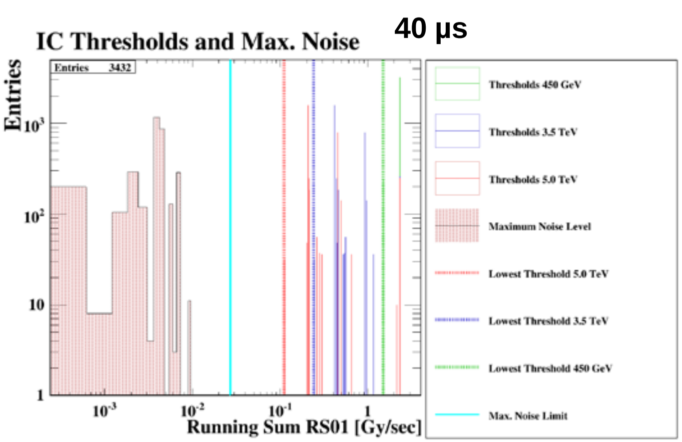
≈300 SEM

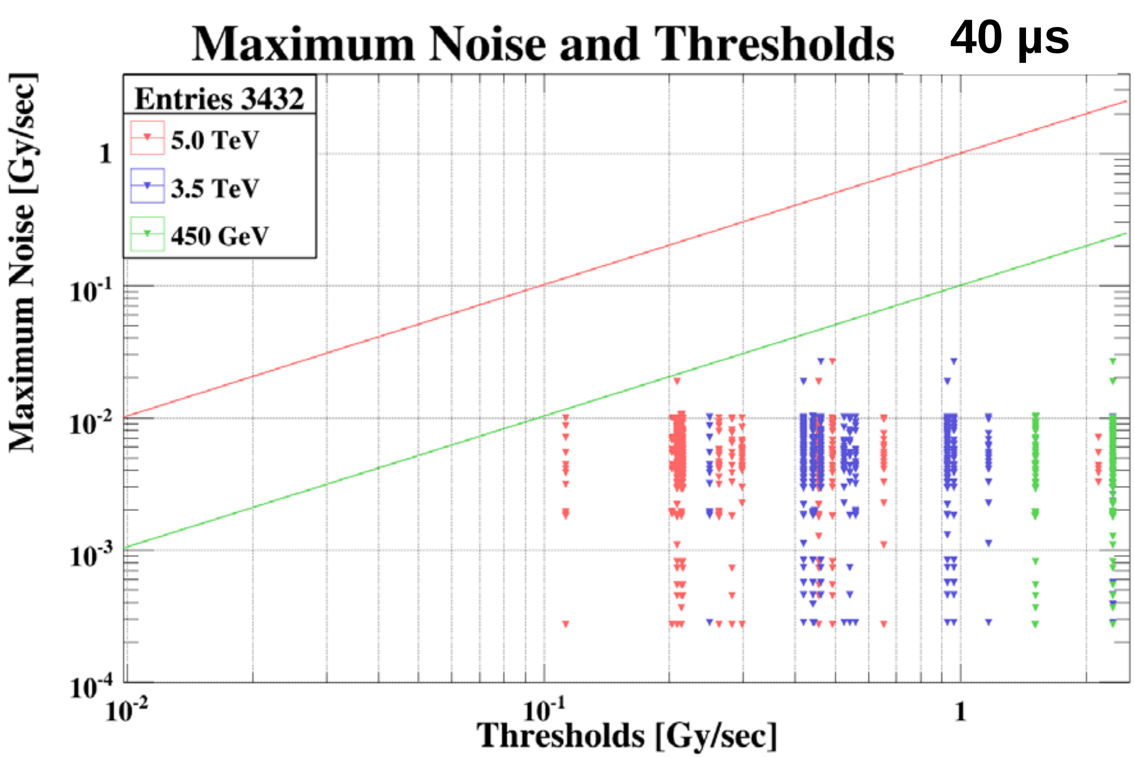
A SEM is always installed next to an IC, it is less sensitive by factor of 70.000

Threshold levels compared to dynamic range

- Are the thresholds at higher energies still safely above the noise levels? → yes (analyzed IC 40 µs, 1.3 s and 84 s integration time window up to now)

Data set of 10 days: 18.12.2009 - 25.12.2009 and 08.01.2010 - 15.01.2010





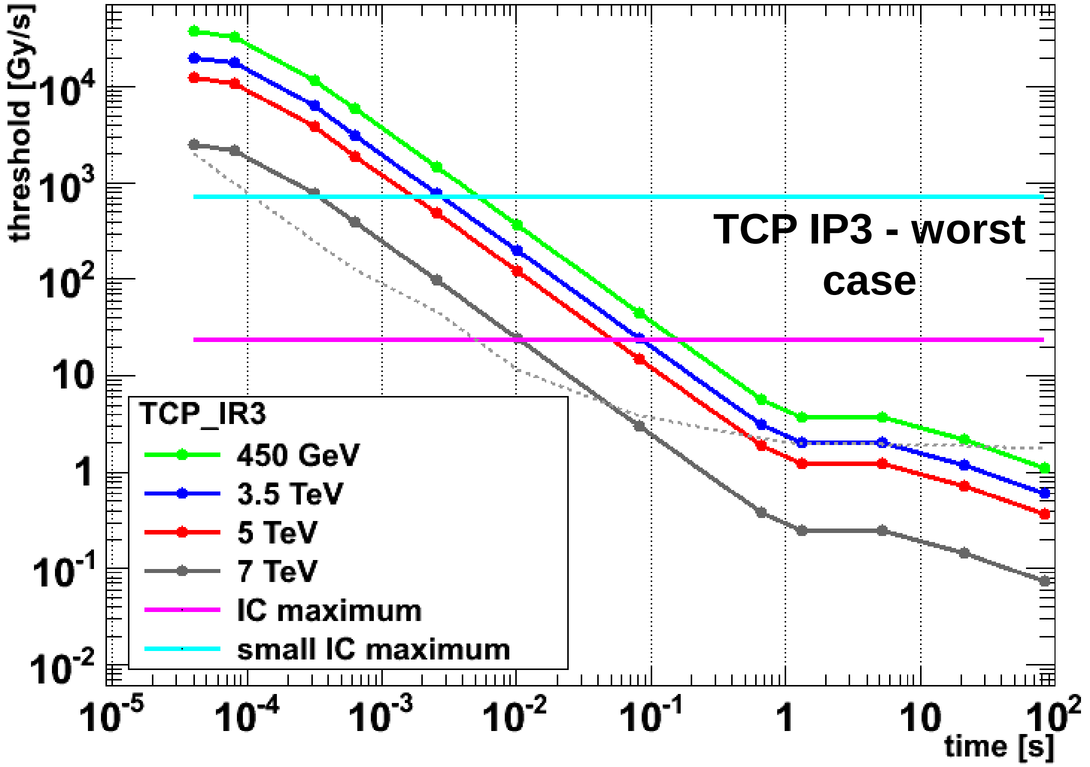
Known Limitations – Dynamic Range

- SEM noise
  - Spurious signal: insulation problem - being corrected now
  - High noise (≈2000 Gy/s for short integration time)
    - Ambiguity for short losses in the gap between IC and SEM dynamic range
    - Thresholds cannot be set in SEM
- Partial activation of beam abort functionality was not foreseen in electronics (thresholds partially in SEM and partially in IC)
  - Installation of additional capacitors to spread the signal over longer time
  - Depending on requirement: new monitor type, small IC, 30 times less sensitive than IC (installation during 2010), ≈56 monitors.

Threshold levels compared to dynamic range

- Problem reduces with higher energies and integration times
- No problem on W collimators

Element	Factor missing at 40µs and 450 GeV
TCP IP3	1'611
TCP IP7	97
TCSG IP3, TCLI	161
TCSG IP7, TCLP	8

