



Developments for Phase 2 Ion Collimation in LHC

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Thanks to Giulia Bellodi, Nina Holden.



Topics for today

- Performance of cryogenic collimators with lead beams
 - Optics and geometry presented at LCU meeting of 4 Nov 2008
- Magnetised collimator, first results
- Interim conclusions for Phase 2 collimation of heavy ion beams



Optics and geometry for cryogenic collimators

- Preliminary study showed that the installation of cryogenic collimators in IR7 could significantly improve the loss maps from collimation inefficiency for Pb beams
 - G. Bellodi at earlier meeting
- Moving dipoles and hence a change of geometry of the LHC rings.
 - Preliminary studies were done either with an unchanged V6.500 thin-lens optics (protons) or a mis-matched thick-lens V6.500 optics (Pb ions) with beta-beating.
- Geometry perturbations now correctly accommodated and the optics of IR7 has been properly rematched.
 - Optics based on LHC Version 6.503, both sequences LHCB1 and LHCB2 treated.
 - Presented on 4 Nov 2008



Performance of cryo-collimators with Pb beams

TCPs at 6σ

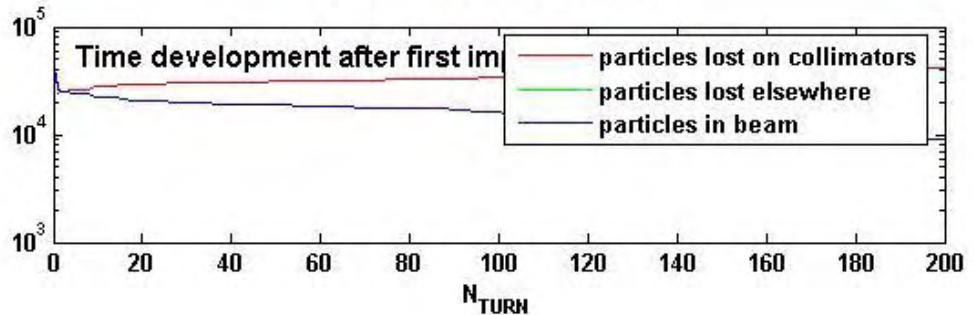
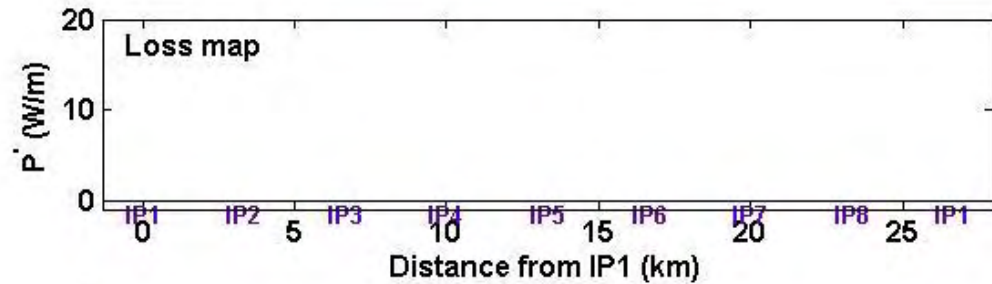
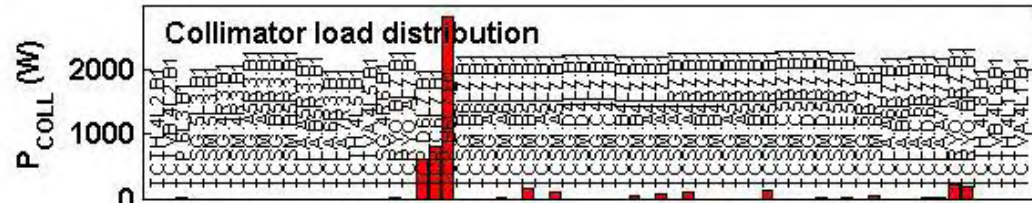
TCSGs at 26.5σ

