Ion collimation performance during energy ramping

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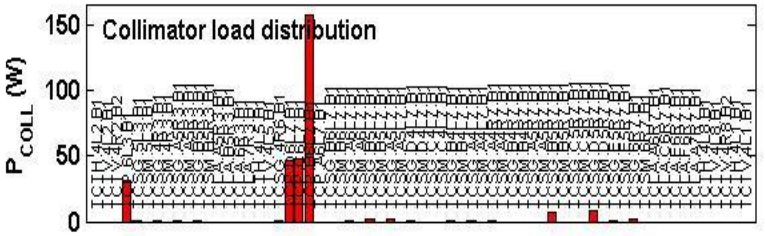
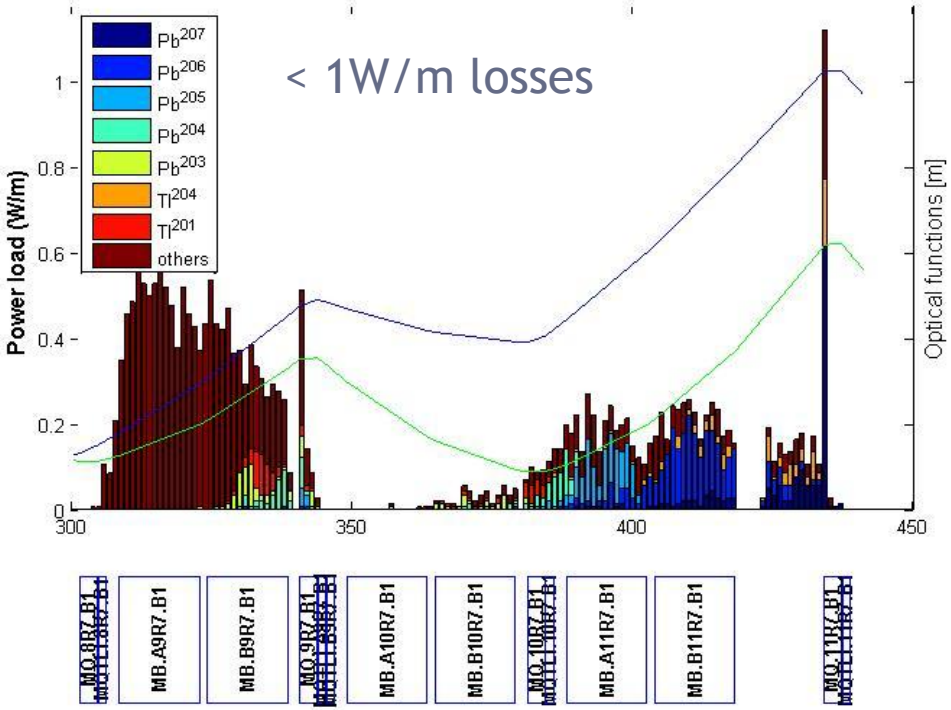
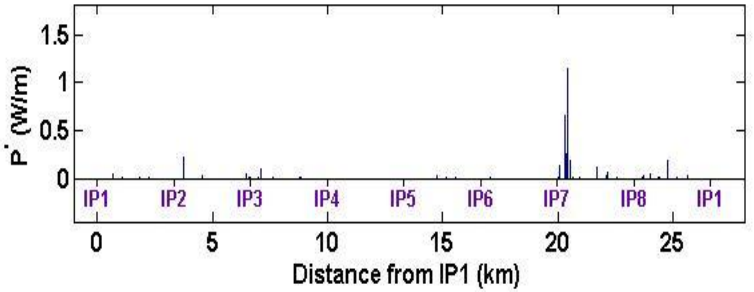
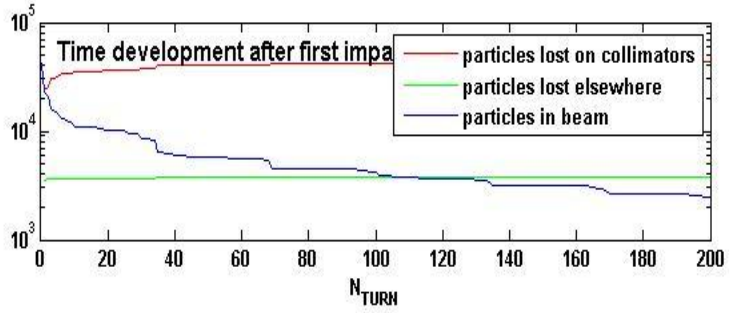
Two scenarios analysed so far: Pb injection (E=177 A GeV)

