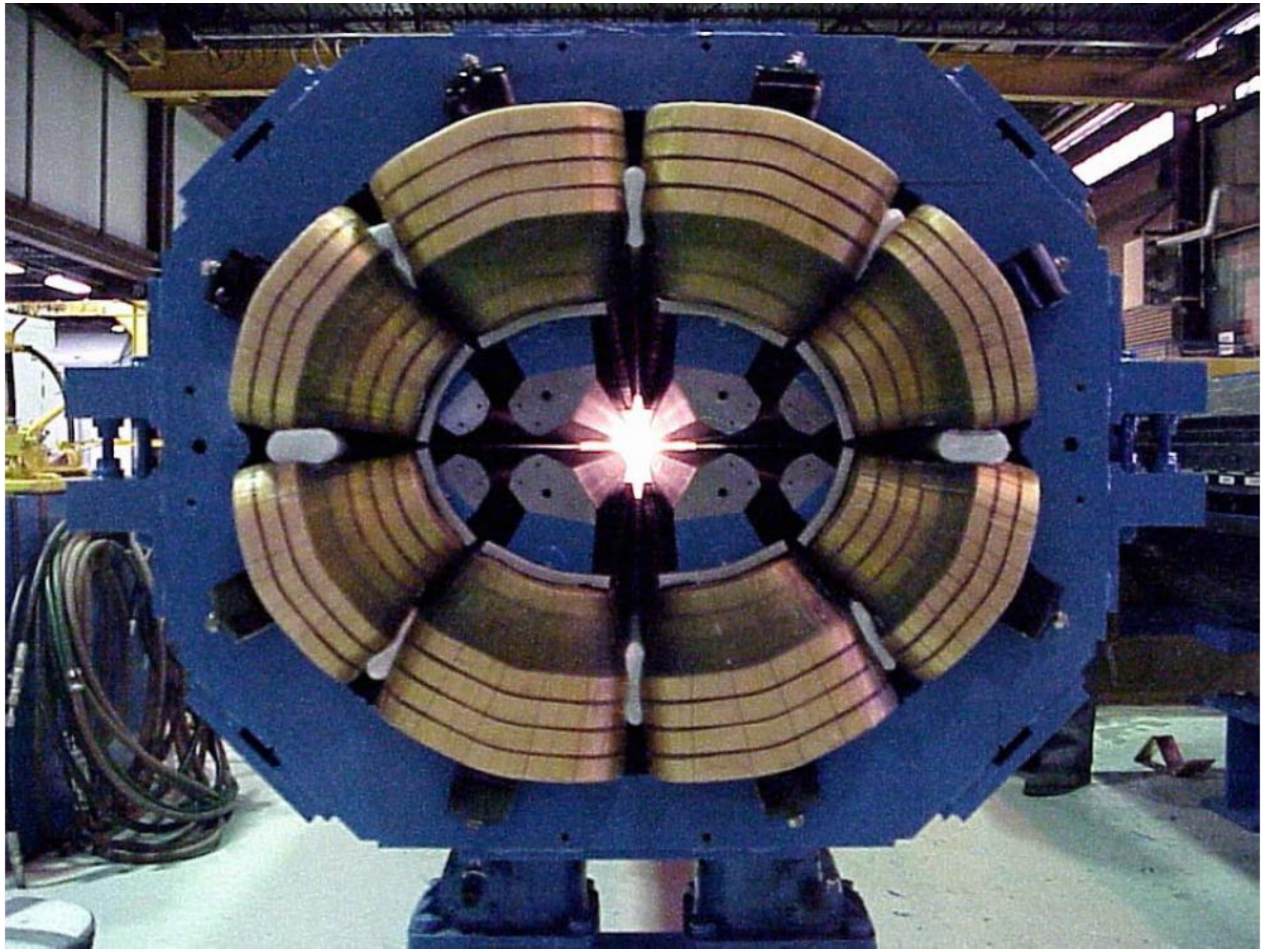
BLM thresholds for MQW magnets

V. Raginel, B. Auchmann, D. Wollmann

MQW normal conducting quadrupole magnet



- **Position : Cleaning Section IR3 and IR7, Q4 and Q5 consist of a group of 6 MQW.**
  High radiation level (collimation system) not compatible with superconducting magnets