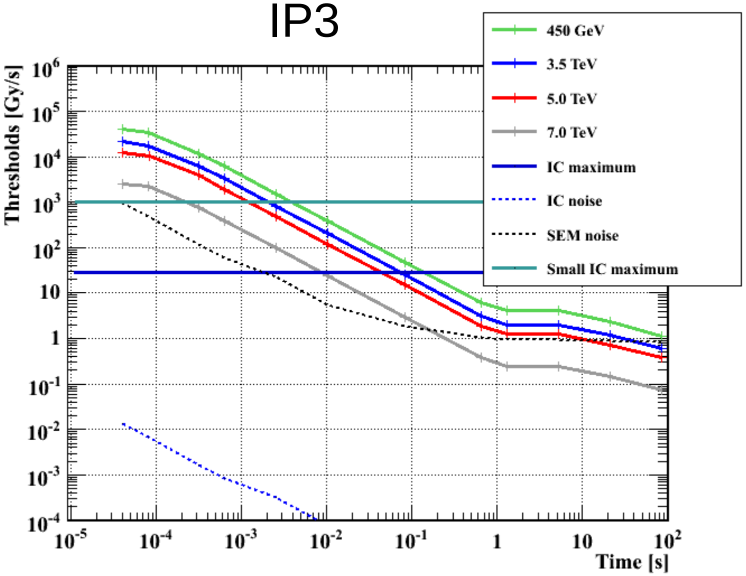


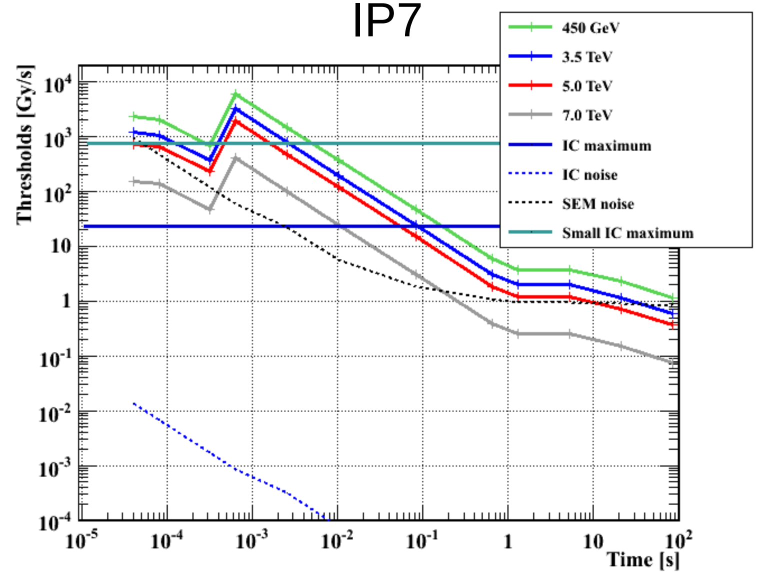
TCP and TCSG

IP3

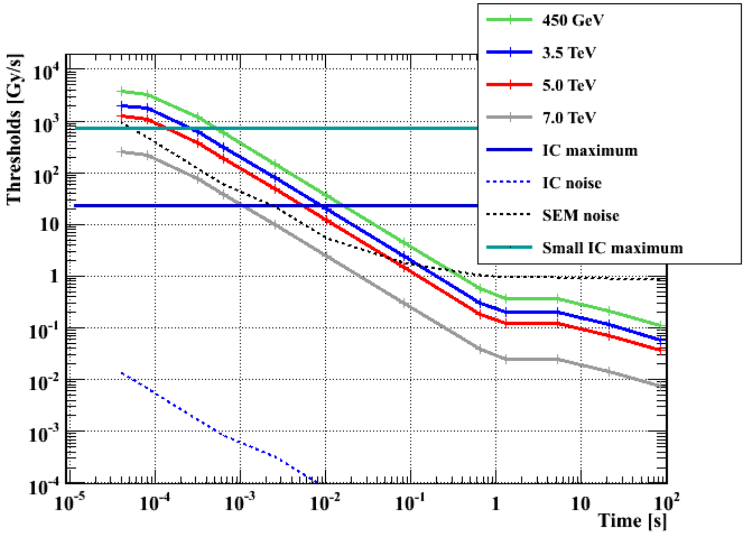
IP7

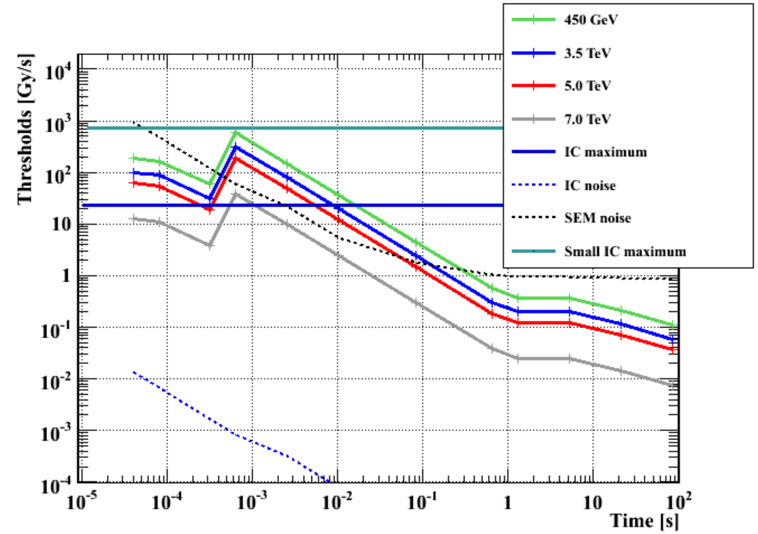
TCP





TCSG





TCP in IR7 – Andres Gomez Alonso

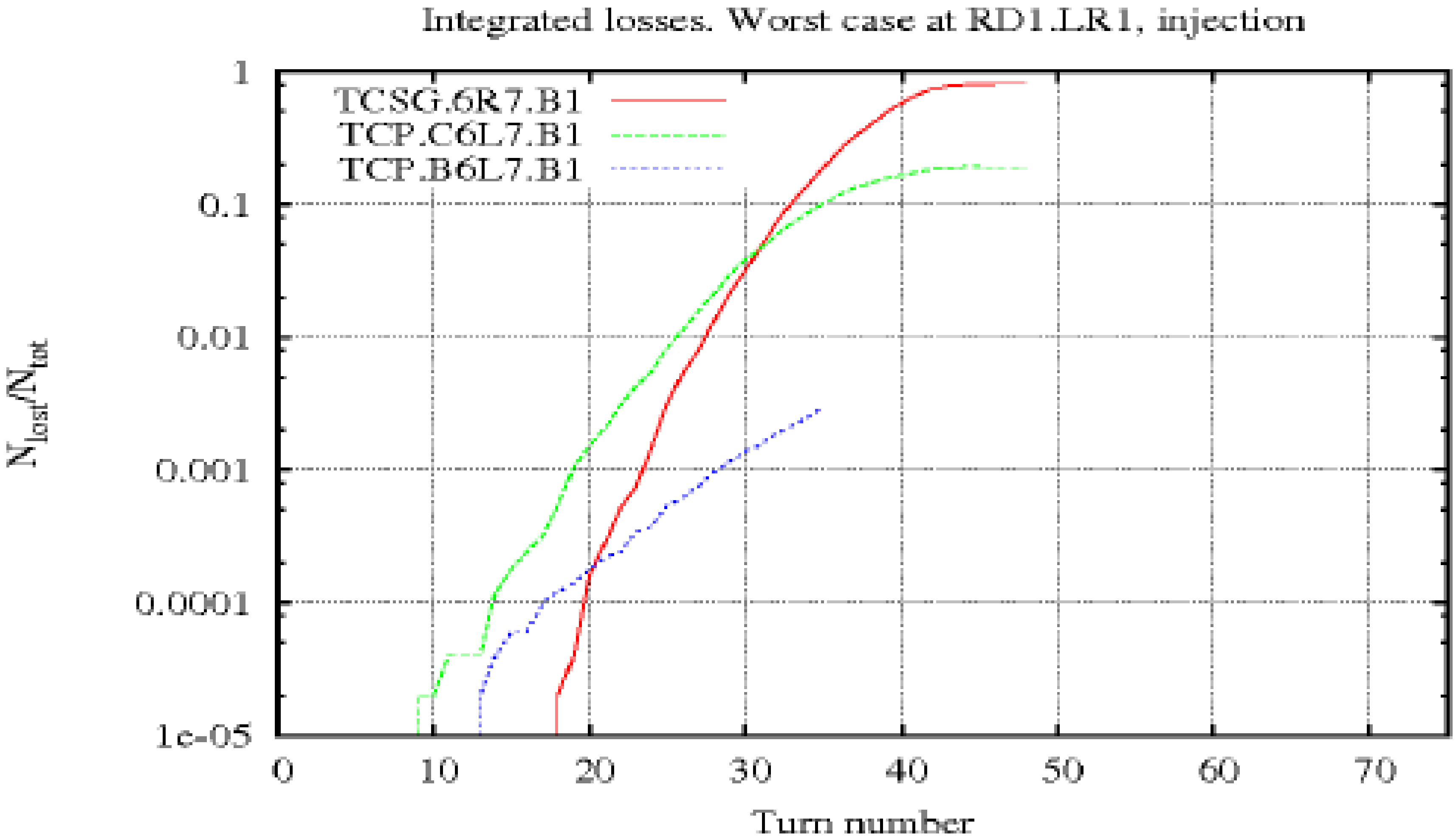
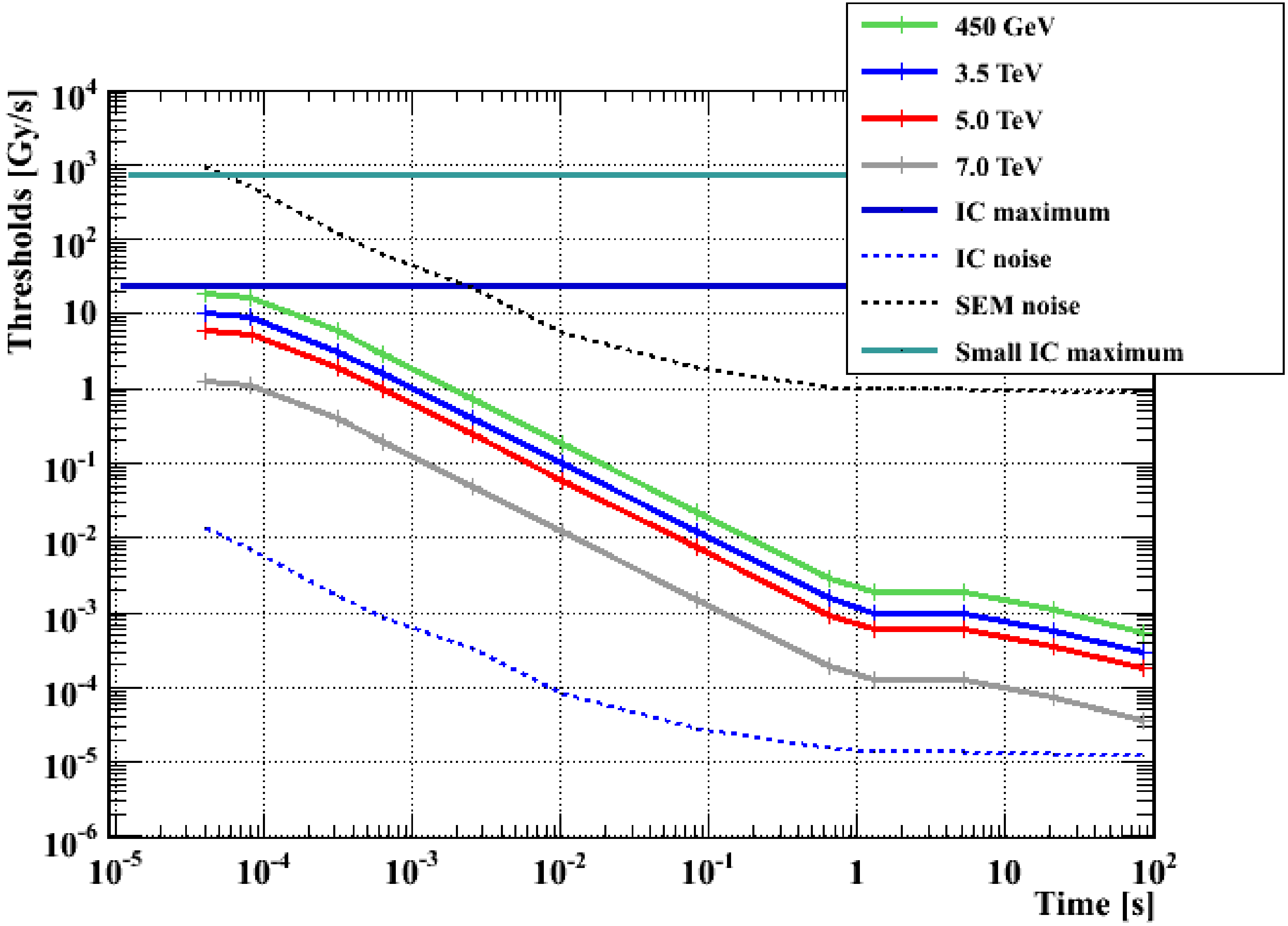
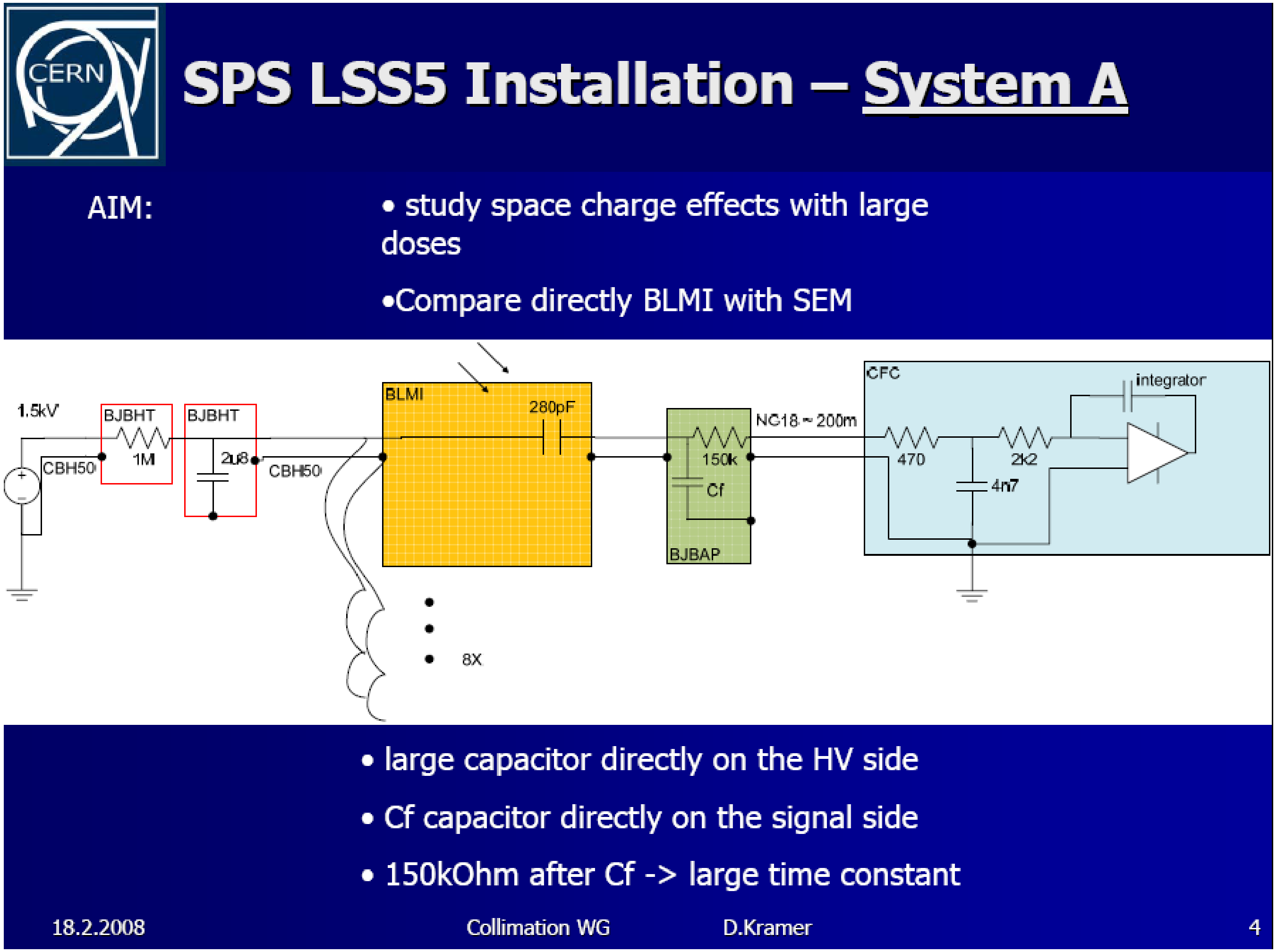


Illustration 1: Number of lost protons integrated from the beginning of the failure normalized to total number of circulating protons before the failure [4].

TCT and TCLA


450 GeV
3.5 TeV
5.0 TeV
7.0 TeV
IC maximum
IC noise
SEM noise
Small IC maximum
Thresholds [Gy/s]
10^{4}
10^{3}
10^{2}
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
10
10^{2}
Time [s]