TCSMs at 7σ

TCRYOs at 15σ

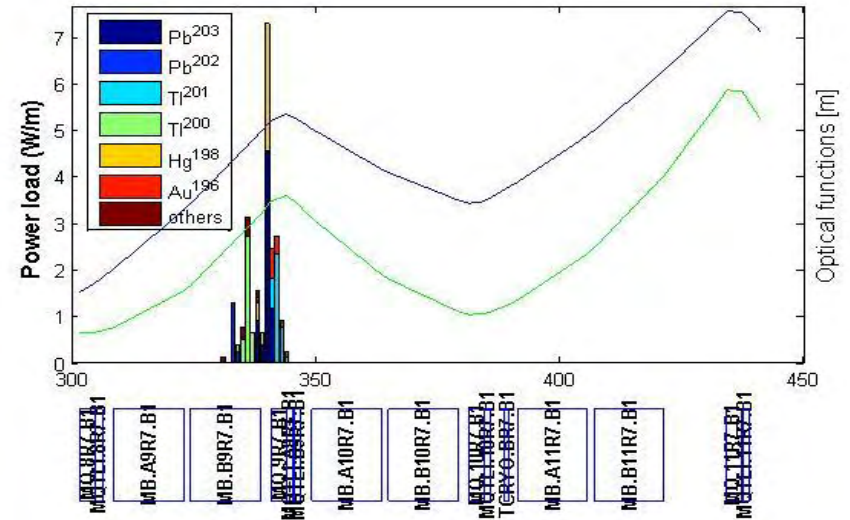
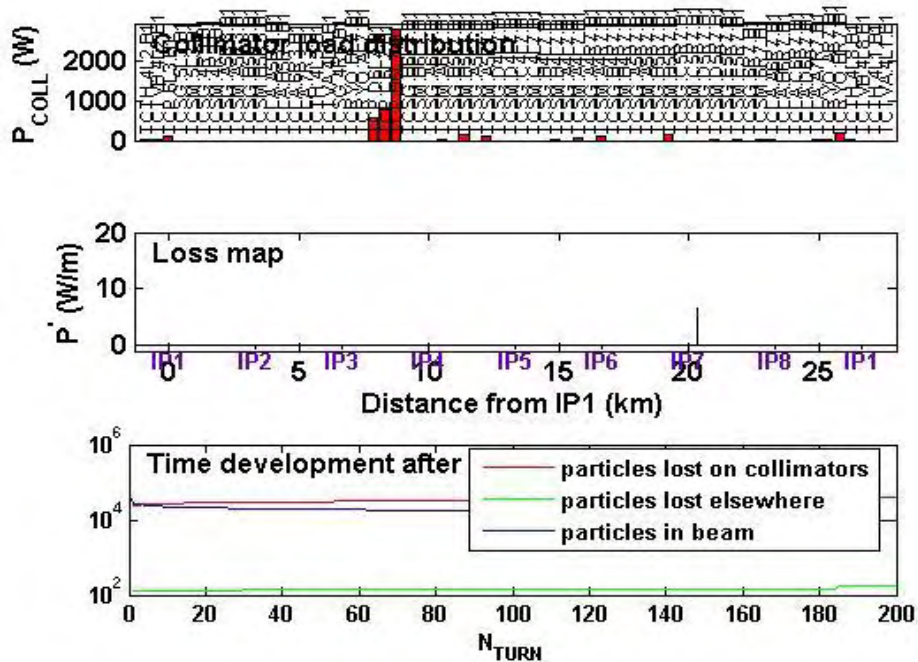
Opened the TCTs from 8.3 to 10s, to avoid significant load on the TCTH in IR5.

Losses in IR7 are gone.





TCRYOS partially retracted



With TCRYOs retracted to 45σ , the usual losses start to come back.
Shows that result is robust.



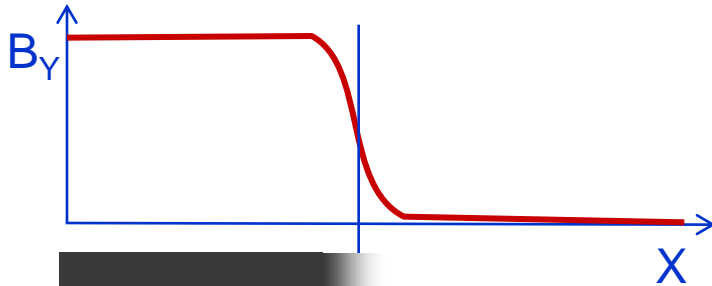
Magnetised collimators

- Magnetised collimators were discussed for the LHC in 1993 (P.J. Bryant et al, CERN SL/93-15).
 - The risk of unacceptable vibration from cooling their magnetic excitation coils, questions related to their alignment and the difficulty of ensuring that their highly non-linear fields did not have detrimental effects on the main beam seem to have been among the reasons why the idea was not adopted at that time (B. Jeanneret, private communication).
- Suggested again more recently by H. Braun as a possible solution for heavy ion beams.
 - So far no manpower available to study possible hardware implementation.