	TCPs	TCSs	TCLAs
IR3	8	9.3	10
IR7	5.7	6.7	10



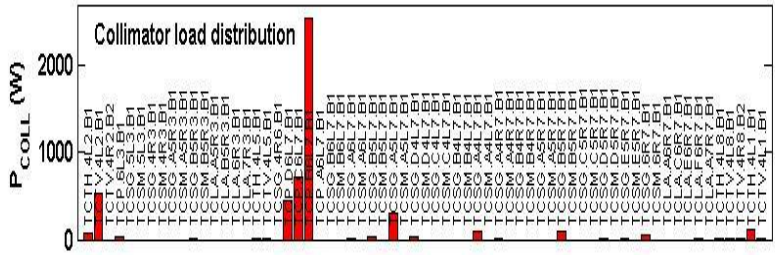


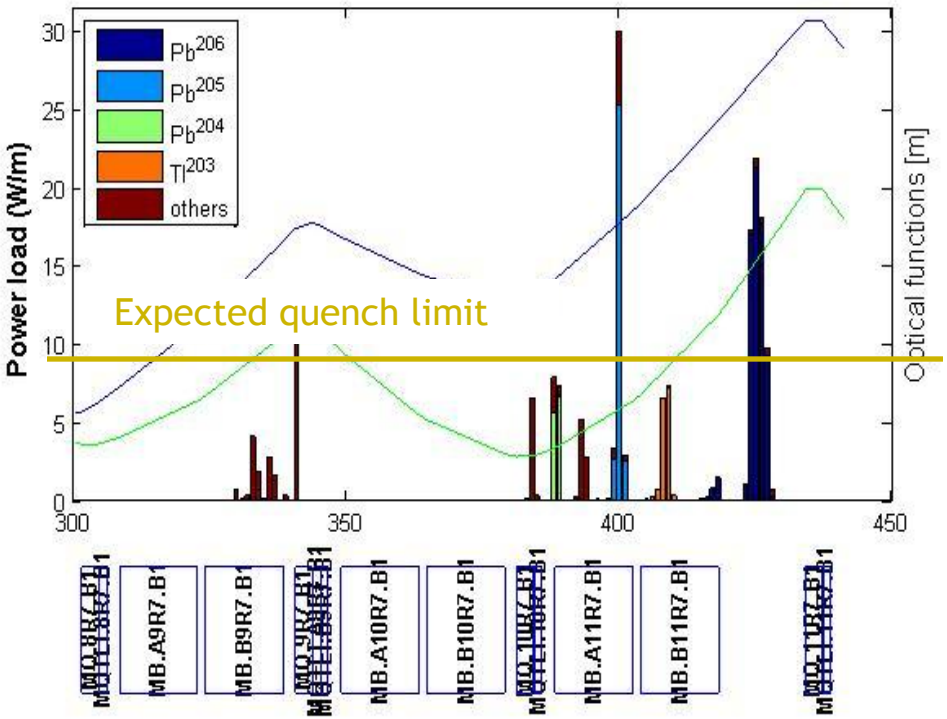


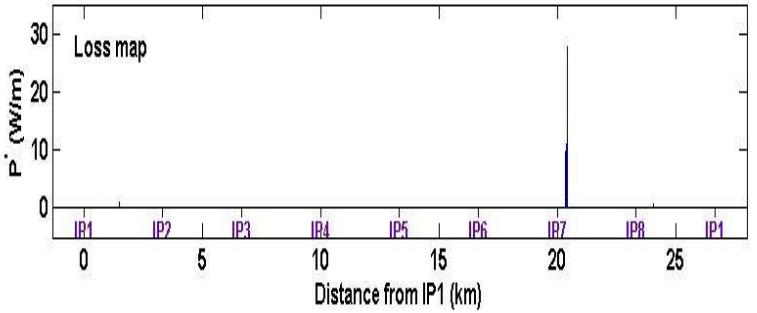


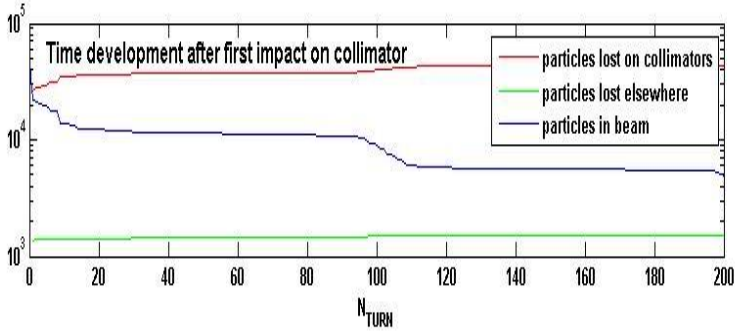
Top energy: Pb^{82+} at 2.76 A TeV

	TCPs	TCSs	TCLAs
IR3	15	18	20
IR7	6	7	10







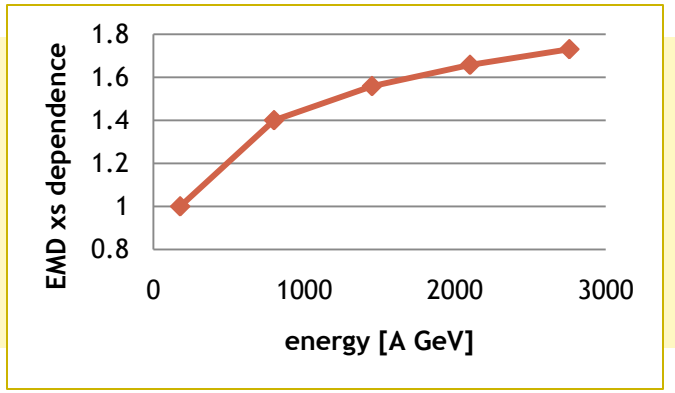


Energy dependence

Cross sections:

