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Fast Current Changes of RD1, RD34 and RBXWTV

Tobias Baer

Machine Protection Panel

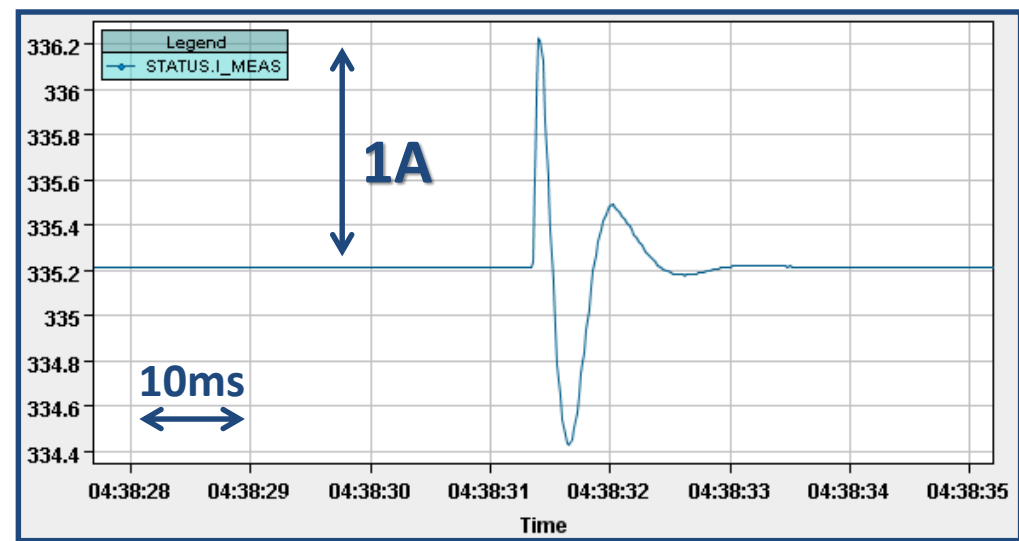
September, 2nd 2011

Acknowledgements: M. Zerlauth, K. Fuchsberger, R. Schmidt, J. Wenninger



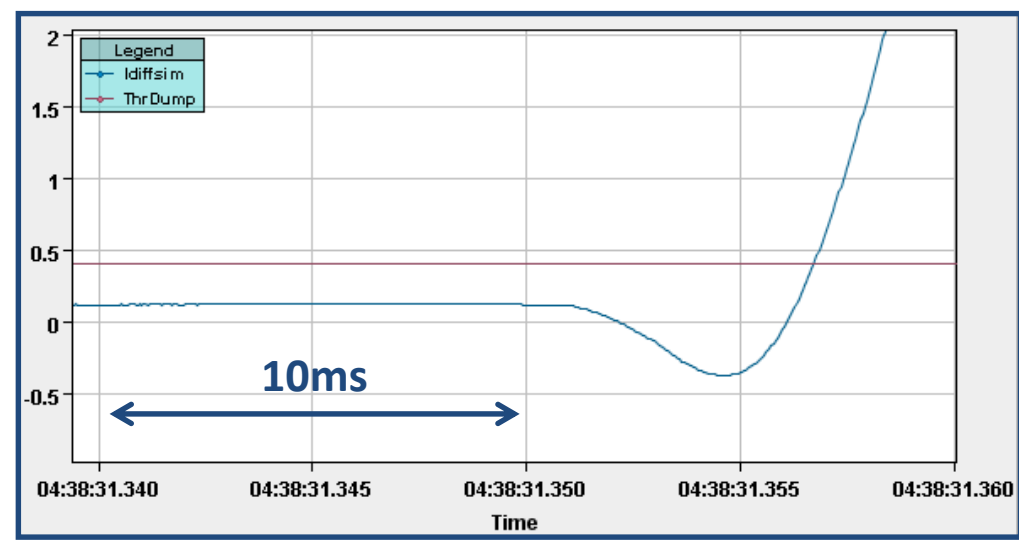
Electrical glitch on 28.07.2011

*Fast current change on RD1.LR5 by about 1A.
On ms timescale: adiabatic orbit changes.*



The FMCM dumps the beam about 6ms after the start of the failure.

See Markus' talk for more details.



Content

1. **Fast Current Changes of RD1**
2. **Fast Current Changes of RD34**
3. **Fast Current Changes of RBXWTV
(ALICE compensator)**

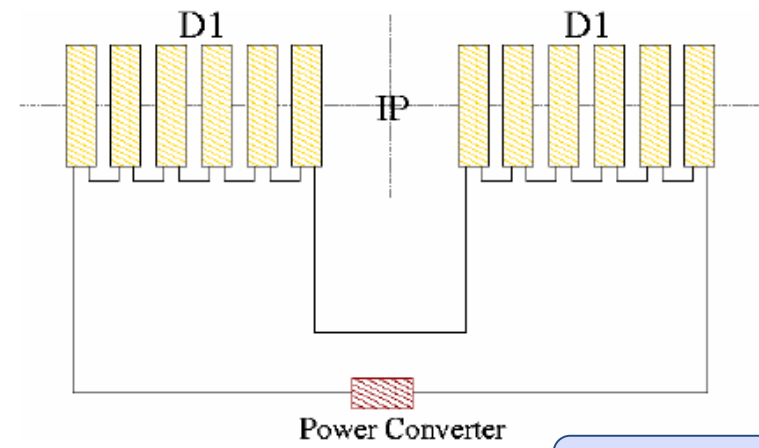
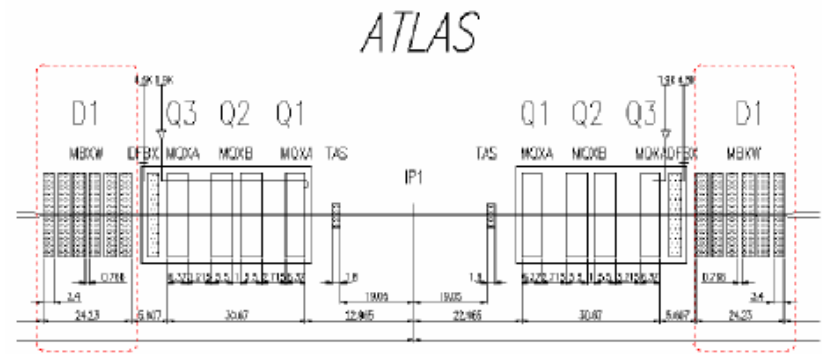
Content

1. **Fast Current Changes of RD1**
2. **Fast Current Changes of RD34**
3. **Fast Current Changes of RBXWTV
(ALICE compensator)**