Magnetic collimator concept

Introduce a magnetic field which extends over the diffuse boundary region of the collimator ensures that particles getting close to surface will be deflected to a secondary collimator.

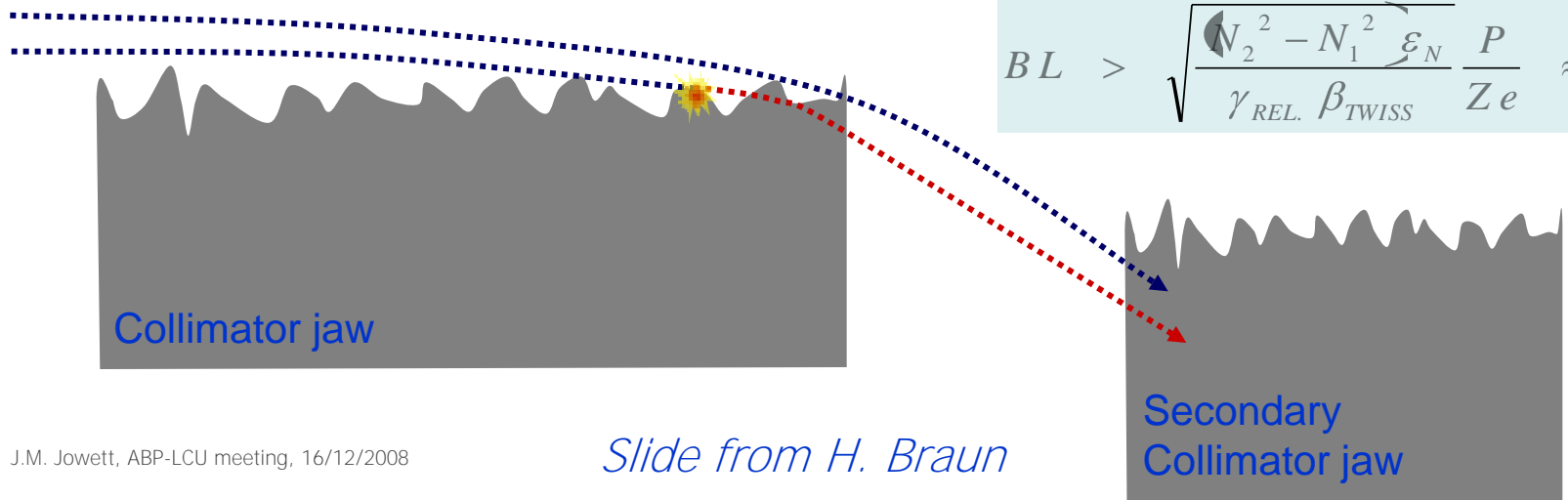


Condition to bend particle sufficiently to hit secondary collimator

$$\delta x' > \sqrt{\frac{N_2^2 - N_1^2}{\gamma_{REL.} \beta_{TWISS}} \epsilon_N}$$