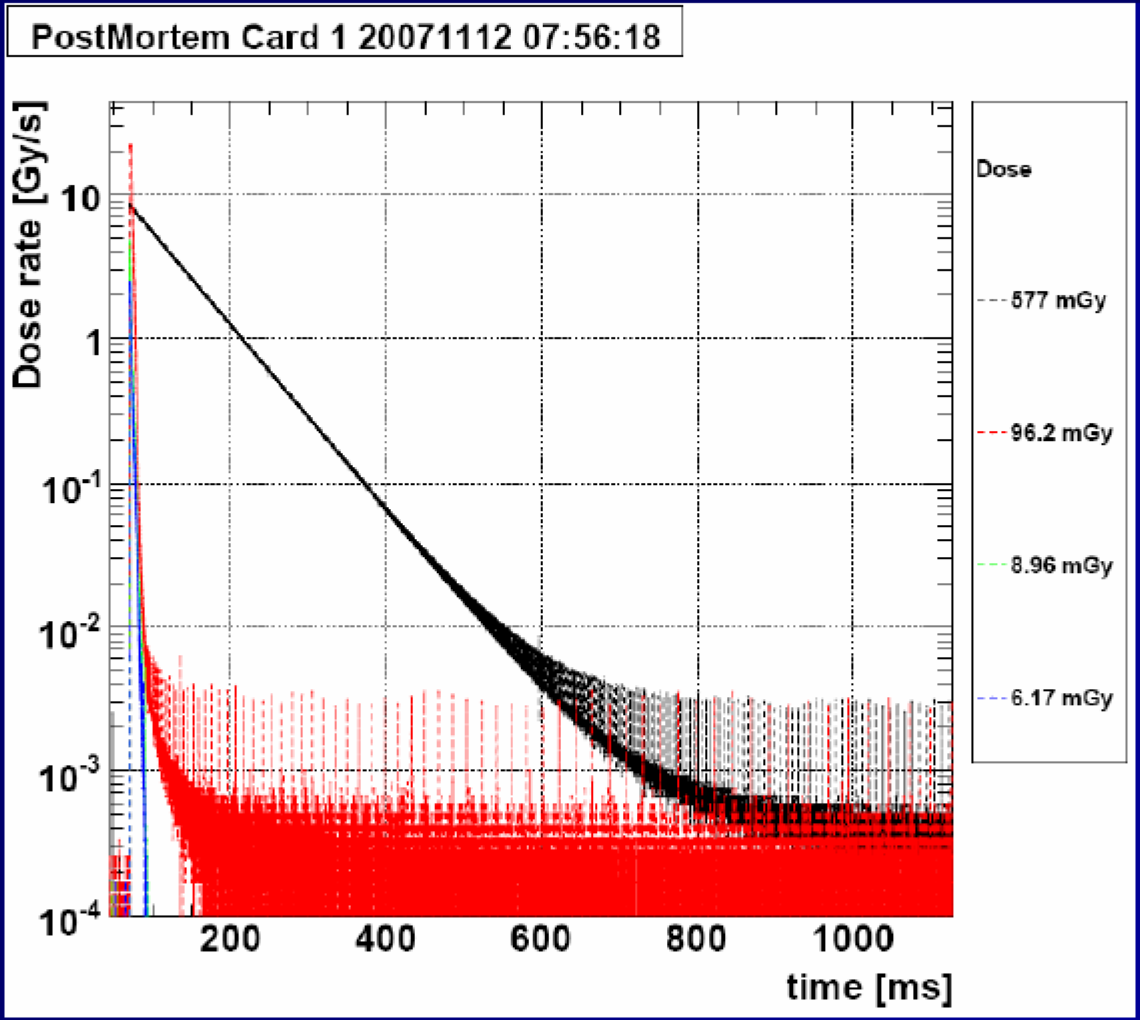
Resistor-Capacitor Delay



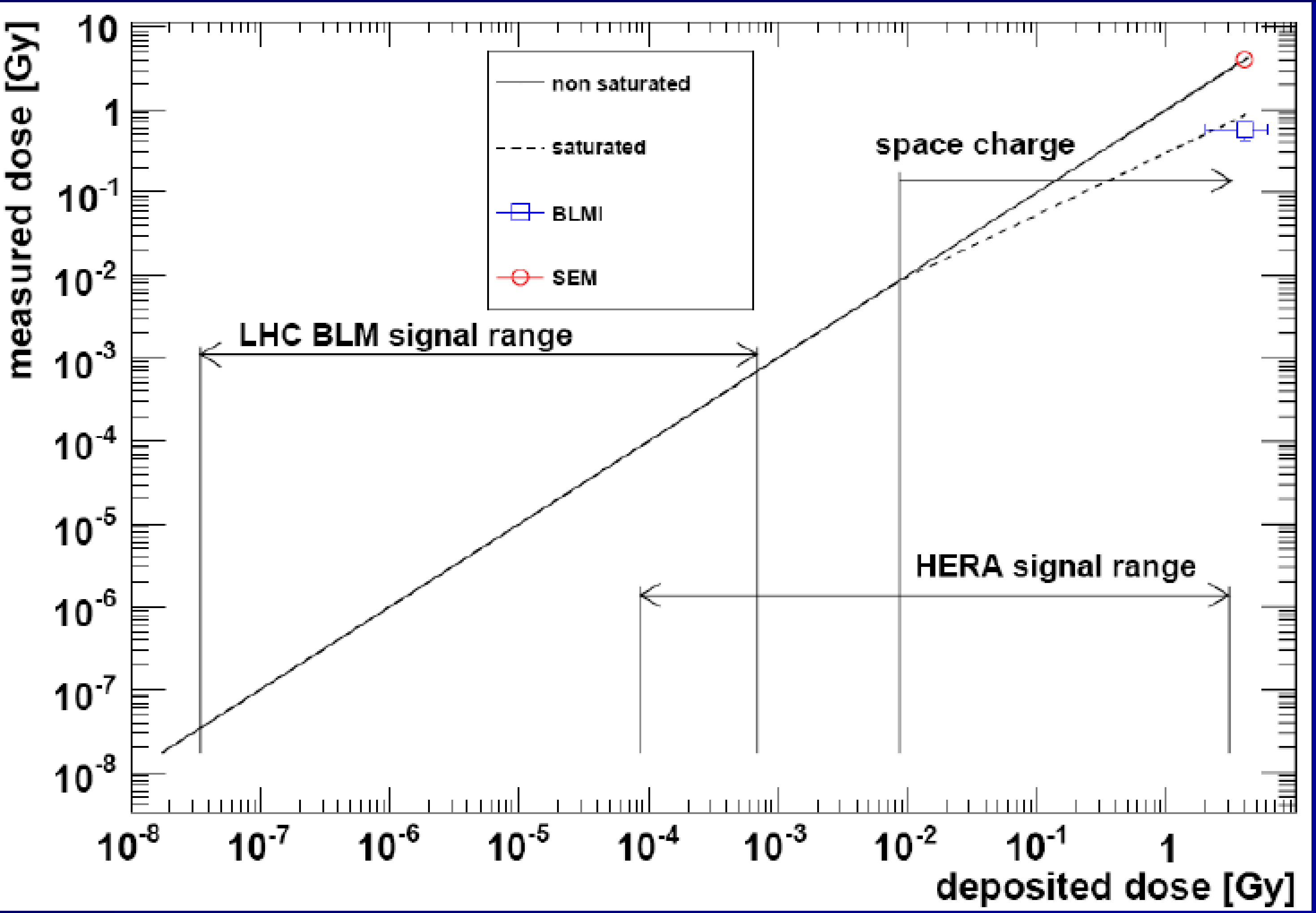
Experience:

- **LHC dump lines**
- **HERA and various IC response tests (thesis M. Stockner)**
- **Some of the SPS LHC collimator tests (thesis D. Kramer and T. Bohlen)**

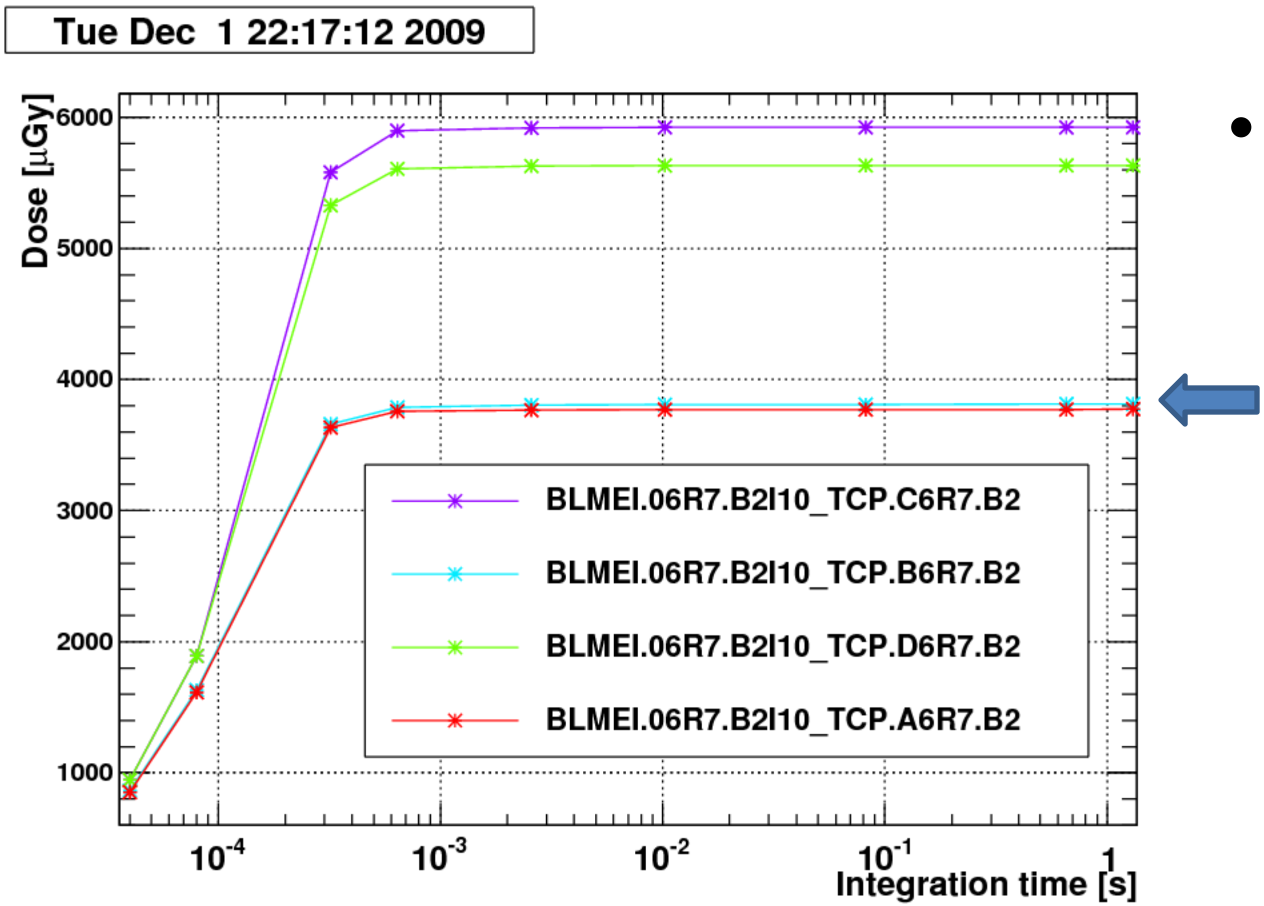
System A 1.3e13 p⁺ dumped on collimator, Left Jaw at -5 mm, Right Jaw out