RD1 circuit

- Normal conducting separation dipoles D1 in IR1 and IR5
- 12 modules powered in series
- $\beta_x > 2000\text{m}$
- time constant: $\tau = \frac{L}{R'}$, $\tau = 2.53\text{s}$

$$B(t) = B_0 \cdot e^{-\frac{t}{\tau}}$$

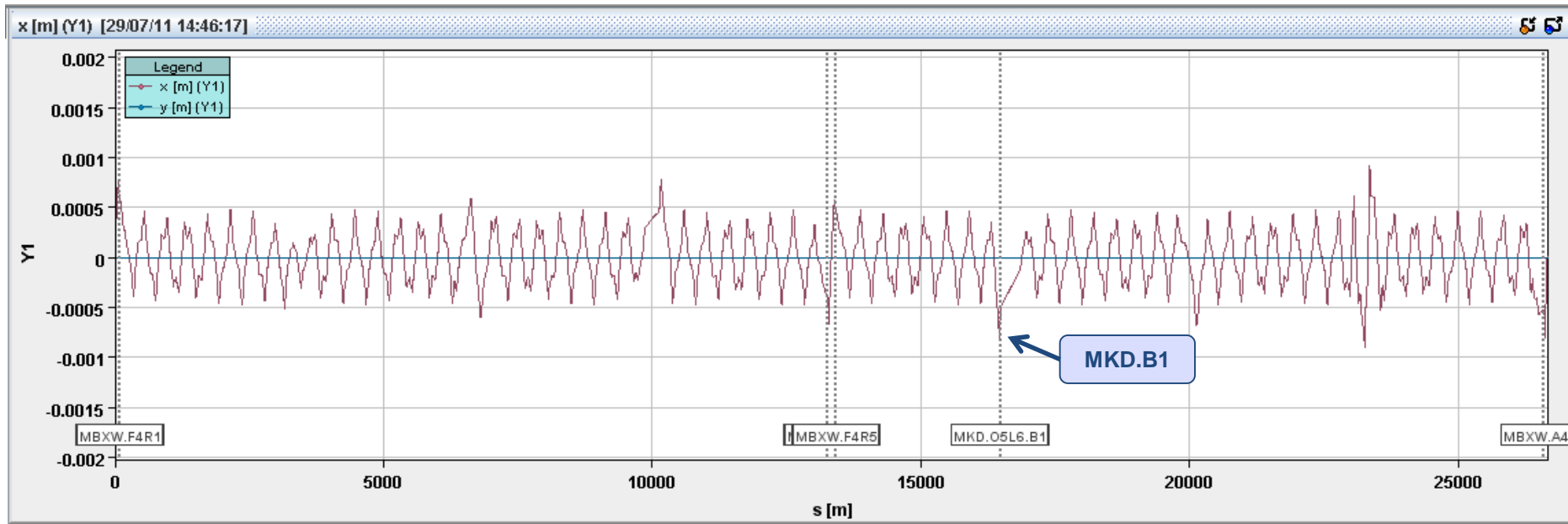


Courtesy of Verena Kain

$$\beta^* = 1.5\text{m}$$

Collision optics, $\beta^* = 1.5\text{m}$, current change RD1.LR1: +1A.

Phase advance RD1.L1 \rightarrow RD1.R1 $\approx 180^\circ$, but opposite deflection.