EMD: $\sigma_{EMD} \propto \ln\left(0.025 \cdot \left(2\gamma^2 - 1\right)\right)$

HAD: more moderate
(~10% over whole E range)



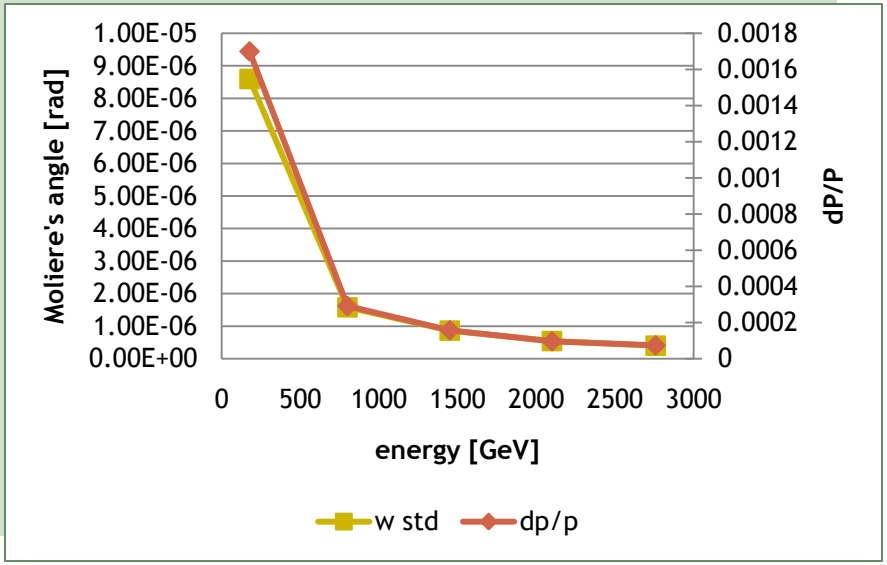
Energy deposition and scattering:

Bethe-Bloch

$$\frac{dE}{dx} = \rho K \frac{Z_P^2 Z_T}{A_T \beta^2}\left[\frac{1}{2}\ln\left(2m_e c^2 \beta^2 \gamma^2 \frac{T_{\max}}{I^2}\right) - \beta^2 - \frac{\delta}{2}\right]$$

Moliere

$$Wrms = \frac{19.3 \cdot 10^6}{\beta^2 \gamma} Zp \sqrt{\frac{s}{X_0}}\left[1 + 0.038 \ln\left(\frac{s}{X_0}\right)\right]$$