⇓

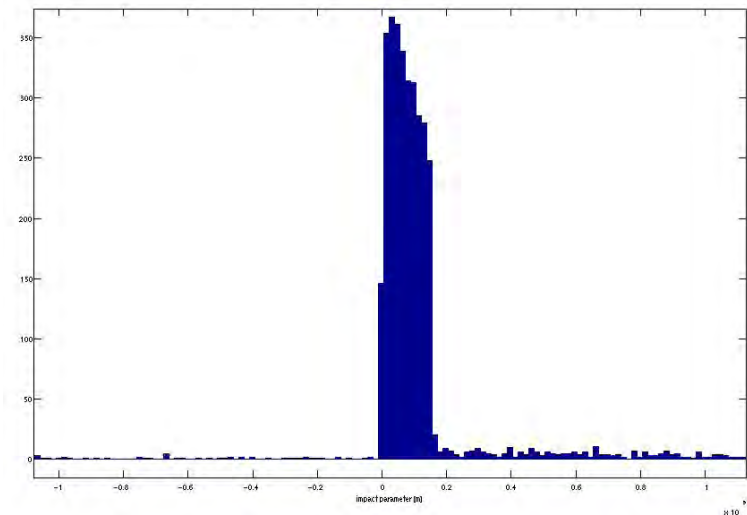
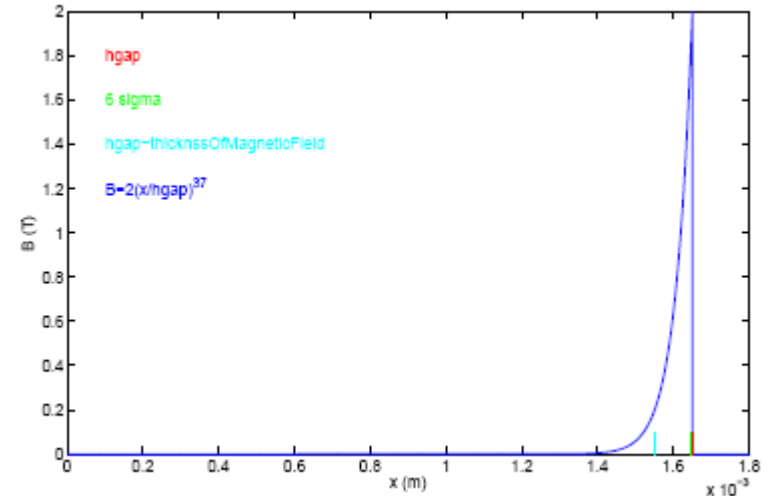
$$B L > \sqrt{\frac{N_2^2 - N_1^2}{\gamma_{REL.} \beta_{TWISS}} \frac{P}{Z e}} \approx 0.2 \text{ Tm}$$





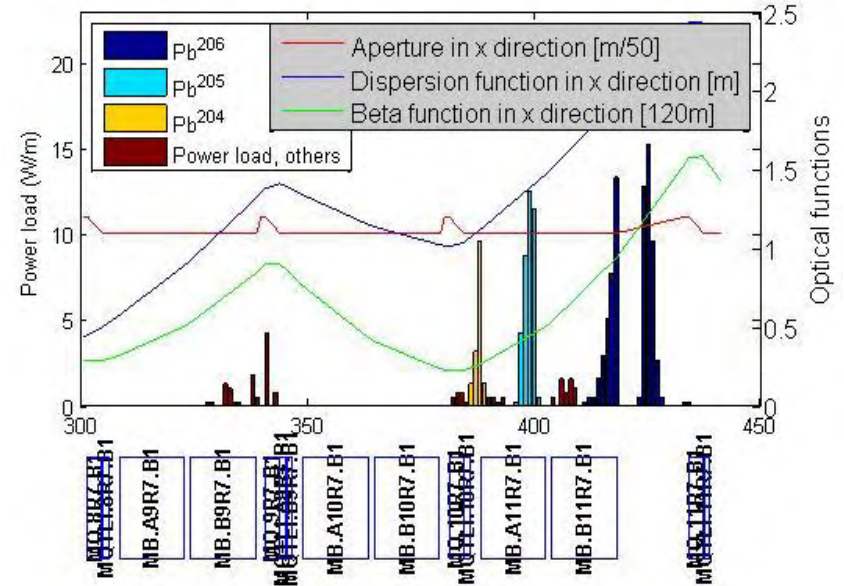
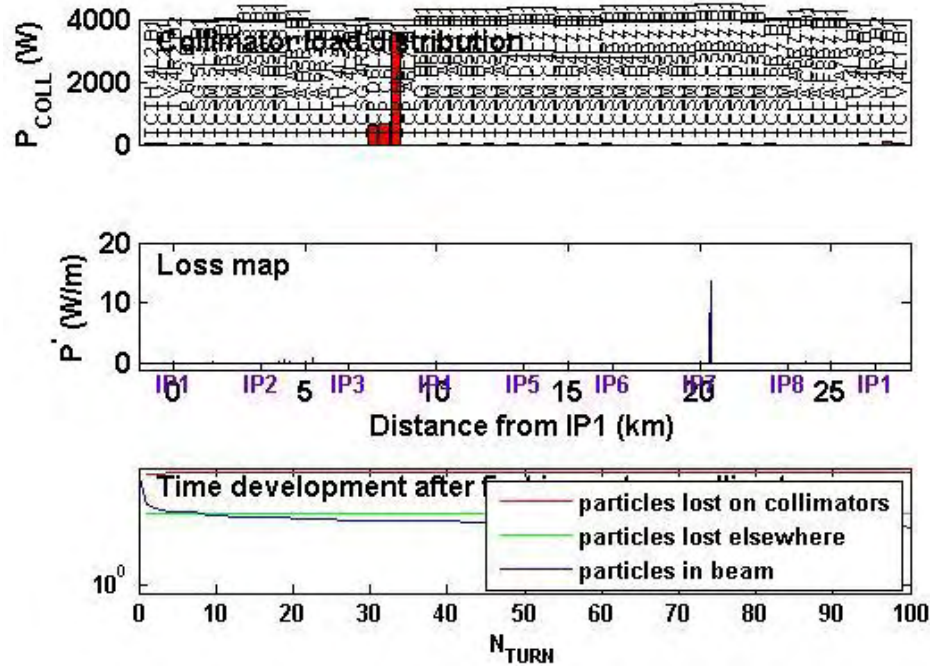
Implementation in ICOSIM (by Nina Holden)