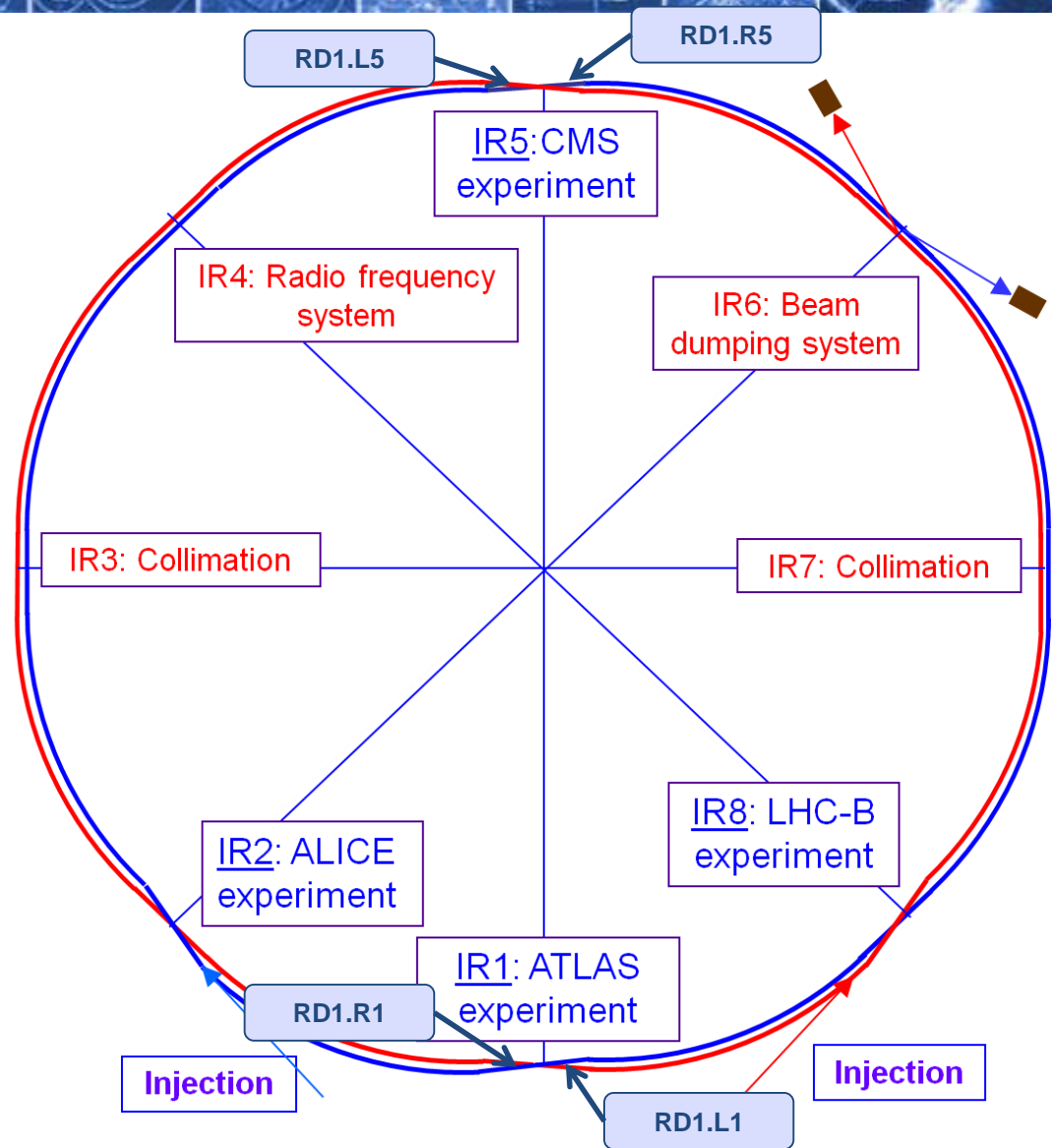


Max excursion (arc) $\approx 500\mu\text{m}$

Excursion MKD $\approx 800\mu\text{m}$

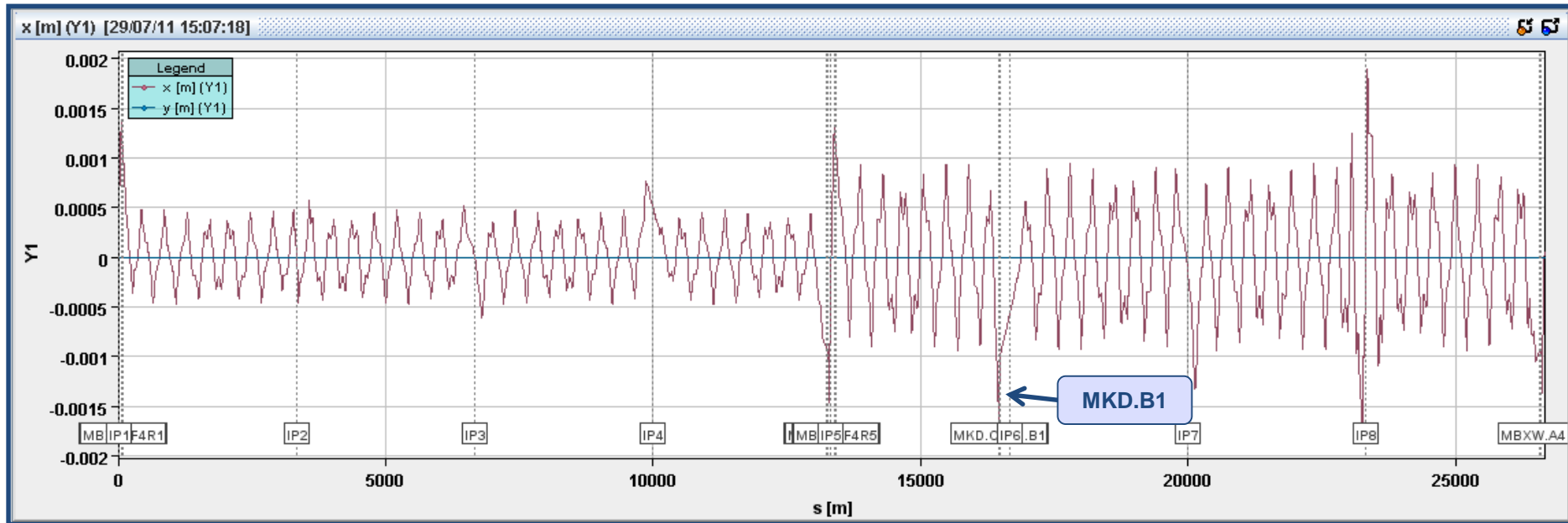
Additivity of Failures

- Deflection of RD1.L1 and RD1.R1 is in opposite direction. Phase advance $\approx 180^\circ$
Failure adds up.
- Deflection of RD1s in IP1 and IP5 symmetric. Phase advance $\approx 360^\circ$
Failure adds up.



$$\beta^* = 1.5\text{m}$$

Collision optics, $\beta^* = 1.5\text{m}$, current change RD1.LR1 and RD1.LR5 +1A.
Phase advance IP1 \rightarrow IP5 $\approx 360^\circ$



Max excursion (arc) $\approx 1\text{mm}$

Excursion MKD $\approx 1.6\text{mm}$

Excursion TCTH.4L1 $\approx 1\text{mm}$

Summary of scaling laws

Maximal excursion Δx is

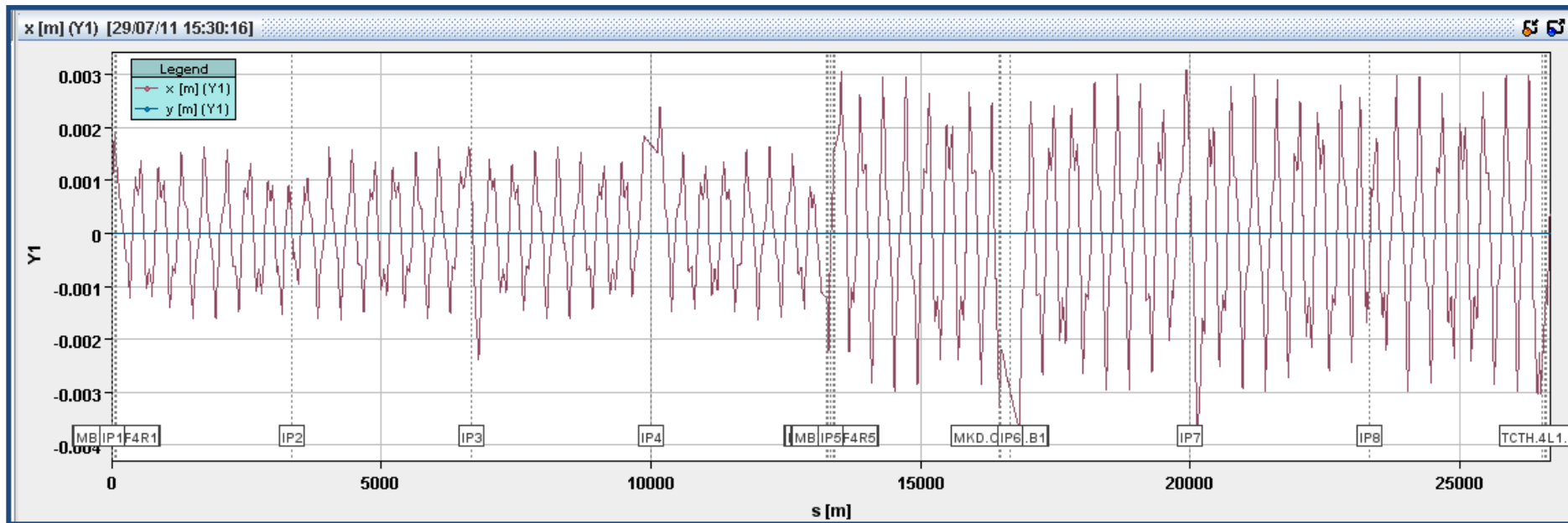
- Proportional to current change I . (assumed 1A)
- Inverse proportional to beam energy E (assumed 3.5TeV)
- Proportional to $\sqrt{\frac{1}{\beta^*}}$. (assumed $\beta^*=1.5\text{m}$)

$$\Delta x_{max} \propto \frac{\Delta I}{E \cdot \sqrt{\beta^*}}$$

Injection Optics

- Injection optics, 450 GeV, current change D1.LR1 and D1.LR5 +1A.