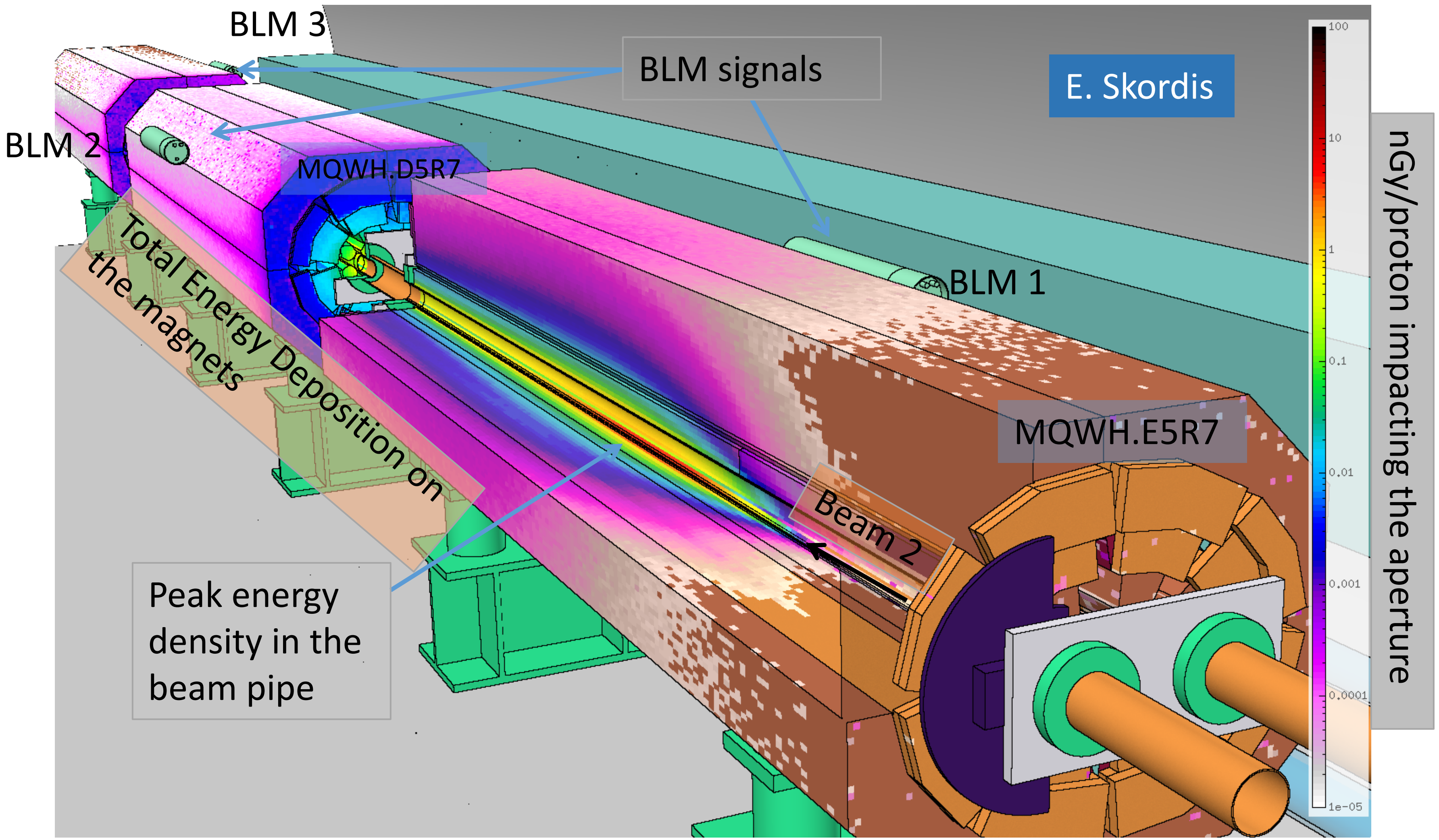
- **Two Apertures in common yoke** due to limited space in the tunnel