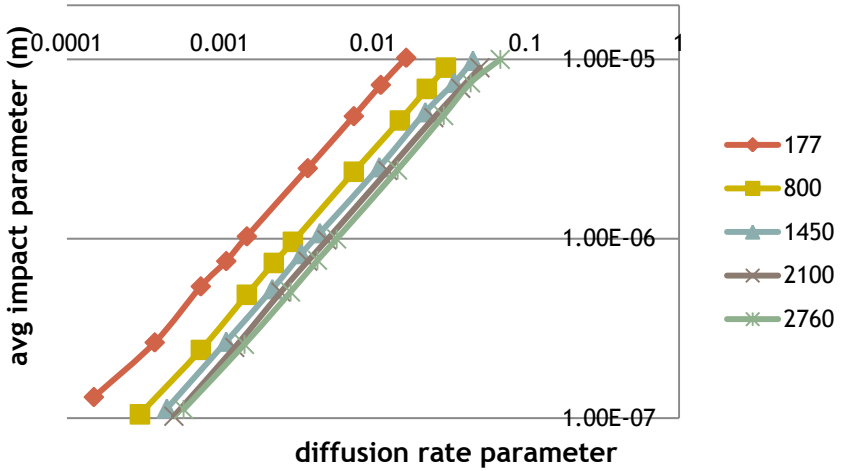


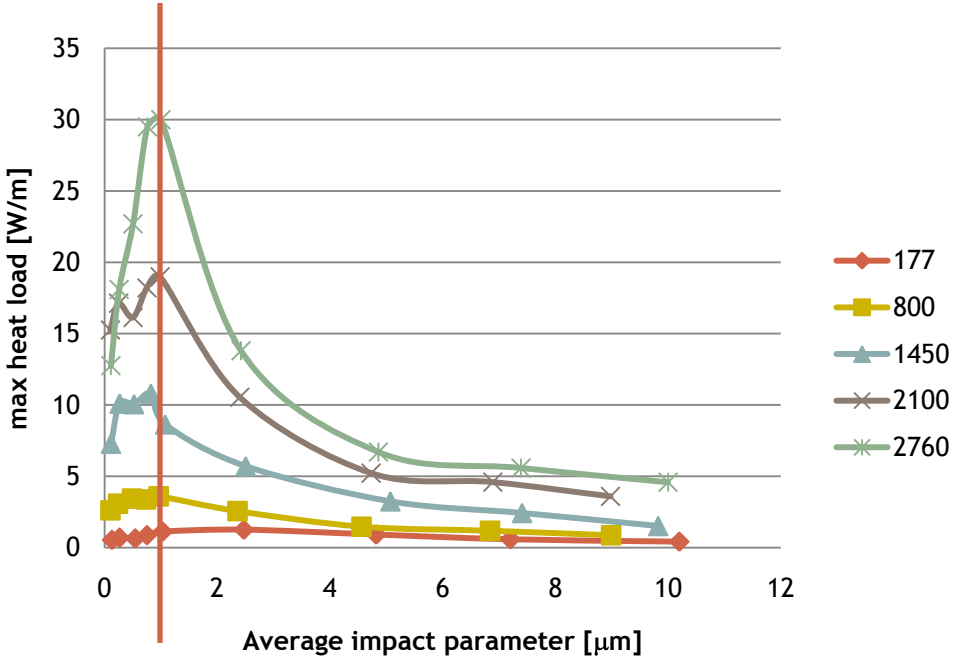
Settings

- 5 energy points at E=177.4, 800, 1450, 2100, 2760 A GeV
- All cross sections regenerated with FLUKA for different energies
- V6.500 injection optics used for all cases
- Gap settings assigned following "rigid scaling scenario" (*C.Bracco, CWGM 23/04/2007*) : TCPs at 6σ, fixed offset between TCPs and downstream collimators, TCTs open except at top energy

E [A GeV]	TCP7	TCS7	TCLA7	TCP3	TCS3	TCLA3
177.4	5.7	6.7	10	8	9.3	10
800	6	8.1	15.1	10.9	13.6	15.1
1450	6	8.9	18.3	12.6	16.3	18.3
2100	6	9.4	20.8	13.9	18.4	20.8
2760	6	7	10	15	18	20

Initial beam distribution and diffusion rates have been adjusted with energy to keep target of 1μm average impact parameter on TCPs at first turn (equilibrium beam distribution→ LHC Project Report 592)