$$\text{Factor: } \frac{3500\text{GeV}}{450\text{GeV}} \cdot \sqrt{\frac{1.5\text{m}}{11\text{m}}} = 2.8$$



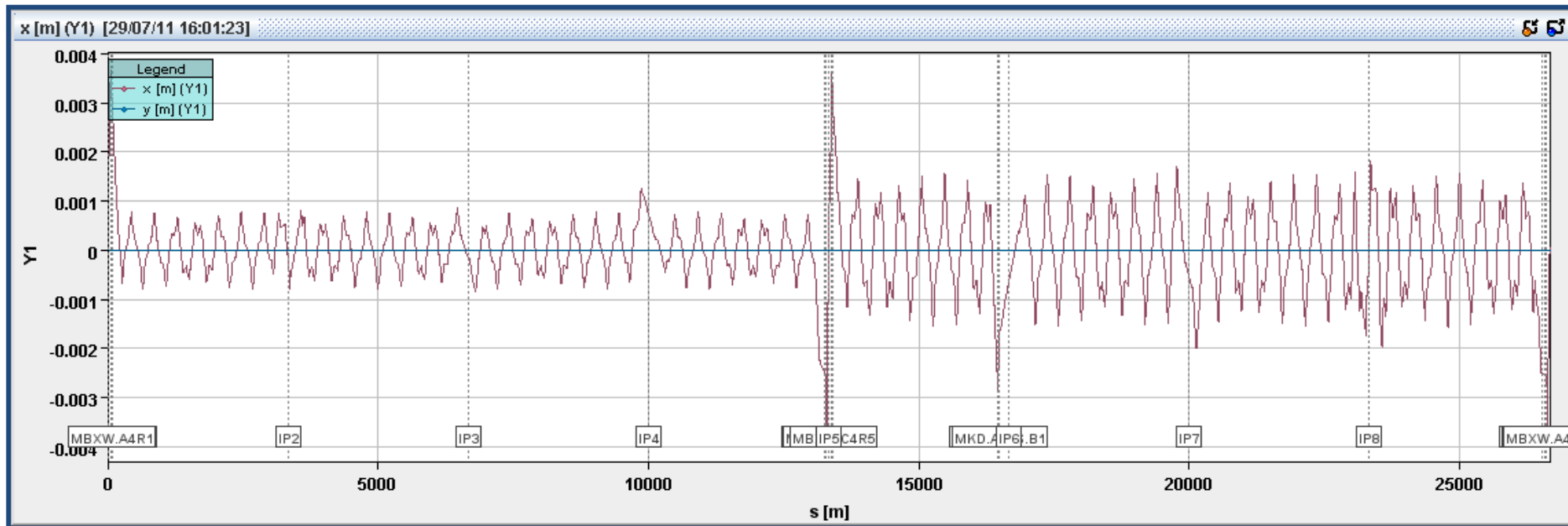
Max excursion (arc) \approx 3mm

Excursion MKD \approx 3.2mm

Nominal Collision Optics

- Collision optics, $\beta^* = 0.55\text{m}$, current change D1.LR1 and D1.LR5 +1A.

$$\text{Factor: } \sqrt{\frac{1.5\text{m}}{0.55\text{m}}} = 1.7$$



Max excursion (arc) $\approx 1.7\text{mm}$

Excursion MKD $\approx 2.7\text{mm}$

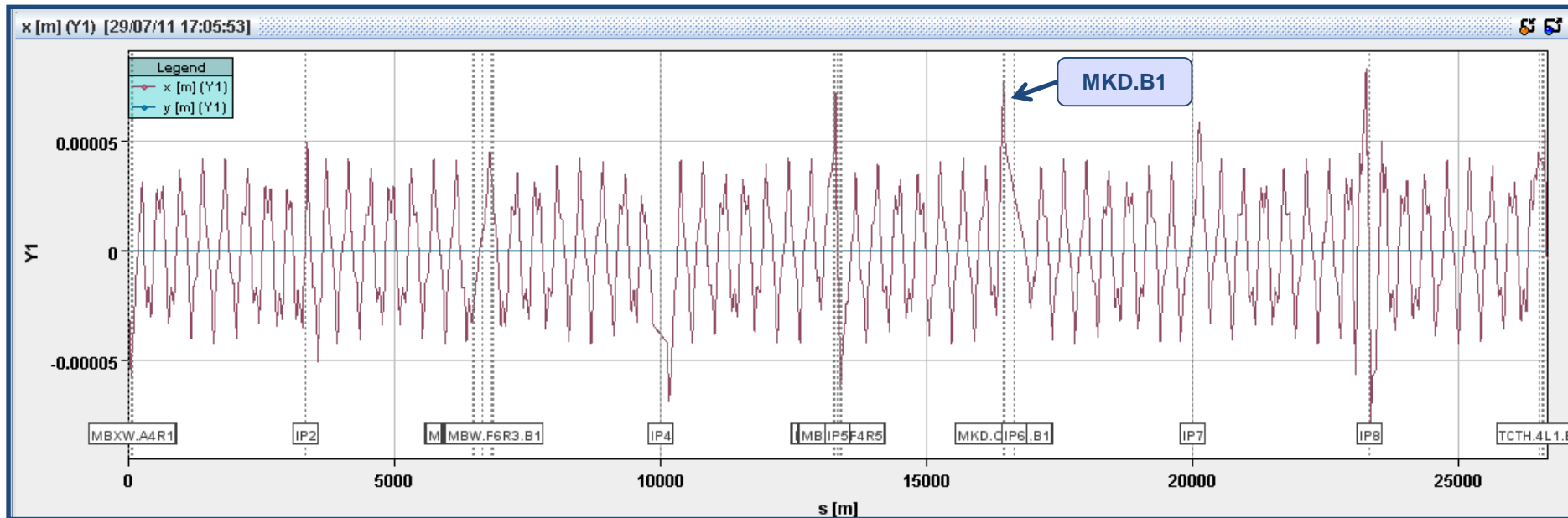
Content

1. Fast Current Changes of RD1
2. Fast Current Changes of RD34
3. Fast Current Changes of RBXWTV
(ALICE compensator)

RD34.LR3 +1A

Collision optics, $\beta^*=1.5\text{m}$, current change RD34.LR3: +1A.