- Group of 6 magnet: **5 MQWA, 1 MQWB**

Damage Limits of MQWs

- **Fast Losses limit from TT40 Experiment** (1.32×10^{12} protons @450 GeV,~500 °C) used as input for the Setup Beam Flag => **ΔE = 1.9 kJ/cm3**
- **Steady-state Losses limit given by the cooling power of the coils, Coils Temperature** < 65 °C (Thermo-switch to protect the coils)

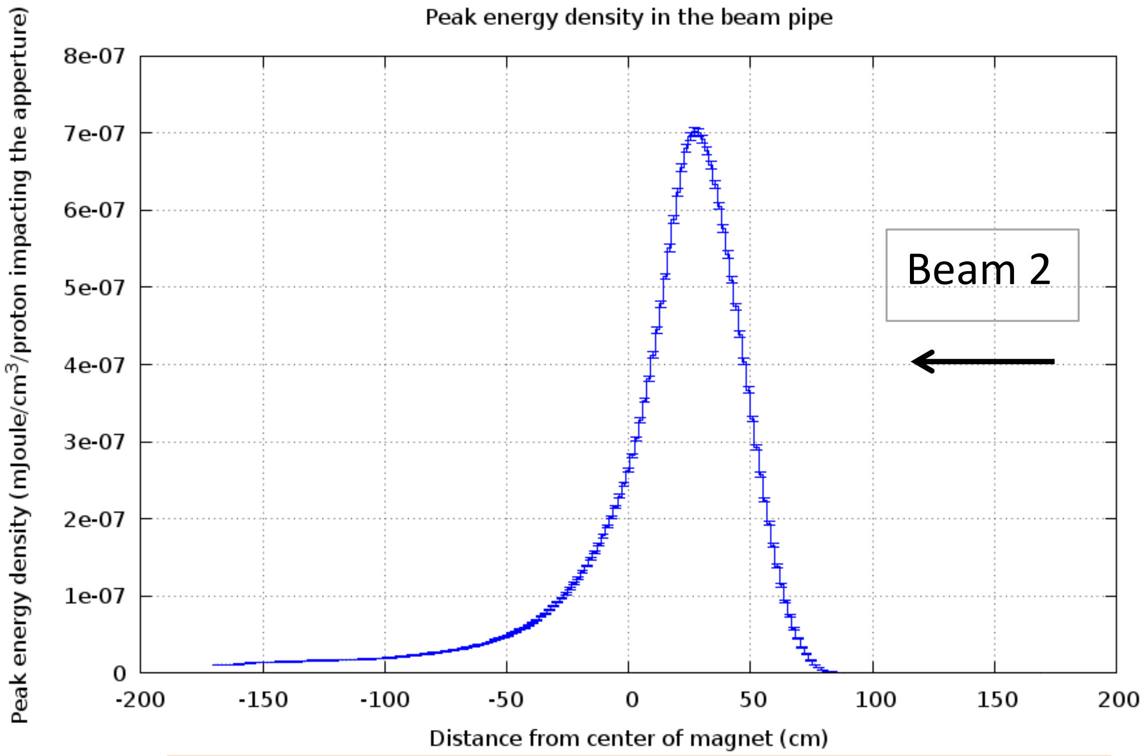
BLM Threshold losses scenario



- **Vertical orbit bump** on the lower part of the beam pipe
- Beam Energy **3.5 TeV**
- Maximum deflection to the lower vertical beam aperture:
  - 26 mm
  - about 1 meter upstream the centre of MQWH.E5R7

FLUKA Results

Fast Losses (beam pipe)



For fast losses: The peak energy density in the beam pipe is the limiting point

Steady-state Losses (whole magnet)