- Simplified model of magnetic collimator with essential features.
- Normal material collimator with layer of vertical magnetic field outside jaw, decaying rapidly to zero on mm scale.
- Peak field on surface up to 2 T.
- Somewhat delicate to setup inside ICOSIM. Generally we replace a primary collimator (usually the middle horizontal one) with a magnetic collimator. The material part is moved out by a distance Δ_{gap} so that the 6σ set-point for the primary jaws corresponds to a point in the magnetic field.
- Because of the way ICOSIM works, Δ_{gap} has to have values comparable to the width of the initial impact parameter distribution prepared in ICOSIM ($\sim 1 \mu\text{m}$).





Reference case – Phase 1 normal collimators



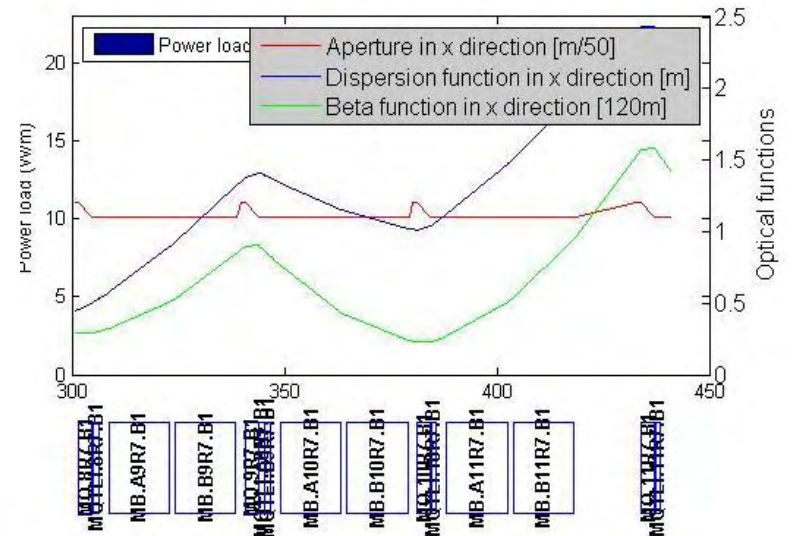
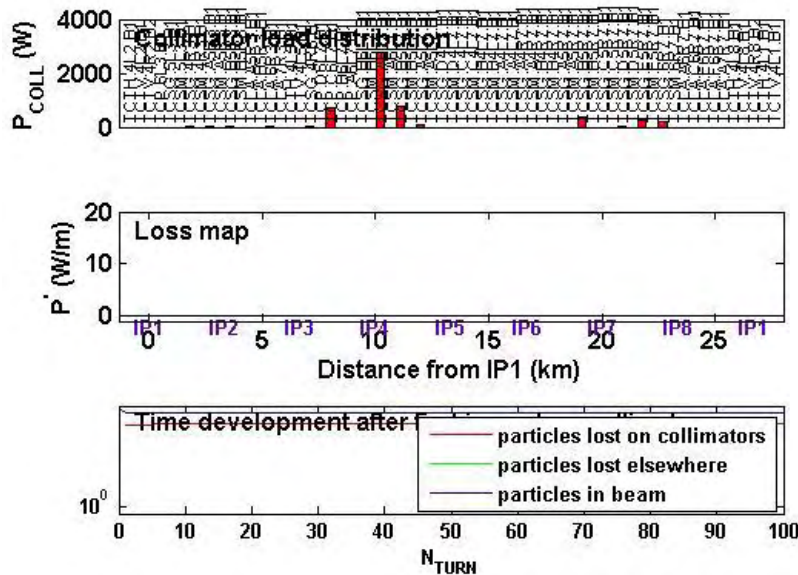
CASE 0	TCP.D6L7.B1	TCP.C6L7.B1	TCP.B6L7.B1
hgap	6 sigma	6 sigma	6 sigma
Bmax (T)	0	0	0