More complex: asymmetric deflection of D4 and D3, L/R symmetric, different beta functions, $\varphi_{D34.R3}-\varphi_{D34.L3}=56^\circ - 66^\circ$



Max excursion (arc) $\approx 50\mu\text{m}$

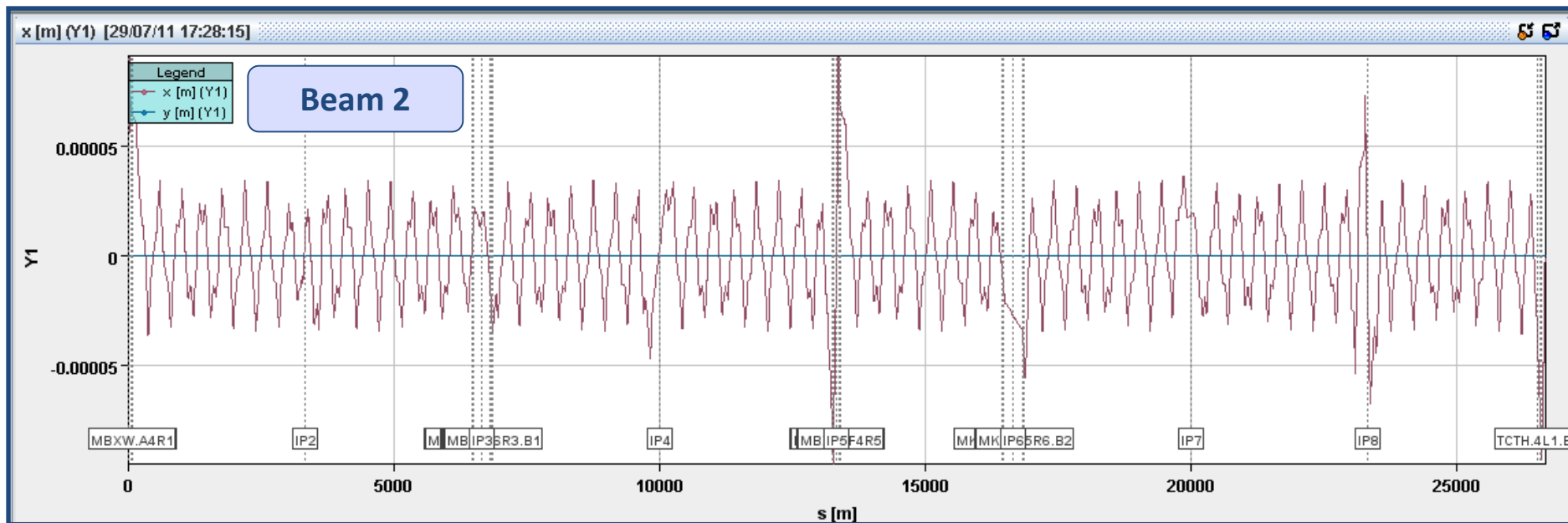
Excursion MKD $\approx 80\mu\text{m}$

Everything about 7 times larger at 450 GeV

RD34.LR7 +1A

Collision optics, $\beta^*=1.5\text{m}$, current change RD34.LR7: +1A.

A bit worse for MKD.B2

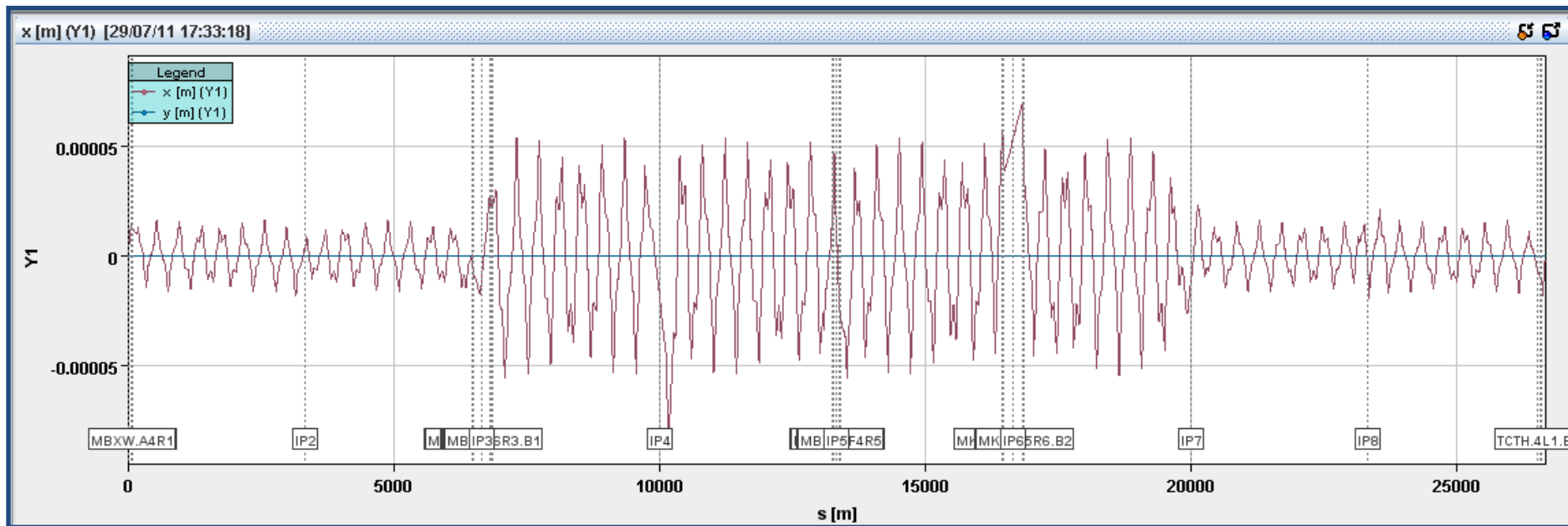


Max excursion (arc) $\approx 35\mu\text{m}$

Excursion MKD $\approx 50\mu\text{m}$

RD34.LR3 and RD34.LR7 +1A

Collision optics, $\beta^*=1.5\text{m}$, current change D34.LR3 and D34.LR7: +1A.