MAGNET	MQWH. C5R7	MQWH. D5R7	MQWH. E5R7
Total Energy deposition (nJoule/ proton)	7	13	**42**

Beam 2 ←

BLM	3	2	1
Signal (10^{-14}Gy /proton)	1.6	5.6	**7.5**

E. Skordis

All values are normalised per proton impacting the beam pipe

Fast losses on vacuum pipe at 3.5 TeV

- Energy Threshold = 1.9 kJ/cm^3 (from TT40 damage experiment)
- Peak Energy Deposition = 7.2×10^{-10} $J/cm^3/p+$

Maximum allowed proton lost @3.5 TeV = 2.64×10^{12} p+

Steady-state losses at 3.5 TeV, cooling limitation

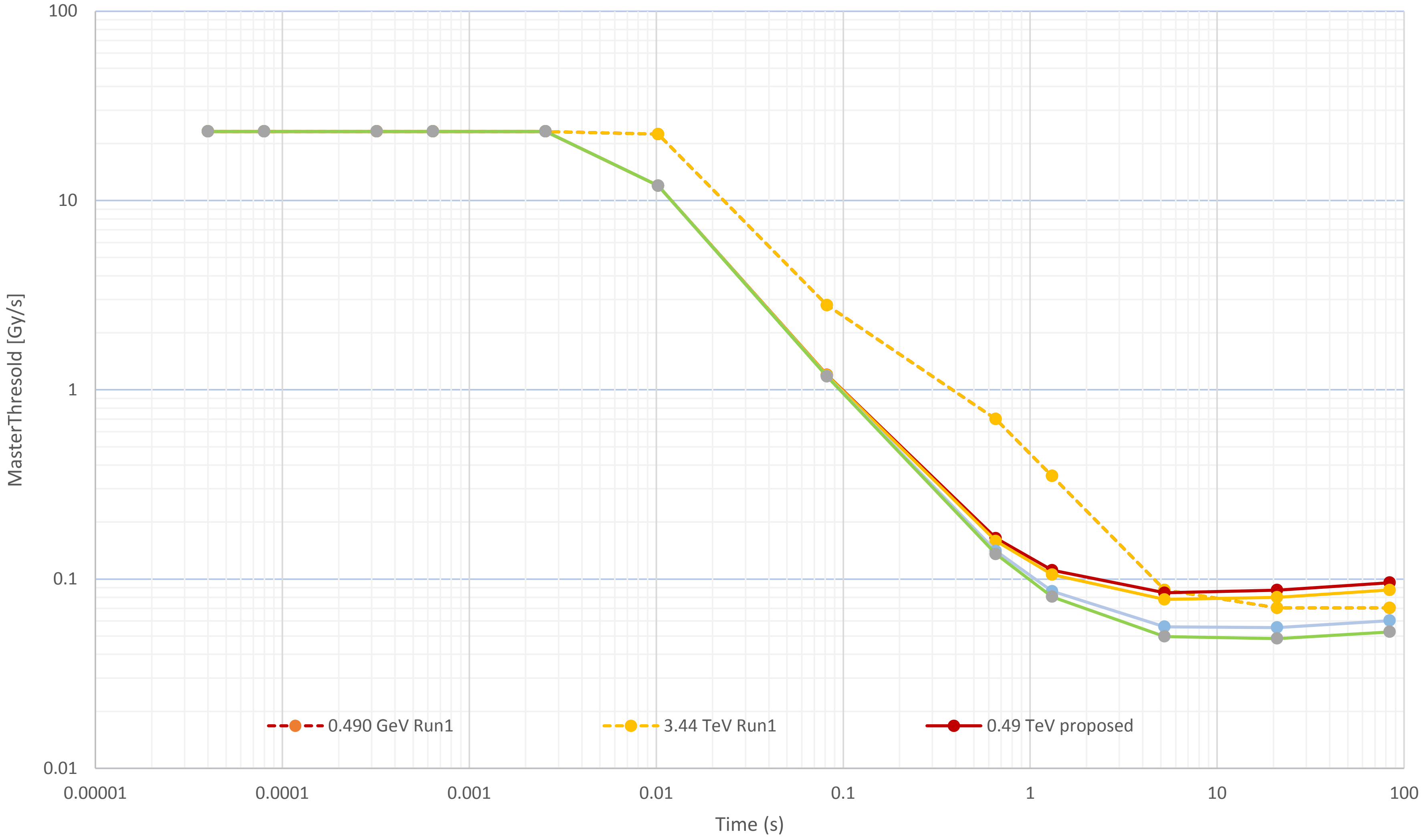
- Coils Temperature interlocked at **65°C**