Usual high losses in cold magnets R7.

Initial distribution of particles “about to hit collimators” from this run is saved and used for (some) other runs in order to make meaningful comparisons.



Magnetic collimator alone (test case)

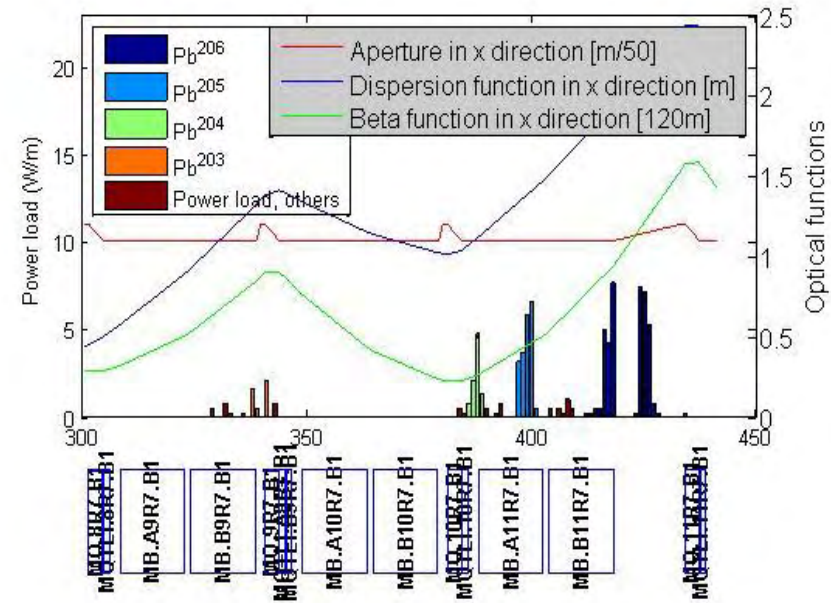
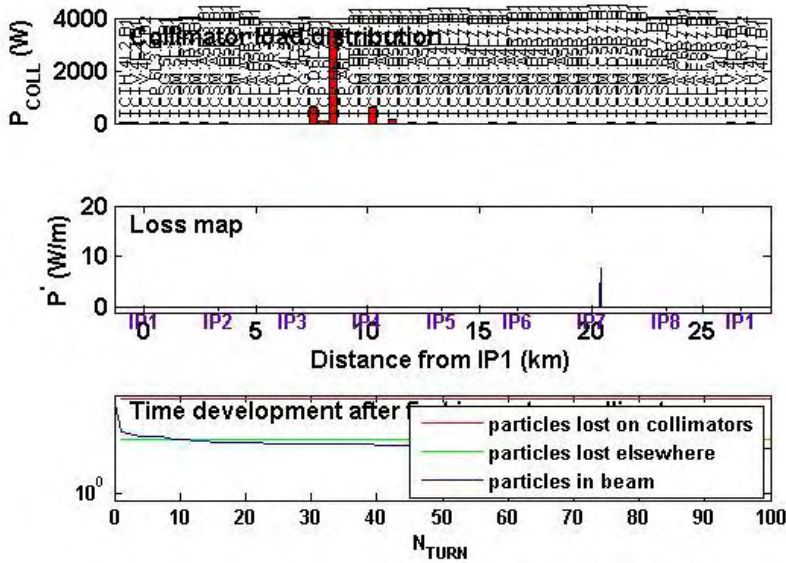


CASE 1	TCP.D6L7.B1	TCP.C6L7.B1	TCP.B6L7.B1
hgap	500 sigma	6 sigma+0.0015mm	500 sigma
Bmax (T)	0	2	0

With the same initial distribution as the reference case, few ions are actually lost in the tracking and ICOSIM amplifies the losses that there are.