Max excursion (arc) $\approx 50\mu\text{m}$

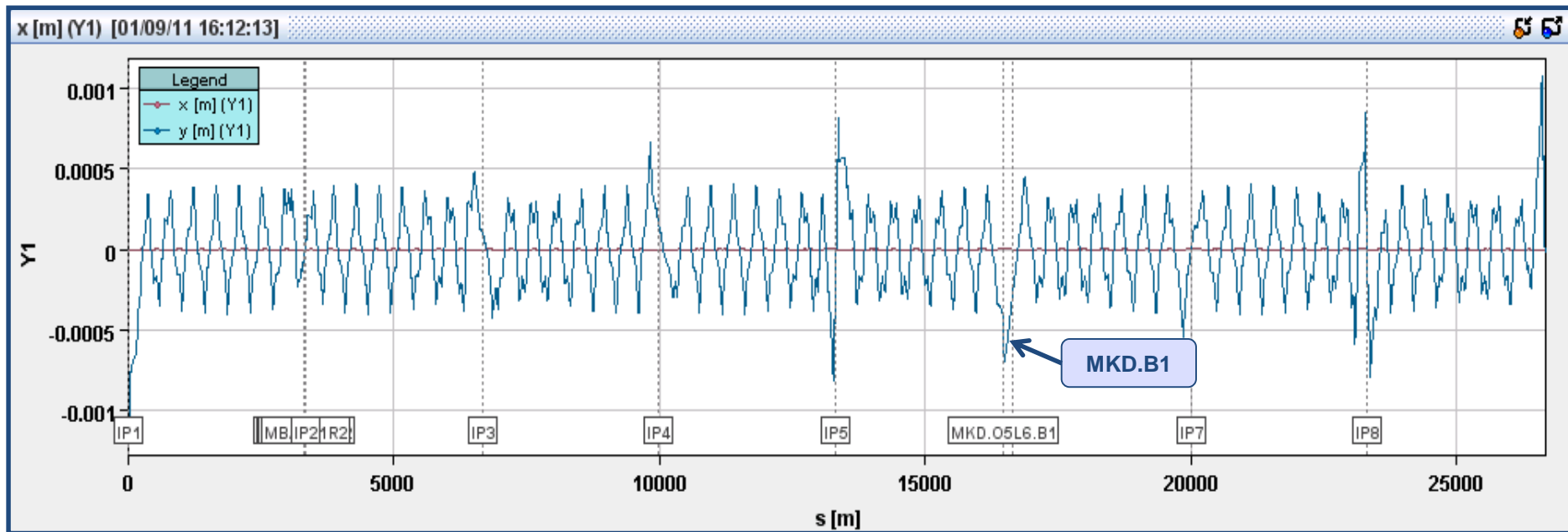
Content

1. Fast Current Changes of RD1
2. Fast Current Changes of RD34
3. Fast Current Changes of RBXWTV
(ALICE compensator)

$\beta^* = 10\text{m}$

Collision optics, $\beta^* = 10\text{m}$, current change RBXWTV.LR2: **+1A**.

Phase advance RBXWTV.L2 \rightarrow RBXWTV.R2 $\approx 130^\circ$, opposite kick.



Max excursion (arc) $\approx 400\mu\text{m}$

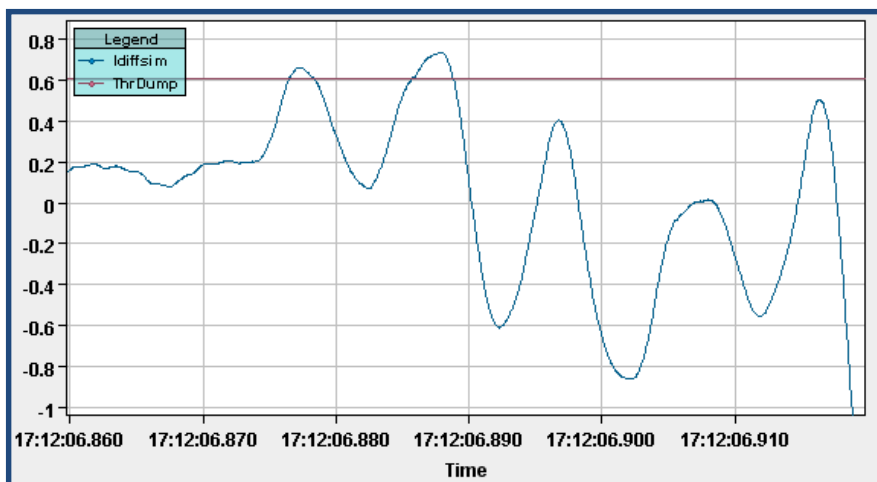
Excursion TCTV.4L8 $\approx 550\mu\text{m}$

Excursion MKD $\approx 800\mu\text{m}$

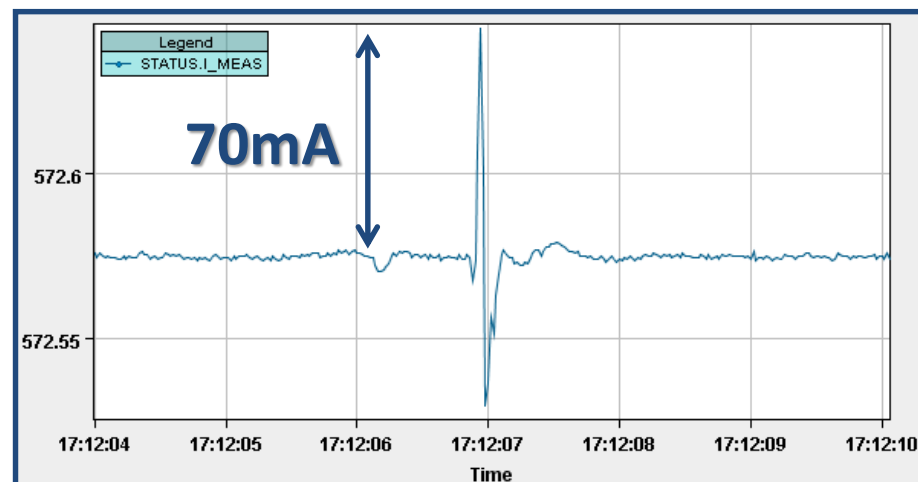
BUT: FMCM Threshold allows much smaller current changes (cf. Slide 19).