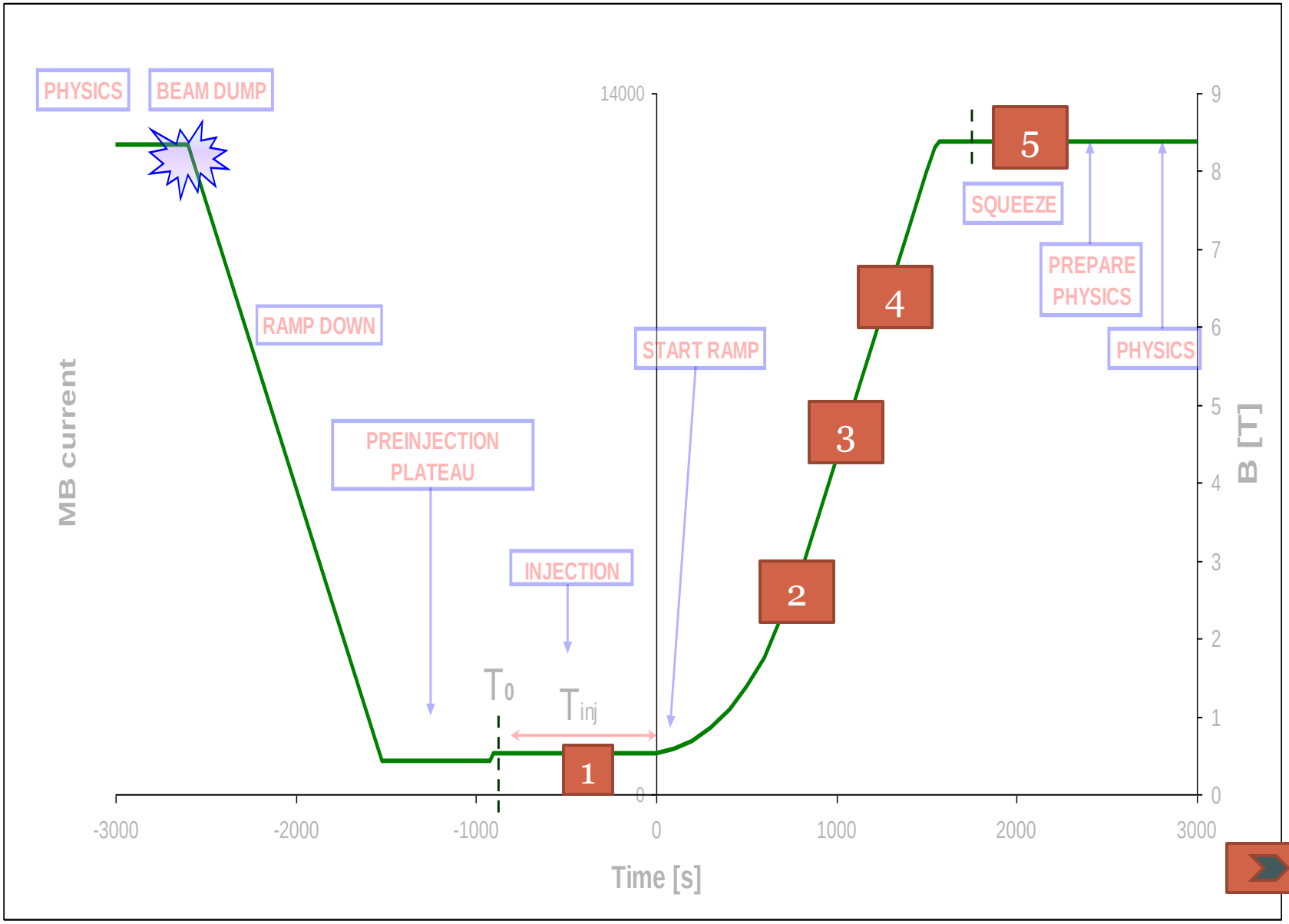


More pessimistic point for simulations:

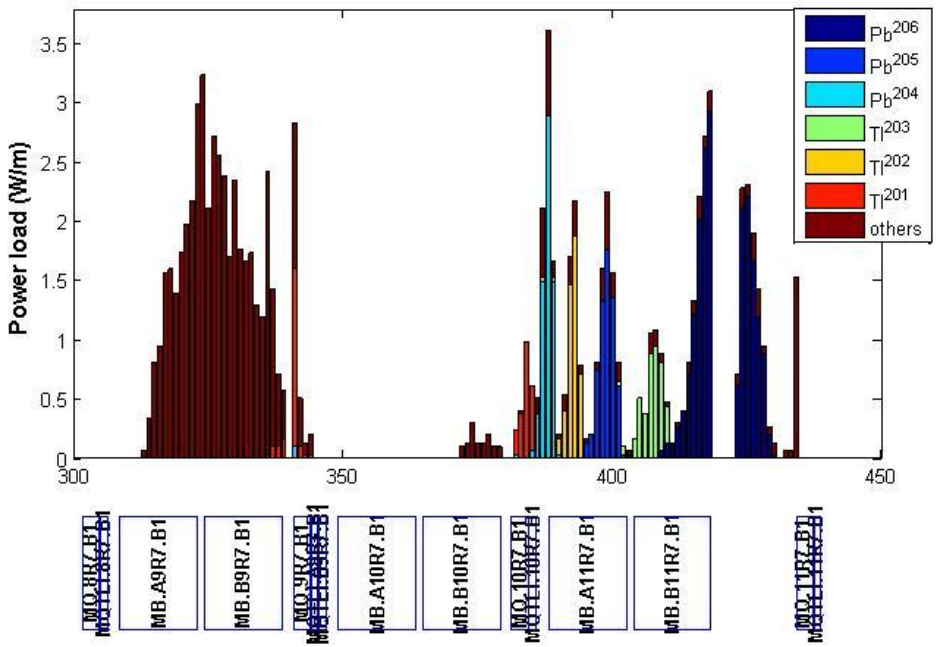
<b>=1μm

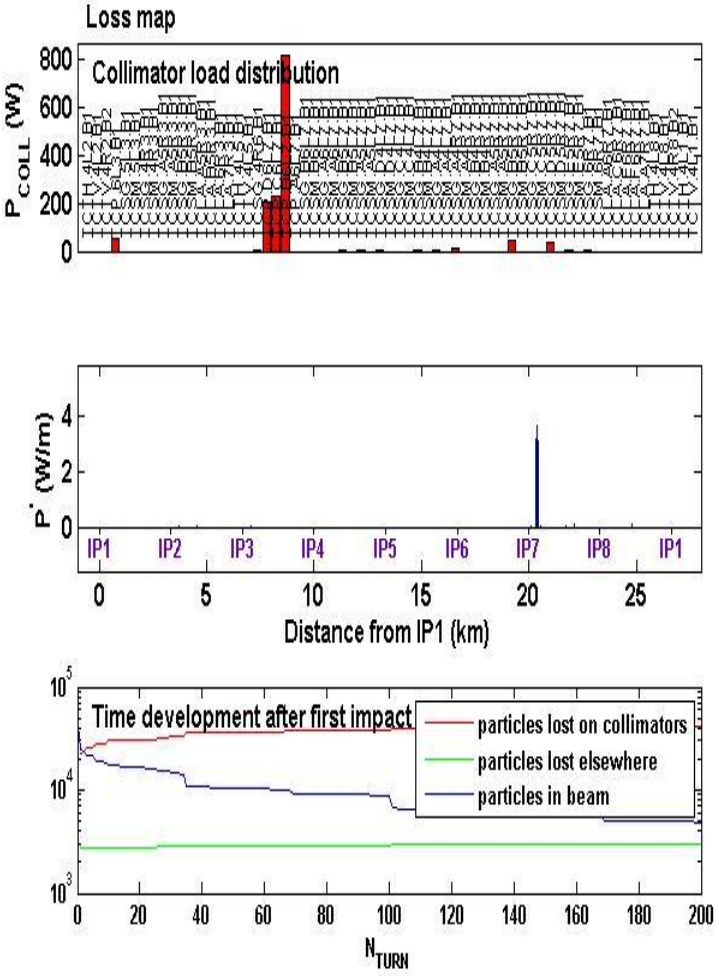
<l>= 2.5-3cm path length ≈ λint in carbon