Water Flow (Q)*	22l/min
Water Temperature*	20 to 30 °C
Max allowed ΔT Water	35 °C
Max Power evacuated $P_{cool} = Cp\, Q\rho\Delta T$	53.6 kW
Nominal Magnet Current	360 A
Ohmic Losses $P_{Ohm} = R * I^2$	4.8 kW
Energy Deposition whole magnet E_{dep}	42 nJ/p+
Max. allowed loss rate $(P_{cool} - P_{ohm})/E_{dep}$	**1.17×10^{12} p+/s**

* Operational values confirmed by *D. Tommasini and P. Thonet*

BLM Master Thresholds

MasterThreshold= nMaxProton/ Time × BLM response



Losses induced by collimation

- Are we **safe** with the proposed threshold **in case of collimation losses + orbit bump**?

$$\Rightarrow \frac{EnergyDep_{COL}}{BLMResp_{COL}} \leq \frac{EnergyDep_{OB}}{BLMResp_{OB}}$$

$$3.69 \times 10^{14} GeV/Gy < 1.45 \times 10^{15} GeV/Gy$$

For the **same BLM signal's amplitude**, the **energy deposition** into MQWs is at least **3 time less for collimation losses than for orbit bump losses.**

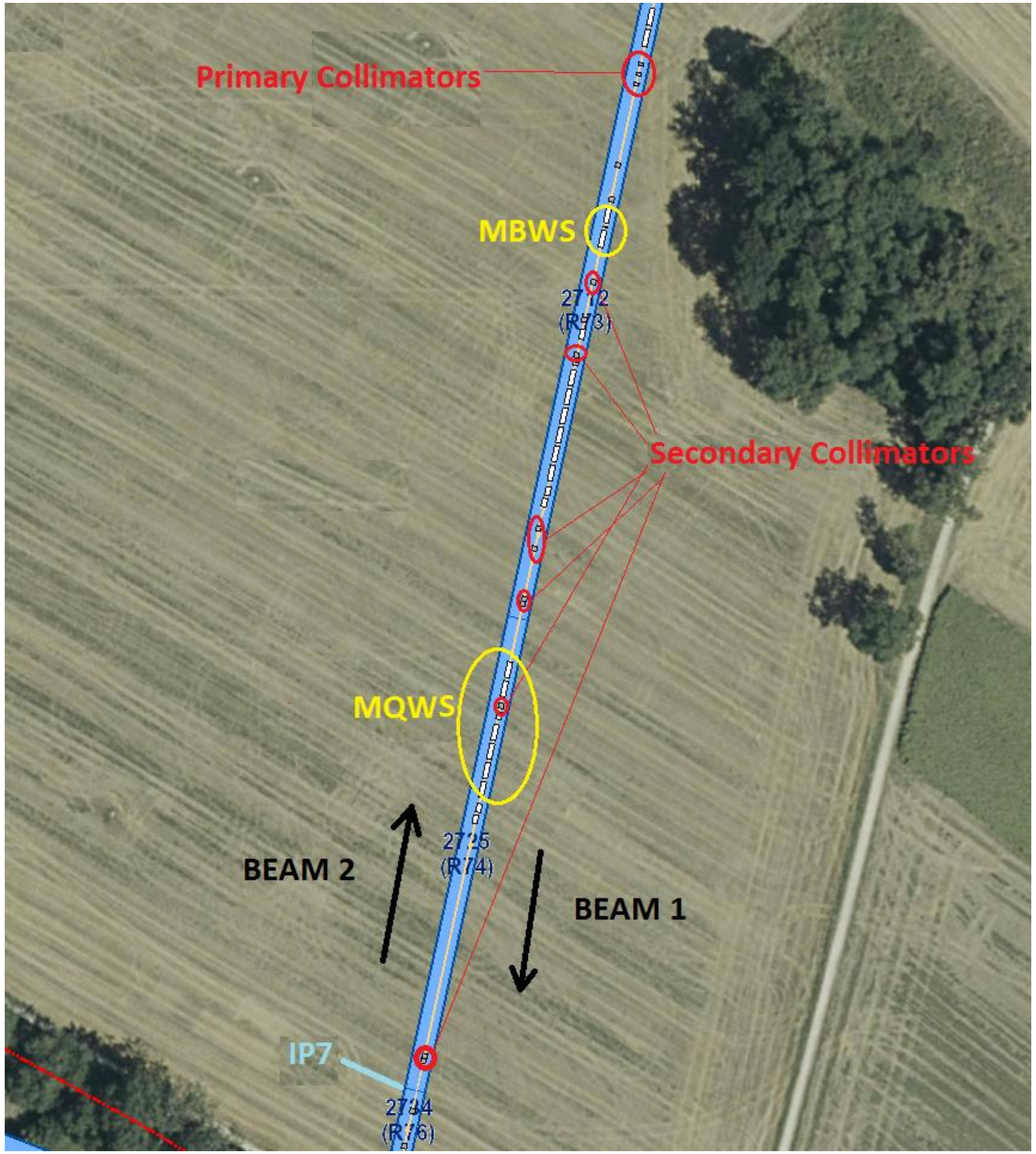
⇒ **SAFE**

MQW thresholds ready to be implemented

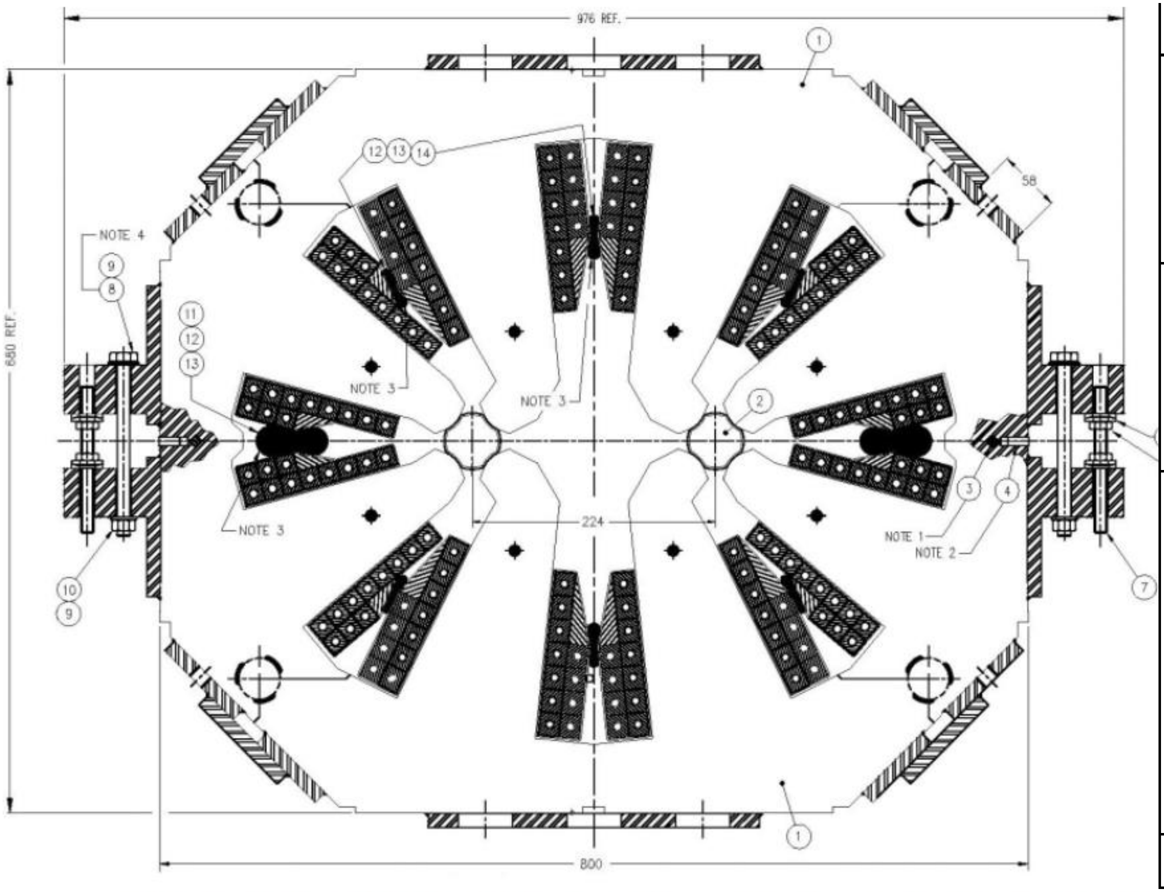
- **New Thresholds proposed for the MQWs derived from an orbit bump scenario**
  - Short running sum: no beam energy dependency
  - Long running sum: beam energy dependency
    – Ohmic losses are proportional to I^2.
- Thresholds **safe in presence of background** (collimation losses)