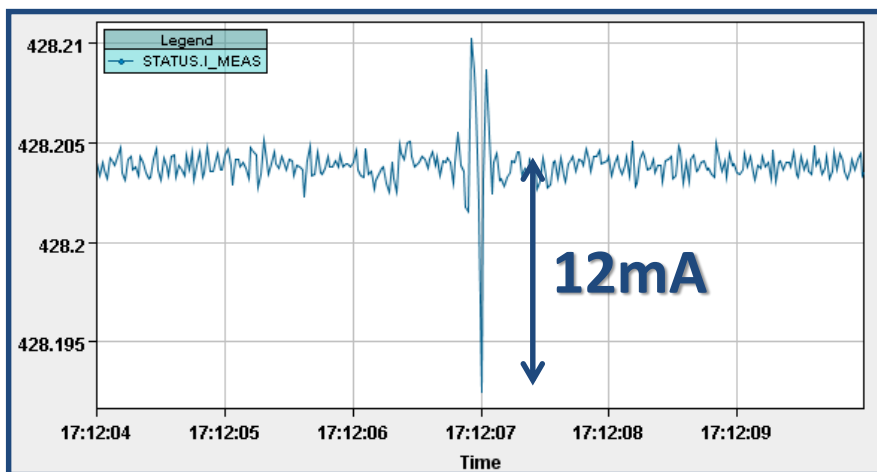
Electrical glitch on 27.02.2011



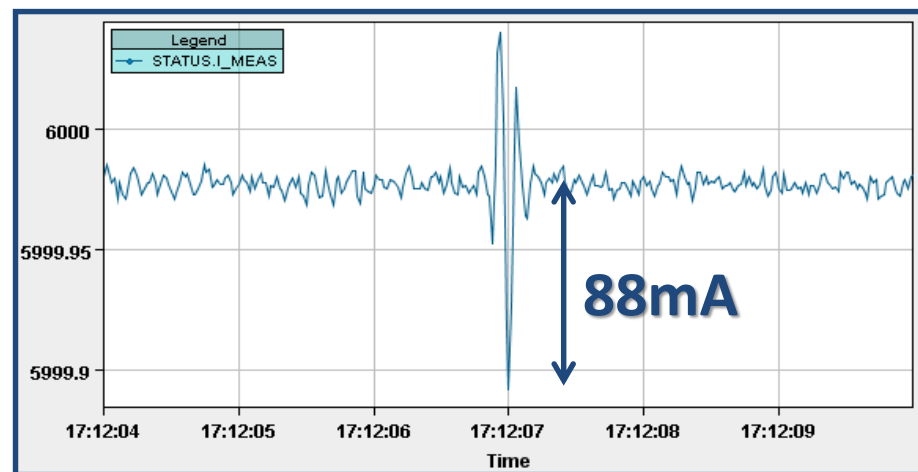
FMCM (RBXWTV.L2)



RBXWTV.L2 (left compensator)

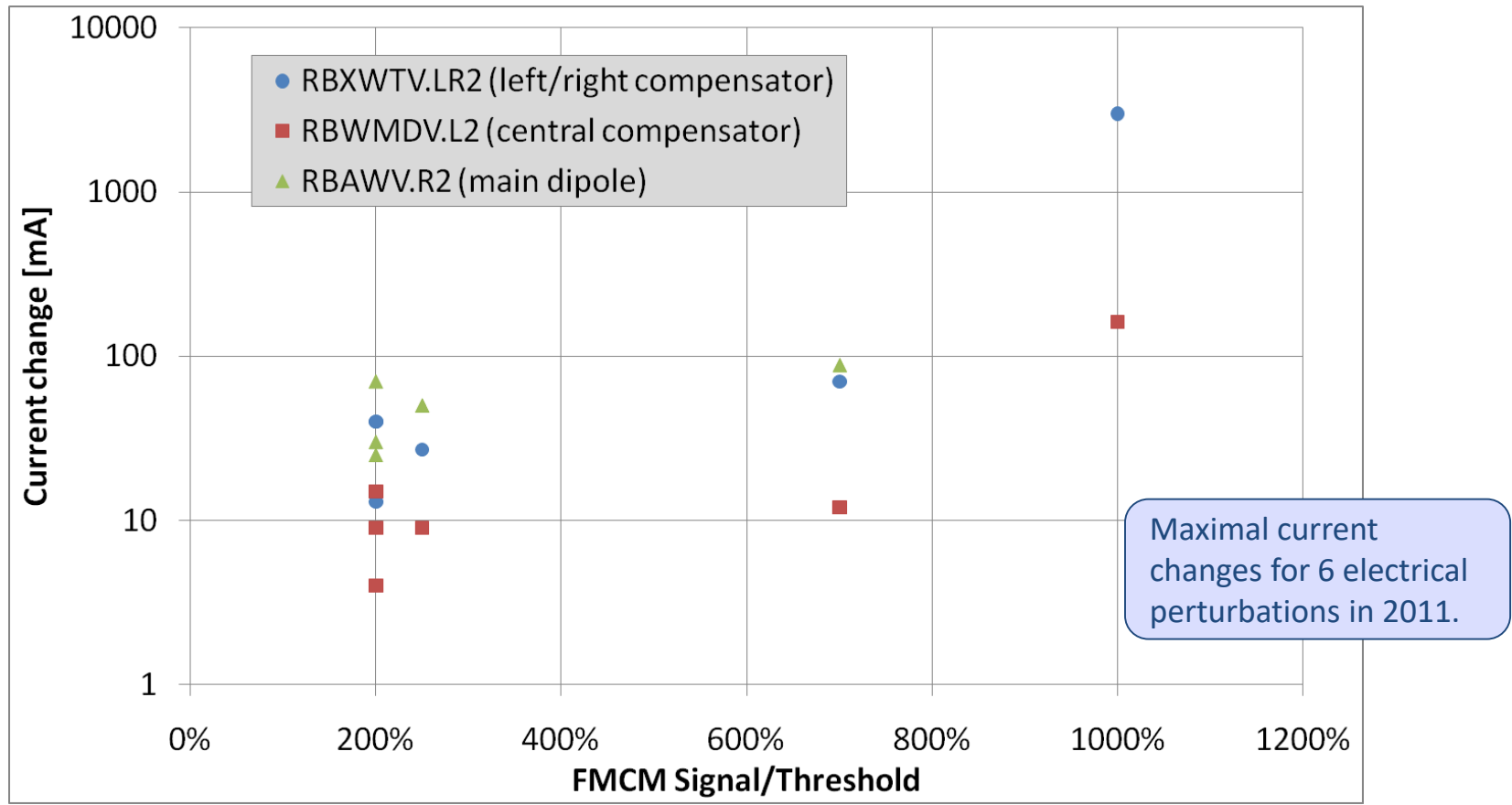


RBWMDV.L2 (central compensator)



RBAWV.R2 (main dipole)


Expected Current Change



Also for events where the FMCM signal was several times above its thresholds, the maximal current change was limited to 100mA.



ALICE spectrometer circuits

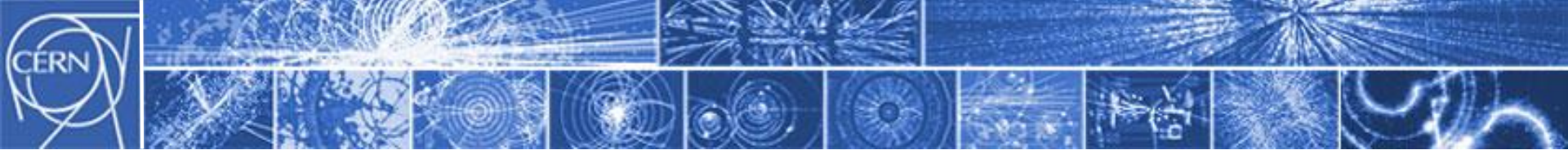
Circuit	μ_y (phase)	I_{nominal} [A]	$\Delta y'/I$ [$\mu\text{rad}/\text{A}$]	β_y [m]
RBXWTV.L2 (left compensator)	7.455 (0.000)	574.42	-3.84	48.0
RBWMDV.L2 (central compensator)	7.499 (0.044)	428.20	13.41	24.4
RBAWV.R2 (main dipole)	 90° 7.752 (0.297)	5999.98	-1.56	56.0
RBXWTV.R2 (right compensator)	7.819 (0.364)	502.68	3.91	18.9

Parameter for beam 1

- Failure of left compensator and right compensator add up.
- Failure of left/right compensator and central comp./main dipole counteract each other (assuming constant phase of electrical perturbation).