LHC cycle

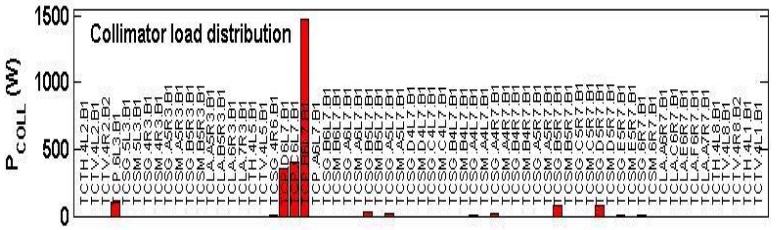

PHYSICS
BEAM DUMP
RAMP DOWN
PREINJECTION
PLATEAU
INJECTION
START RAMP
SQUEEZE
PREPARE
PHYSICS
PHYSICS
1
2
3
4
5
T0
Tinj
MB current
B [T]
Time [s]
14000
0
-3000
-2000
-1000
0
1000
2000
3000
0
1
2
3
4
5
6
7
8
9

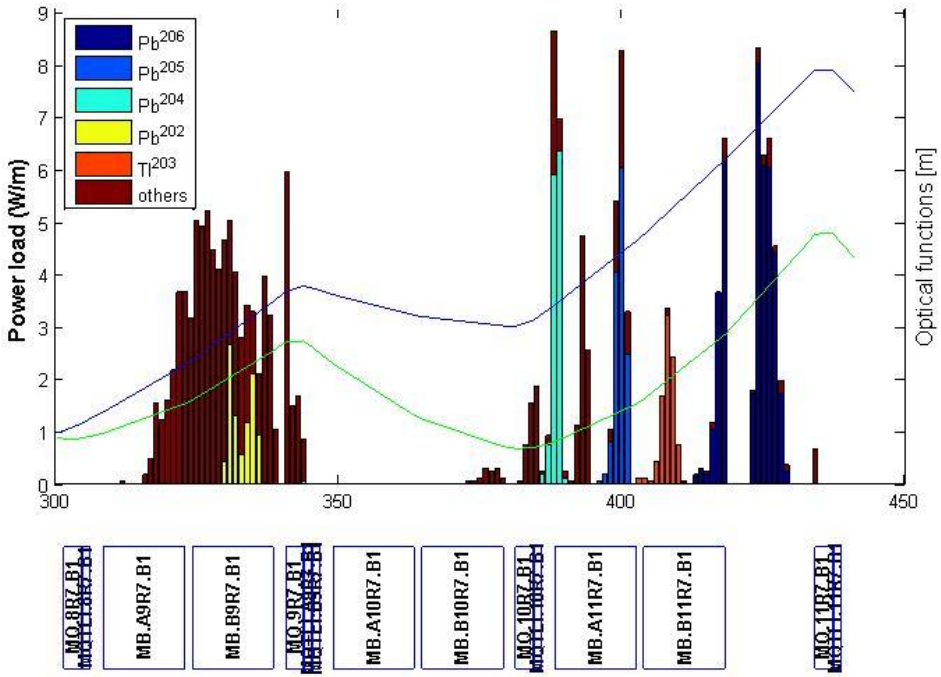
800 GeV

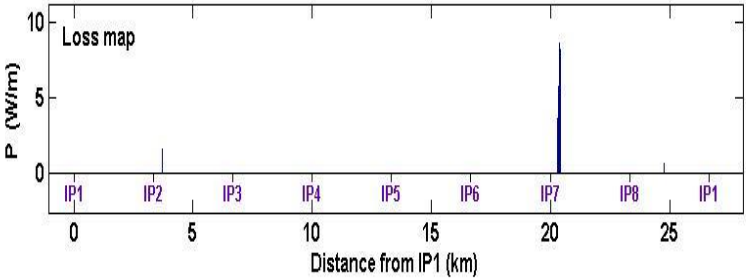

Power load (W/m)
Pb206
Pb205
Pb204
Tl203
Tl202
Tl201
others
MB.A9R7.B1
MB.B9R7.B1
MB.A10R7.B1
MB.B10R7.B1
MB.A11R7.B1
MB.B11R7.B1