BLMI Space charge effect estimation ("signal saturation")

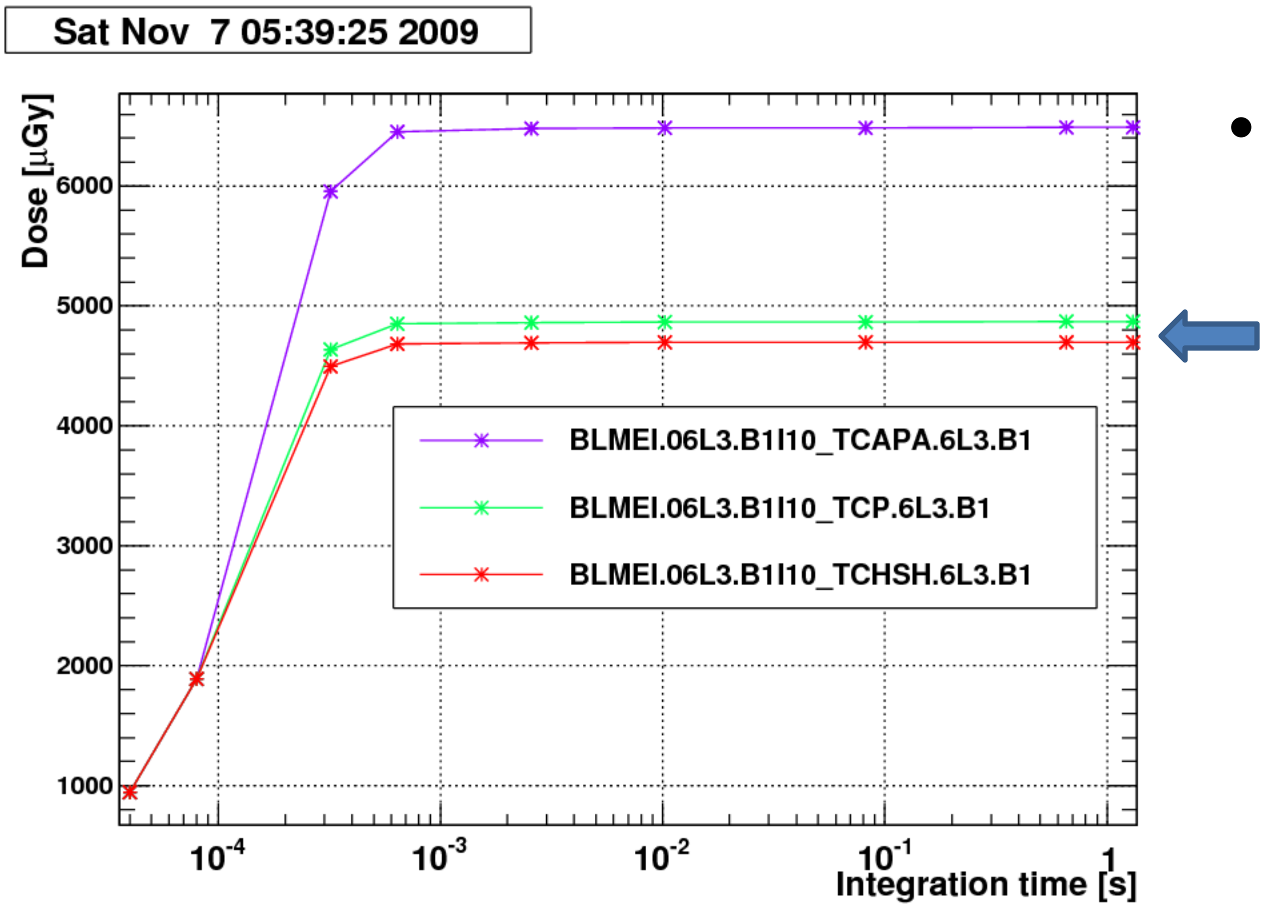


TCP in IP7



- Signal collected within 640μs
- IC on last collimator and IC 1.5-2m afterwards (no element in between) show same signal

TCP in IP3



- Signal collected within 640µs
- IC on last collimator and IC 1.5-2m afterwards (no element in between) show very similar signal

TCP Thresholds with R-C Delay

- Add a capacitor and a resistor to the readout chain of ICs after (the last) TCP
  - Reduce the peak signal by a factor of 175
  - Increase length of the signal by 175 → signal collected within 112 ms
  - For 1.3s integration time (logged every 1s) → practically no difference
- Increase the upper end of the dynamic range by a factor of 175
- Thresholds would have to be recalculated

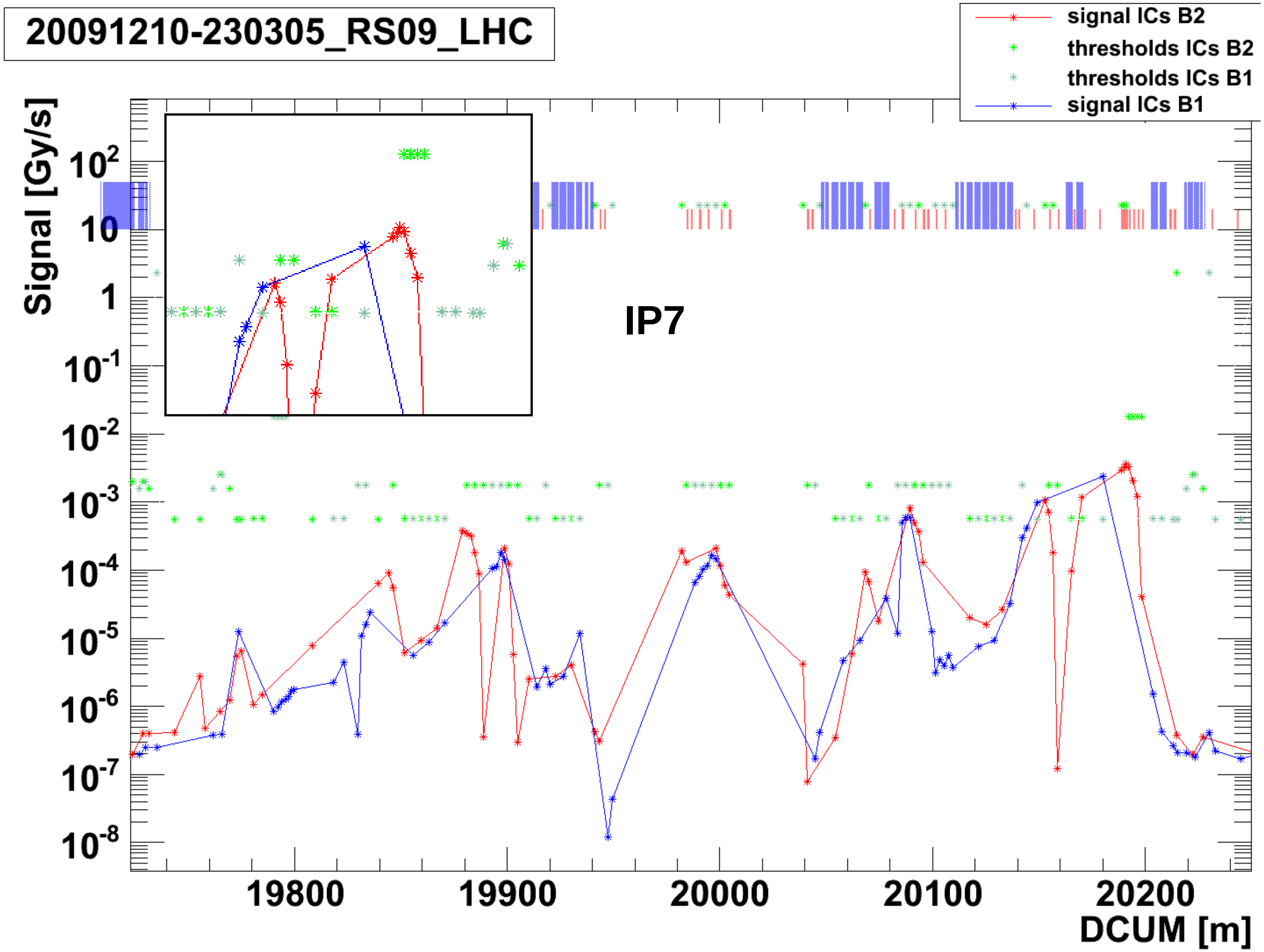
- 40µs 450 GeV threshold values:

TCP	Theoretical threshold [Gy/s]	Old thres. [Gy/s]	New thresh. [Gy/s]
IP3	~40’000	23	4’025
IP7	~2’000 (correction for ultrafast losses due to RD1.LR1 failure	23	4’025

Extrapolation to Higher Intensities

- Preliminary results
- Assuming intensity increases, all other conditions unchanged
- 6 data sets analyzed (same data sets as presented in Evian by Ch. Bracco and W. Bartmann)
- At what intensity do we reach the loss threshold? Which are the most-critical elements?
- Collimation cleaning 450 GeV (1.3 s loss data compared to 84 s thresholds), scaled to nominal intensity
  - B1 and B1 longitudinal cleaning
  - B1 vertical and B2 horizontal cleaning
- Injection (40 µs loss data compared to 40 µs thresholds)
  - B1 and B2, cleanest injections: SPS scraping, TCDI 6 σ hor. / 4.5 σ vert.