SPARE SLIDES

IP7 Configuration



MQW main parameters



Cross-section of the MQW twin aperture normal conducting matching quadrupole

Magnet type	MQWA	MQWB
Magnetic length	3.1 m	
Beam separation	224 mm	
Aperture diameter	46 mm	
Operating temperature	< 65° C	
Nominal gradient	35 T/m	30 T/m
Nominal current	710 A	600 A
Inductance	28 mH	
Resistance	37 mΩ	
Conductor X-section	20.5 x 18.0 mm² inner poles 17.0 x 17.0 mm² outer poles	
Cooling hole diameter	7 mm inner poles, 8 mm outer poles	
Number of turns per magnet	8 x 11	
Minimum water flow	28 l/min	
Dissipated power at I_{nom}	19 kW	14 kW
Mass	11700 kg	

BLM Thresholds calculation

- **32 Energy level** (from 0.245 TeV to 7.86 TeV)
  - Extrapolation from 3.5 TeV values
- **12 Integration steps** (40 us to 83.9 s)
  - Interpolation between short and steady-state losses

BLM Thresholds vs. Energy

Values for all Energies are extrapolated from 3.5 TeV values

- BLM response linearly extrapolated (e. g. 7.48E-14 Gy/p+)
- Fast losses Limit (number of protons)

$$\mathbf{nShort}(E_{beam}) = \mathbf{nShort}_{3.5TeV} \times {}^{3.5}\!/_{E_{beam}}$$

- Steady-state Limit (number of protons)

$$\mathbf{nLong}(E_{beam}) = \frac{\left(P_{Cool} - P_{Ohm(3.5TeV)} \times \left({}^{E_{beam}}\!/_{3.5}\right)^2\right)}{\left(E_{Dep(3.5TeV)} \times {}^{E_{beam}}\!/_{3.5}\right)} \times Time$$