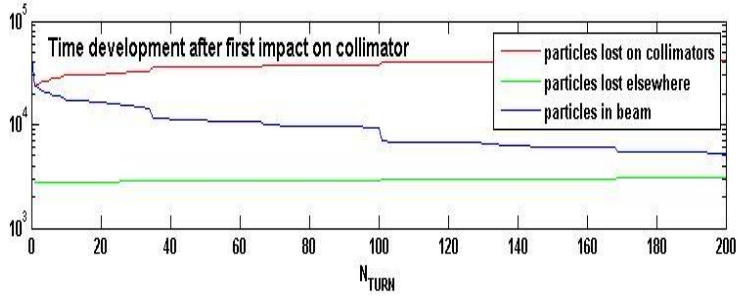

Loss map
Collimator load distribution
P_COLL (W)
P` (W/m)
IP1
IP2
IP3
IP4
IP5
IP6
IP7
IP8
Distance from IP1 (km)
Time development after first impact
particles lost on collimators
particles lost elsewhere
particles in beam
N_TURN

1450 GeV

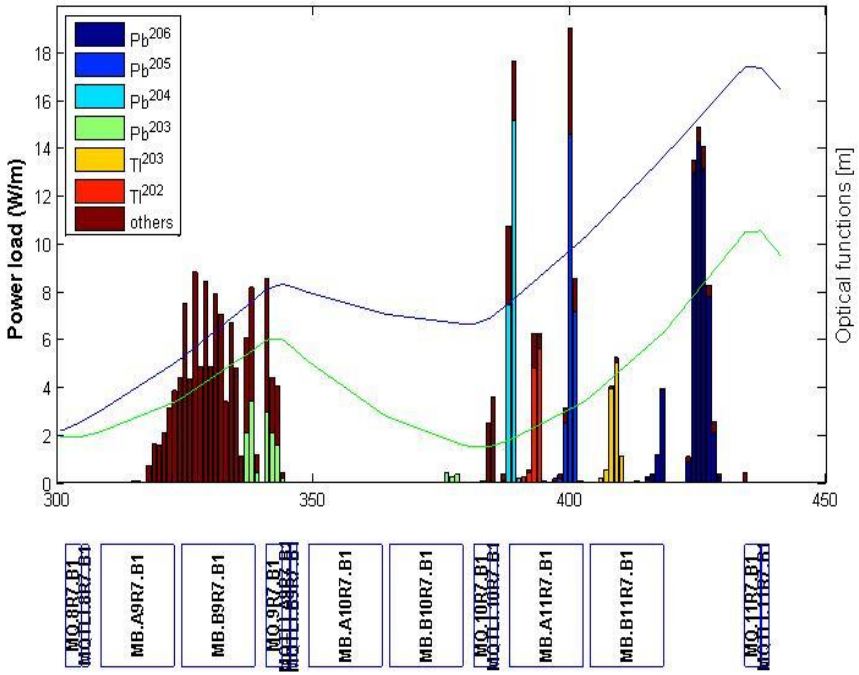

Collimator load distribution
P_{COLL} (W)
1500
1000
500
0

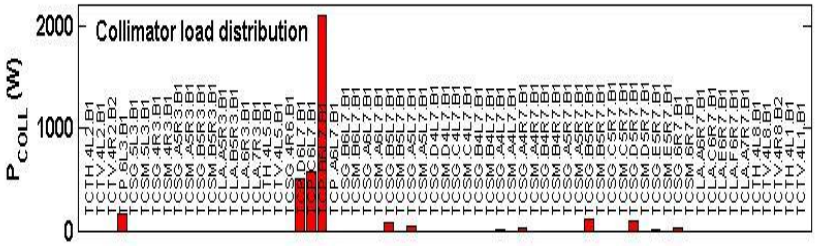

Pb206
Pb205
Pb204
Pb202
Tl203
others
Power load (W/m)
Optical functions [m]
MB.A9R7.B1
MB.B9R7.B1
MB.A10R7.B1
MB.B10R7.B1
MB.A11R7.B1
MB.B11R7.B1

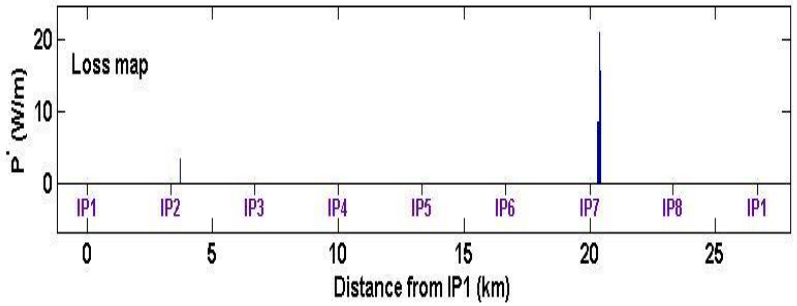

Loss map
P (W/m)
IP1
IP2
IP3
IP4
IP5
IP6
IP7
IP8
IP1
Distance from IP1 (km)