Cleaning - Beam 2 Horizontal



PRELIMINARY

Cleaning - Transversal

Most-Critical Elements at nominal intensity 3E14	*Beam lifetime at threshold [minutes]*
Beam 2 horizontal cleaning	
BLMEI.06R7.B1E10_**TCLA.B6R7.B1**	62 – 86
BLMEI.06R7.B1E10_**TCLA.A6R7.B1**	26 – 37
BLMQI.04**L6**.B2I10_**MQY**	18 – 24
Beam 1 vertical cleaning	
BLMEI.05R7.B2I10_TCSG.B5R7.B2	1 – 1.5

→ *We need more beam tests and possibly simulation studies*

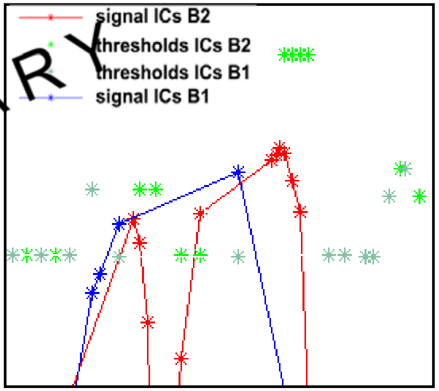
→ *Re-define the protection philosophy*

- Ralph: non-local protection
- Define failure scenarios, and protect by a combination of collimator interlocks (e.g. position) and BLM readings

Beam 2 horizontal:

- TCLA losses seem to be caused by "crosstalk" particle showers from B2
- Most critical cold element in IP6
- No limits from BLM dynamic range (all long integration time thresholds are within the dynamic range of the BLM system)

PRELIMINARY



Cleaning - Longitudinal

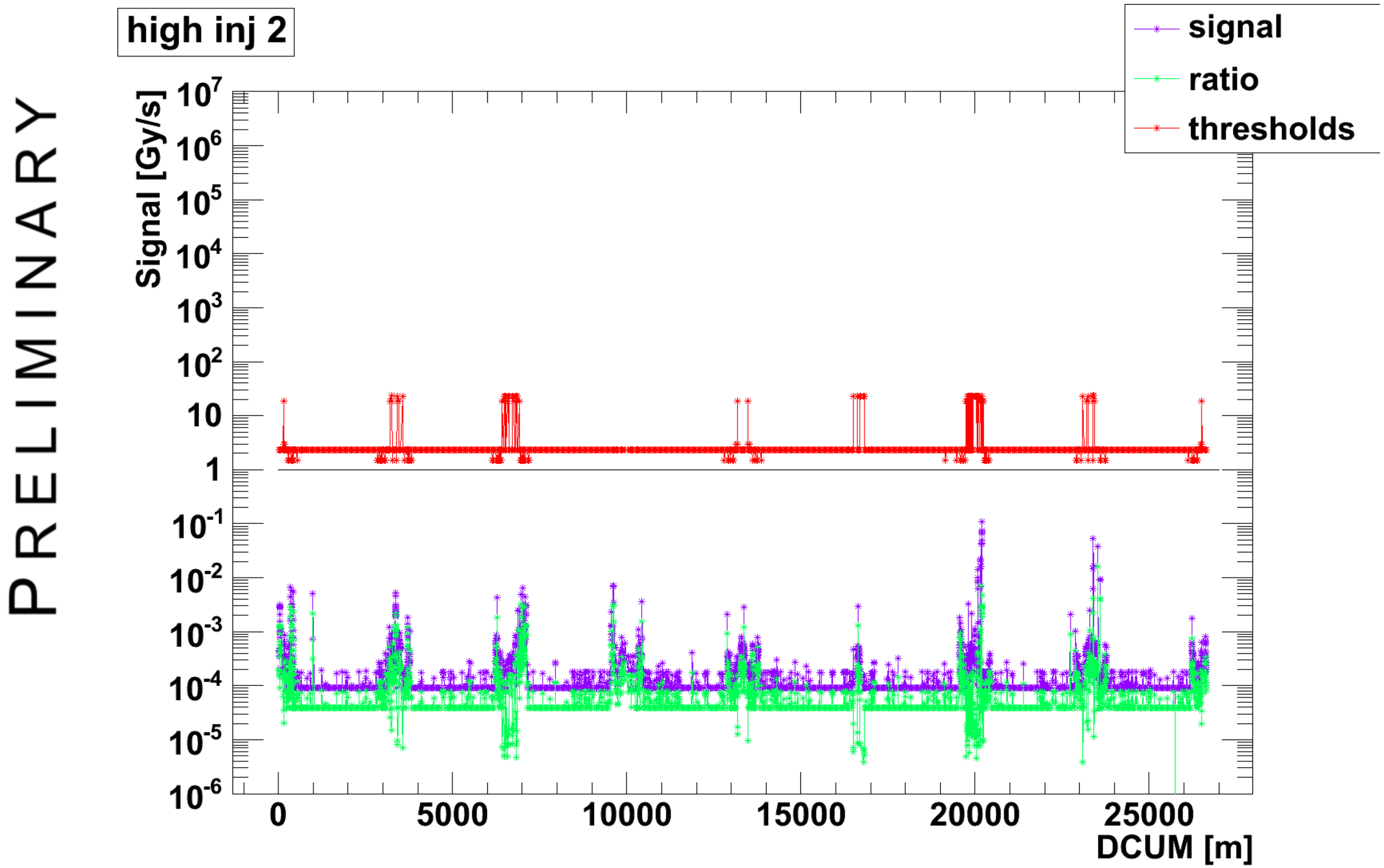
Most-Critical Elements **at nominal intensity 3E14**	***Beam lifetime at threshold [minutes]***
Beam 1 longitudinal cleaning	
BLMEI.05L3.B1I10_**TCSG.5L3.B1**	13 – 18
BLMEI.05R3.B1I10_**TCLA.A5R3.B1**	7 – 10
BLMEI.08R3.B1I23_**MBB**	7 – 10
Beam 2 longitudinal cleaning	
BLMEI.08R3.B2I30_**MBA**	22 – 31
BLMEI.05R3.B2E10_**TCSG.5R3.B2**	7 – 10
BLMEI.05L3.B2E10_**TCLA.A5L3.B2**	5 – 7

- B2: most critical element is a cold dipole
- Losses localized: most-critical elements in IP3
- Most-critical TCSG and TCLA correspond for B1 and B2, MBs are next to each other
- No limits from BLM dynamic range (all long integration time thresholds are within the dynamic range of the BLM system)

PRELIMINARY

Injection with SPS scraping

- SPS scraping, TCDI 6 σ hor. / 4.5 σ vert., Beam 2, 2e10 p



Injection with SPS scraping

Most critical	*Beam 1*	*Number of injected protons at threshold*
16% of 38 most critical elements are cold magnets		
Collimator	BLMEI.06L7.B1E10_**TCP.A6L7.B1**	1.5E+11
Warm magnet	BLMEI.06L7.B1E10_**MBW.B6L7**	5.5E+11
Cold magnet	BLMQI.08L2.B1E30_**MQML**	6.7E+11
	Beam 2	
50% of 30 most critical elements are cold magnets		
Collimator	BLMEI.06R7.B2I10_**TCP.C6R7.B2**	3.4E+12
Cold magnet	BLMEI.04R8.B2E10_**MBXB**	3.9E+12
Warm magnet	BLMEI.06R8.B2E10_**MSIB**	9.8E+12

nominal: 3E13
2010: 4E12

PRELIMINARY

- Numerous elements (collimators, cold and warm magnets) yield similar limits for injected protons
- IC thresholds in warm elements limited by BLM dynamic range. But, losses at cold magnets about equally close to threshold (≈3 times below quench limit).
- → injection losses need to be reduced further, scraping in the SPS seems crucial
- → possible to increase thresholds on primary and secondary collimators and warm magnets (additional capacitors, small IC) but not on cold elements

BLM Issues still to be checked

- Two issues discovered by Collimation team:
  - Noise right of IP3, seemingly correlated with losses in IP3
  - Spurious BLM signals (shift in offset level?) over big parts of the ring at the same time.