Horizontal magnetic collimator + other 2 TCPs



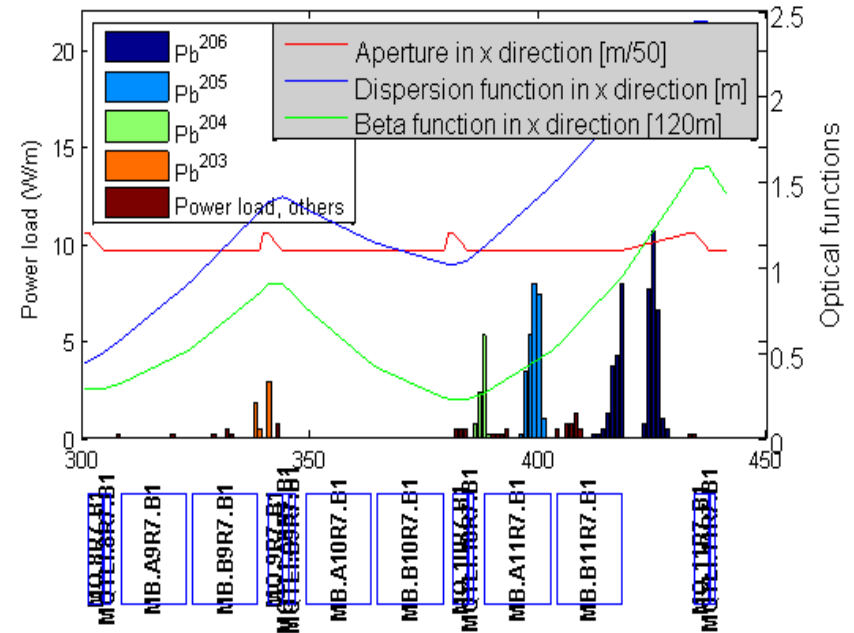
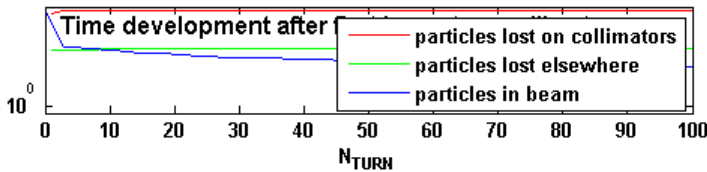
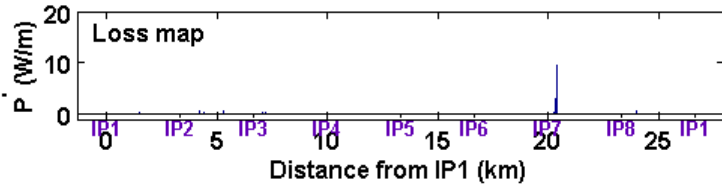
CASE 2	TCP.D6L7.B1	TCP.C6L7.B1	TCP.B6L7.B1
hgap	6 sigma	6 sigma+0.0015mm	6 sigma
Bmax (T)	0	2	0

A more realistic illustration of the effect of the magnetic collimator. Load on 2nd TCP is reduced by magnetic deflection. Losses appear on a secondary collimator, overall beam losses are similar to reference case.

Reduction of loss map in dispersion suppressor by factor ~ 2 .



Skew magnetic collimator + other 2 TCPs



CASE 12	TCP.D6L7.B1	TCP.C6L7.B1	TCP.B6L7.B1
hgap	6 sigma	6 sigma	6 sigma+0.005mm
Bmax (T)	0	0	0.5

Broadly similar to the horizontal magnetic collimator with proper losses in tracking. Some load in IR3. Similar reduction of losses in dispersion suppressor.