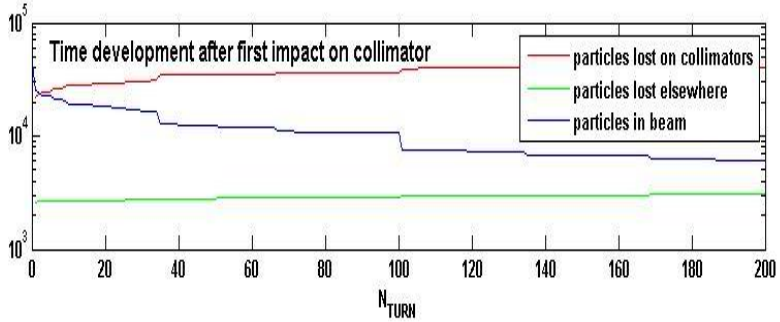

Time development after first impact on collimator
particles lost on collimators
particles lost elsewhere
particles in beam
N_{TURN}

2100 GeV


Pb206
Pb205
Pb204
Pb203
Tl203
Tl202
others
Power load (W/m)
Optical functions [m]
MB.A9R7.B1
MB.B9R7.B1
MB.A10R7.B1
MB.B10R7.B1
MB.A11R7.B1
MB.B11R7.B1


Collimator load distribution
P_COLL (W)


Loss map
P' (W/m)
IP1
IP2
IP3
IP4
IP5
IP6
IP7
IP8
IP1
Distance from IP1 (km)

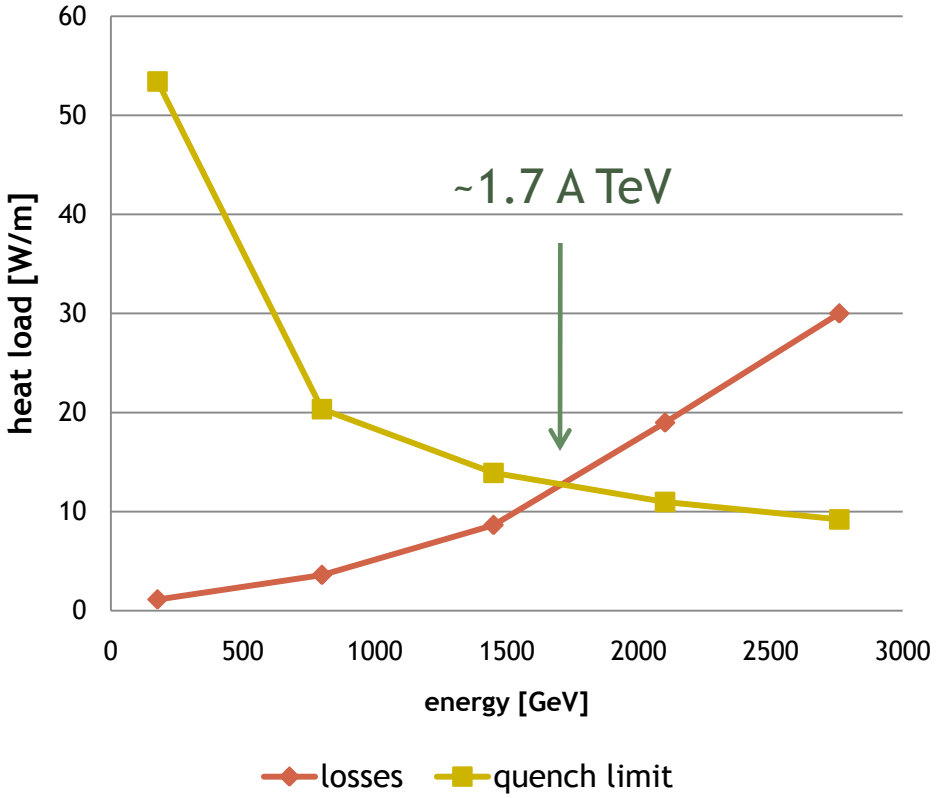

Time development after first impact on collimator
particles lost on collimators
particles lost elsewhere
particles in beam
N_TURN

Quench limit along the ramp

Protons energy dependence:

$$QL = 2\times10^{8}\left[\frac{E}{TeV}\right]^{-1.64} \quad \text{p/m/s [B Dehning]}$$

Energy [GeV/u]	Quench limit [W/m]	Max loss peak [W/m]
177	53.4	1.12
800	20.35	3.6
1450	13.90	8.6
2100	10.97	18.98
2760	9.21	30



Conclusions

One operational scenario for collimation during energy ramping was studied, based on a rigid scaling of collimator gap settings.

- ❑ At all energy points losses are restricted to the IR7 dispersion suppressor.
- ❑ Loss pattern changes qualitatively, with loss peaks becoming ever more localised and discrete with growing energy (beam is more rigid, smaller scattering angle..)
- ❑ Heat load grows with energy and exceeds quench limit around E~1.7 A GeV (for nominal machine).
- ❑ An optimisation of collimation performance with alternative settings still to be investigated…