Changes 2010 with respect to November 2009

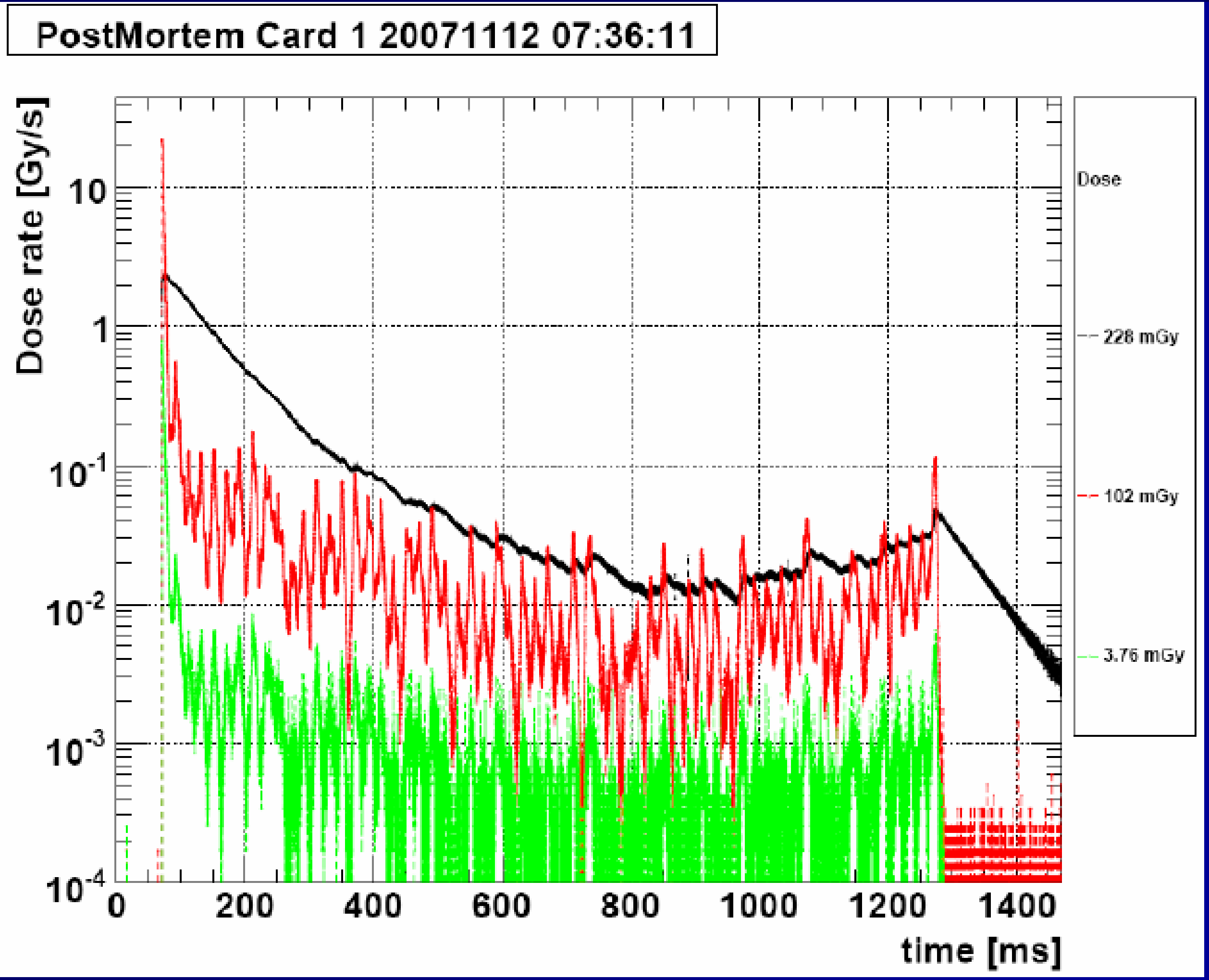
- Monitor factor for all TCxxx elements: 1
- Signal per proton, increase by factor 62: 0.54 aC/p → 33.6 aC/p (measured)
- Hardware on all installed TCxxx elements: no changes
- Monitors after (the last) TCP: R-C delay factor 175
  - Verify the signal and noise levels with the additional delay
  - Start-up: disconnect from BIS
  - Later: recalculate thresholds taking delay into account, algorithm:
    - Delta loss?
    - Loss duration = integration time?
- Test first Small IC next to *BLMEI.06R7.B2I20_TCSG.A6R7.B2*
- Propose: disconnect from BIS all monitors which are already installed for future TCxxx elements
- Connect to BIS TCAPA? (thresholds?)

Modifications on Longer Time Scale

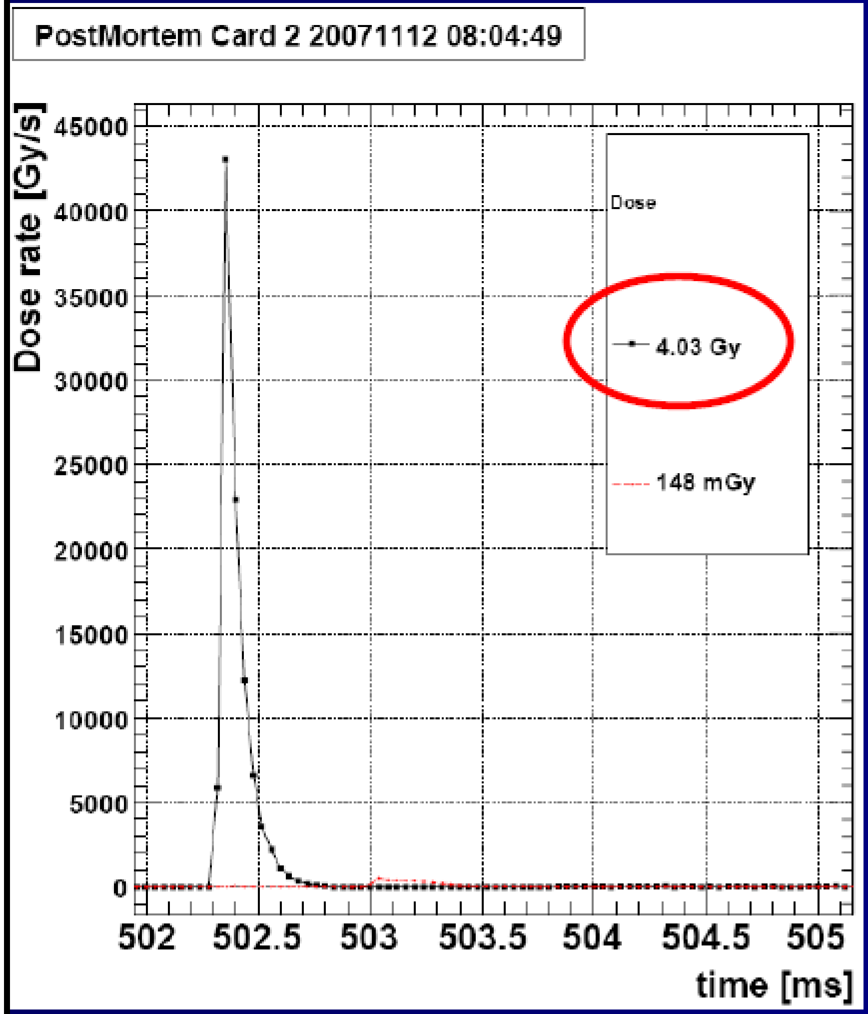
- Noise (lower end of dynamic range)
  - Next shut-down: install single pair shielded cables, noise reduction: > factor 5
  - Development of kGy radiation hard ASIC readout (PhD Giuseppe Venturini, ≈ 4 years): avoid long cables
- High end of dynamic range
  - Small IC and/or RC-delays
- “Cross talk” between beams
  - Work out a new protection scheme
    - Thresholds defined by 0.1 of destruction limit
    - Ralph: non-local protection
    - Correlation of BLM signals – BLM system upgrade
    - Define failure scenarios and protect by a combination of collimator interlocks (e.g. position) and BLM readings

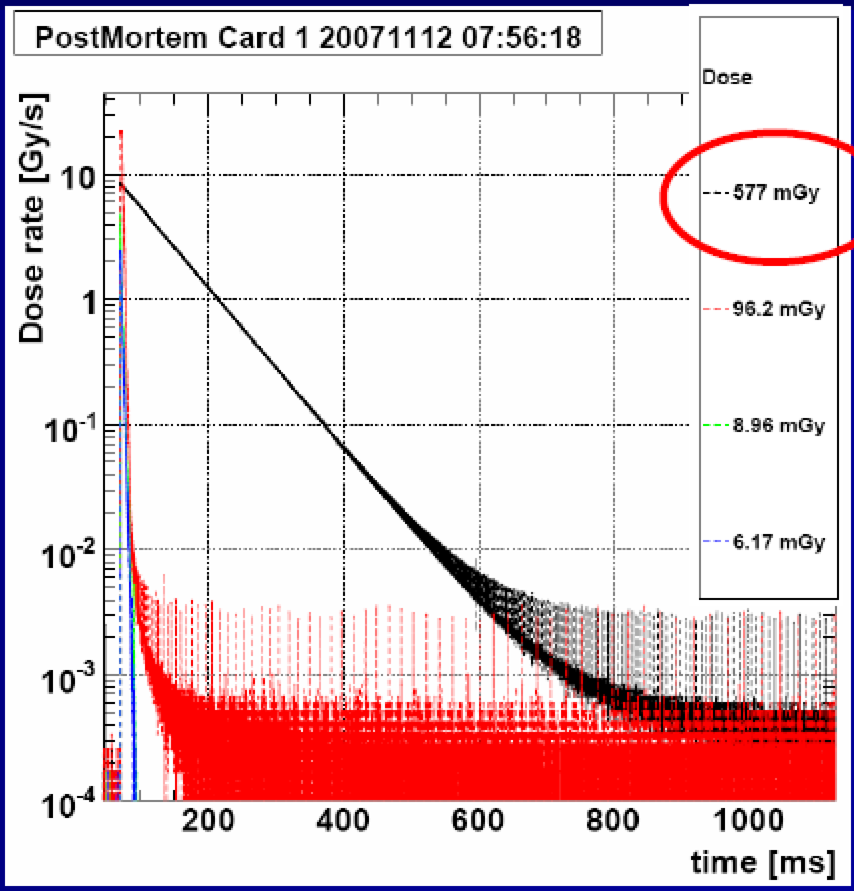
Additional Slides

System A 1.3e13 p+ injection plateau, Left Jaw at 10mm, Right Jaw out, Dump @ 1.2s