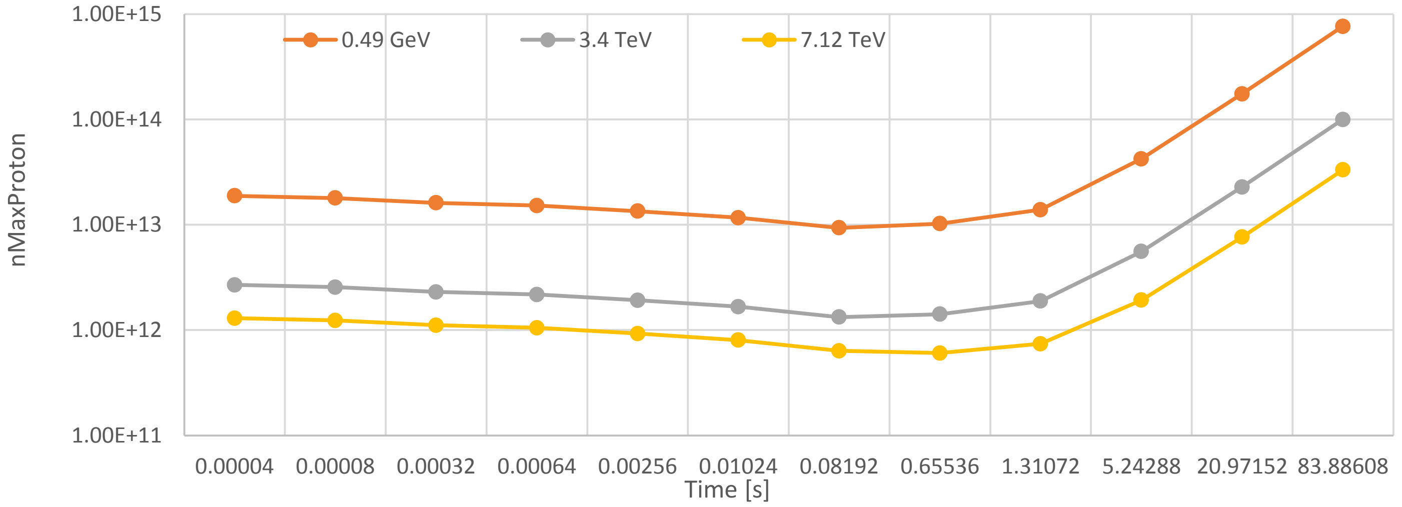
BLM Thresholds vs. Integration Time

Logarithm Interpolation between fast and steady state losses

- $$\boldsymbol{TimeWeight} = \frac{(\log(\boldsymbol{Time}) - \log(40\ \mu s))}{(\log(83\ s) - \log(40\ \mu s))}$$

- Max. allowed losses

$$\boldsymbol{nMaxProton} = \big((1 - \boldsymbol{TimeWeight}) \times \boldsymbol{nShort}\big) + (\boldsymbol{TimeWeight} \times \boldsymbol{nLong})$$



Losses induced by collimation

ORBIT BUMP

Magnets	Energy Deposition [GeV/p+]	BLM signal [Gy/p+]	[GeV/Gy]
MQWHE5R7	262	7.50E-14	3.50E+15
MQWHD5R7	81	5.60E-14	1.45E+15
MQWHC5R7	44	1.60E-14	2.73E+15

COLLIMATION

@ 4TeV - Quench Test collimator settings

Magnets	Energy Deposition [GeV/p+]	BLM signal [Gy/p+]	[GeV/Gy]
MQWHA5R7	23	1.40E-13	1.64E+14
MQWHB5R7	25	9.60E-14	2.60E+14
MQWH5R7	28	1.90E-13	1.47E+14
MQWHC5R7	35	1.30E-13	2.69E+14
MQWHD5R7	44	5.10E-13	8.63E+13
MQWHE5R7	127	3.90E-13	3.26E+14

@ 6.5TeV - Nominal cleaning collimator settings 2012

Magnets	Energy Deposition [GeV/p+]	BLM signal [Gy/p+]	[GeV/Gy]
MQWHA5R7	46	2.28E-13	2.02E+14
MQWHB5R7	54	1.56E-13	3.46E+14
MQWH5R7	58	3.09E-13	1.88E+14
MQWHC5R7	74	2.11E-13	3.50E+14
MQWHD5R7	92	8.29E-13	1.11E+14
MQWHE5R7	234	6.34E-13	3.69E+14