Conclusion

- Failures in **D1.L and D1.R add up.**
- Failures in RD1.LR1 and RD1.LR5 **add up.**
- Scaling law: $\Delta x_{\max} \propto \frac{\Delta I}{E \cdot \sqrt{\beta^*}}$
- A fast current change of RD1.LR1 and RD1.LR5 can lead to an **offset of more than 1.5mm at the MKD!**
- The excursions are smaller ($\approx 50\mu\text{m}$ at 3.5 TeV) for fast current changes of **RD34.LR3 and RD34.LR7**, but these failures are often in the shadow of the D1.
- Fast current changes often affect **RBXWTV**, ALICE main dipole (fast current interlock) and central compensator magnet together, but partly counteract each other (assuming electrical perturbation with constant phase).
- For maximal current change of 100mA in RBXWTV.LR2, the maximal excursion in the arcs would be $\approx 40\mu\text{m}$ at 3.5 TeV ($80\mu\text{m}$ at the MKD, $120\mu\text{m}$ in MQXB.R1).



Thank you for your Attention

Tobias Baer

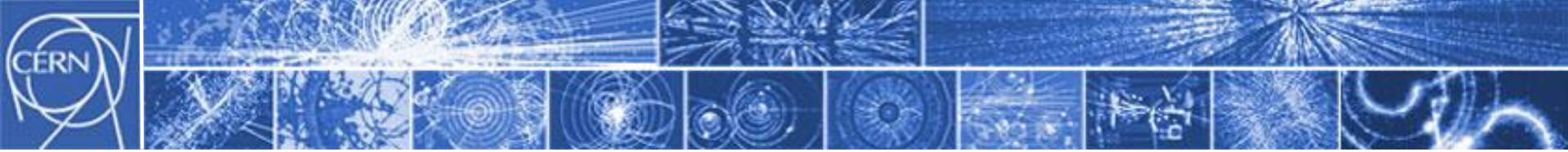
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Further information:

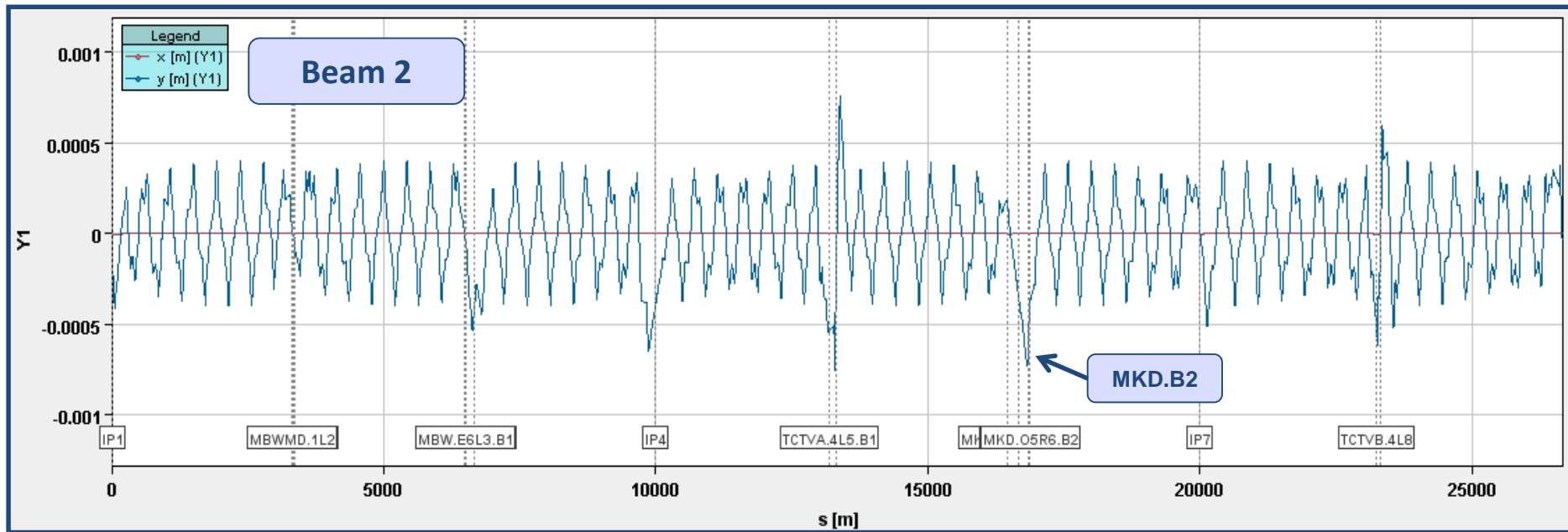
- M. Zerlauth, "Electrical Glitch 06.02.2011", 8:30 Meeting, July 27th 2011.



Backup slides

Collision optics, $\beta^* = 10\text{m}$, current change RBXWTV.LR2: **+1A**.

Phase advance RBXWTV.R2 \rightarrow RBXWTV.L2 $\approx 130^\circ$, opposite kick.



Max excursion (arc) $\approx 400\mu\text{m}$

Excursion MKD $\approx 450\mu\text{m}$

BUT: FMCM Threshold allows much smaller current changes.

FMCM events

- Electrical glitch on 27.07.2011 06:02:34:
 - RD1.LR1: peak at 335.50A (nominal: 335.34A), risetime: 80ms, rel change: 4.7E-4
 - RD1.LR5: peak at 335.11A (nominal: 335.22A), risetime: 40ms, rel change: 3.28E-4
 - RD34.LR3: peak at 318.45A (nominal: 318.32A), risetime: 80ms, rel change: 4.1E-4
 - RD34.LR7: peak at 318.50A (nominal: 318.35A) risetime: 80ms, rel change: 4.7E-4
- Electrical glitch on 28.07.2011 04:38:31:
 - RD1.LR1: peak at 336.16A (nominal: 335.34A), risetime: 40ms, rel change: 2.4E-3
 - RD1.LR5: **peak at 336.22A (nominal: 335.22A)**, risetime: 60ms, **rel change: 2.9E-3**
 - RD34.LR3: peak at 318.95A (nominal: 318.32A), risetime: 60ms, rel change: 2.0E-3
 - RD34.LR7: peak at 319.22A (nominal: 318.35A) risetime: 60ms, rel change: 2.7E-3

+1A

See Markus' talk for more details.