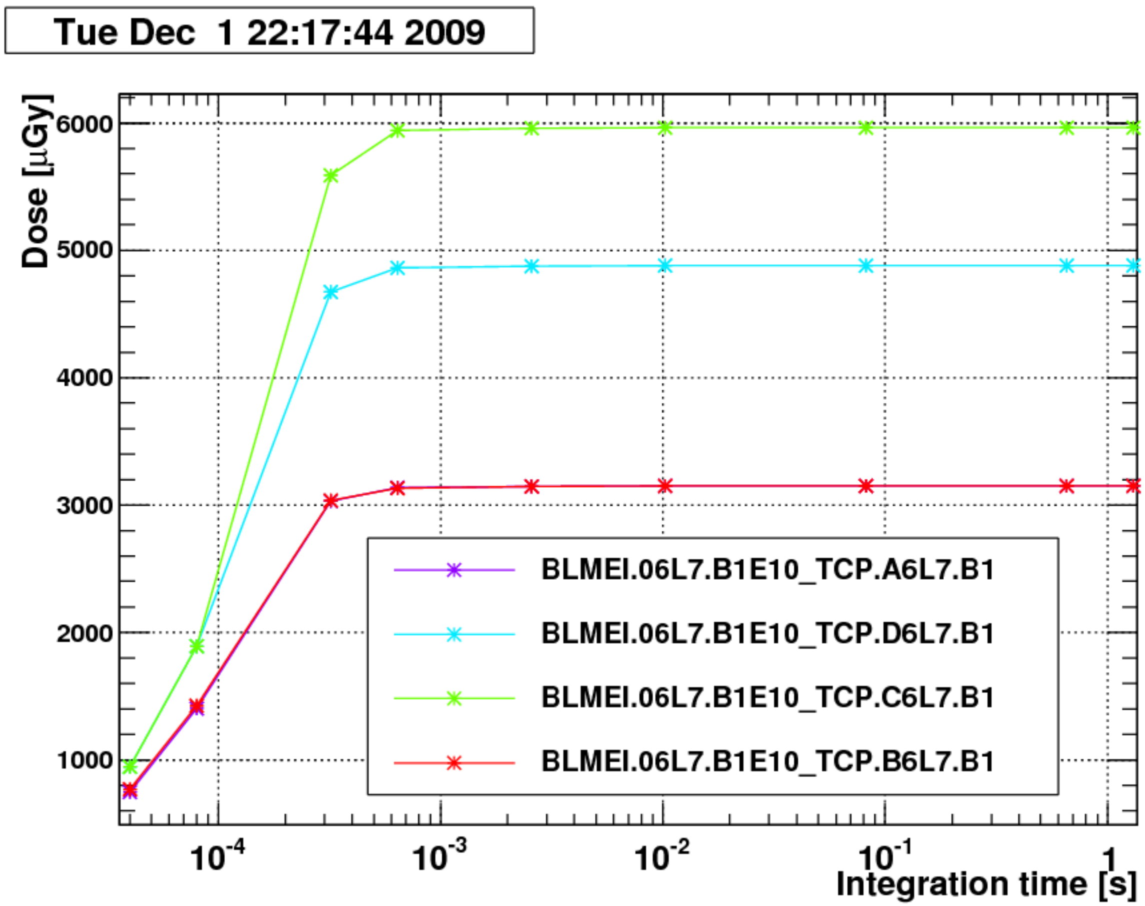
Beam dump on Closed Jaws SEM to BLMI comparison 1.3 $10^{13}p^+$





Black line – signal not clipped

5*τ_filter = 350ms


Tue Dec 1 22:17:44 2009
Dose [μGy]
6000
5000
4000
3000
2000
1000
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
Integration time [s]
BLMEI.06L7.B1E10_TCP.A6L7.B1
BLMEI.06L7.B1E10_TCP.D6L7.B1
BLMEI.06L7.B1E10_TCP.C6L7.B1
BLMEI.06L7.B1E10_TCP.B6L7.B1

TCP in IR7 – Andres Gomez Alonso

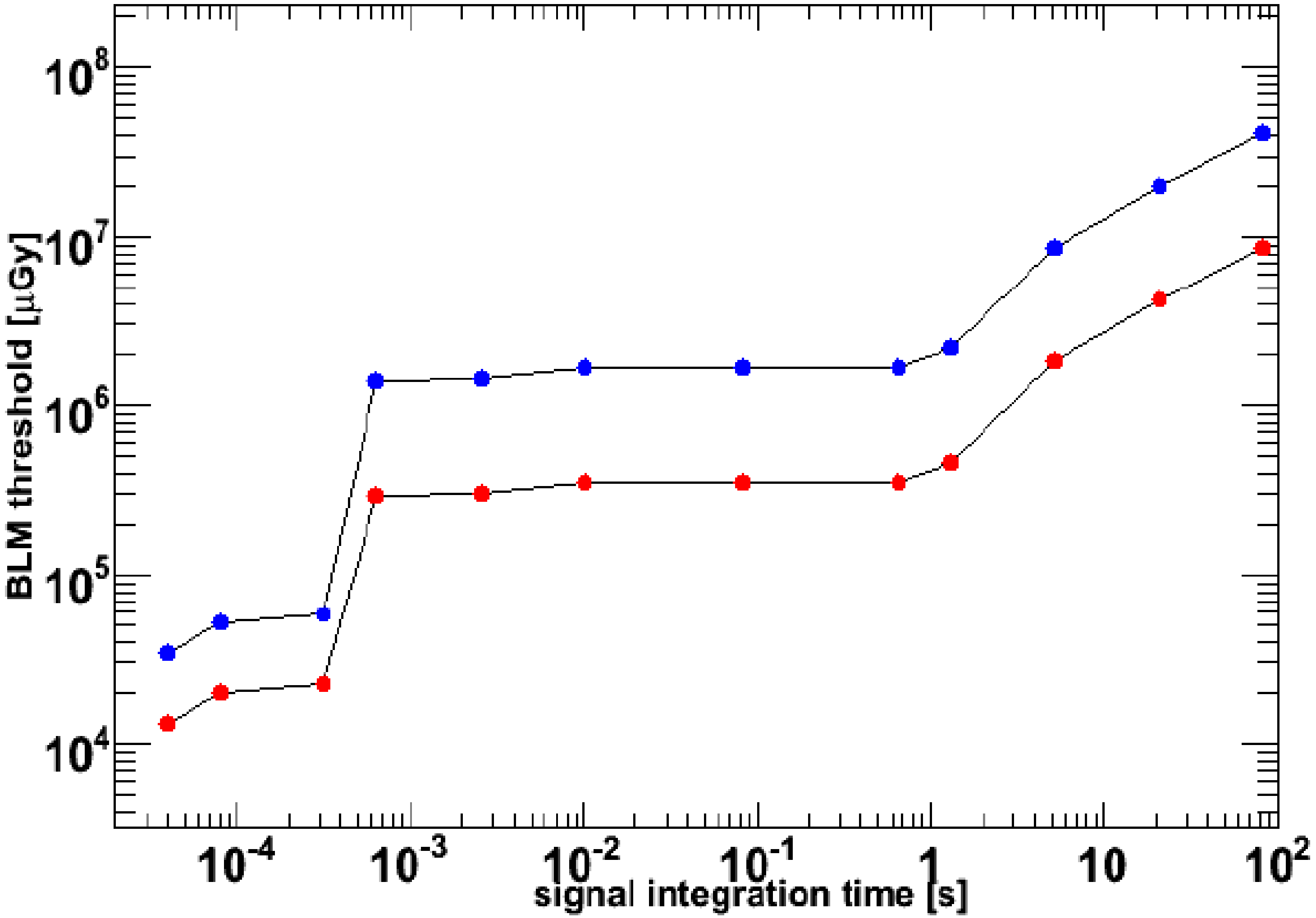


Illustration 4: BLM thresholds on TCP collimator in IR7 expressed in dose, as a function of signal integration time. A dose of 10^{-12} Gy per impinging proton is used.