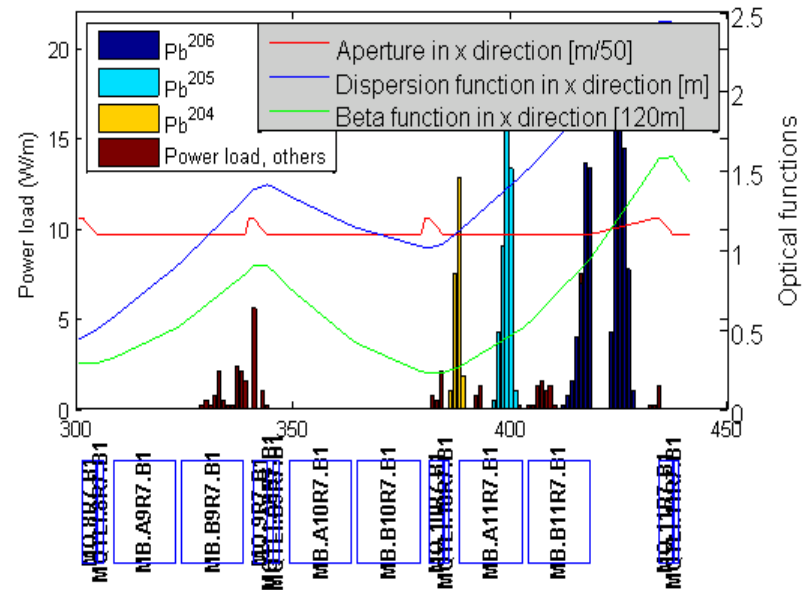
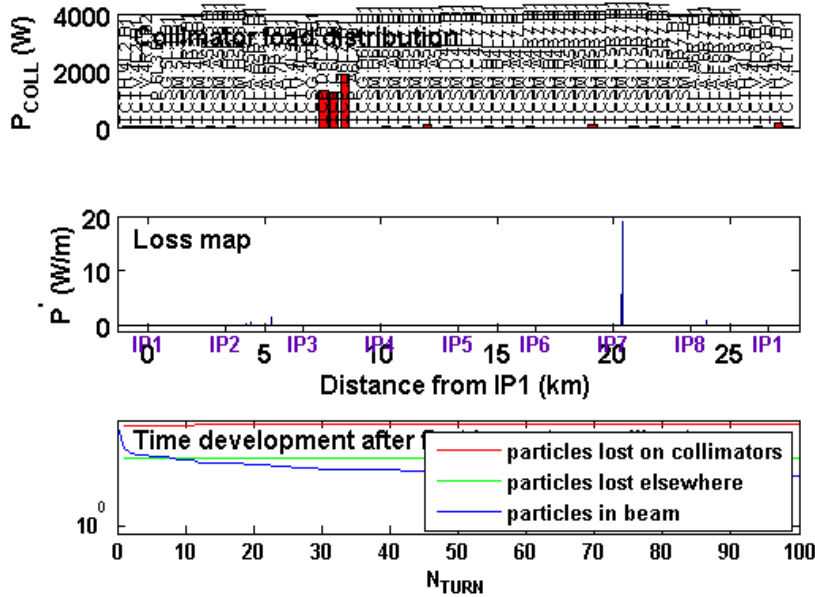
Magnetised collimators: summary

■ Still to do:

- Further optimization by simulation studies
- Magnet design studies with 3D magnet code to find **configuration with best properties and right “magnet field skin depth”**
- Minimize or linearise residual field at beam core
 - Repeat simulations with more realistic model
- Engineering design of prototype
- Build prototype
- Check performance with prototype test in SPS (?)
- Implement as new primary collimators in LHC IR7 (at least for heavy ion runs)



Load-shift on normal collimators



CASE 11	TCP.D6L7.B1	TCP.C6L7.B1	TCP.B6L7.B1
hgap	6 sigma	6 sigma	6 sigma+0.25mm
Bmax (T)	0	0	0

In the reference case, the skew TCP has largest load and is presumably mostly responsible for lost fragments in dispersion suppressor.

Here we tried withdrawing it slightly to shift load to other collimators (new initial distribution). This does not improve loss map.



Interim Conclusions

- Cryogenic collimators in the dispersion suppressors shows the most promise as a relatively straightforward, direct and robust solution
 - Some aspects still to be checked
- Almost certainly also effective for the BFPP problem
 - Even more important for heavy ion operation
 - Probably need to install one cryo-collimator on either side of IP2, IP5 and IP1 (3 heavy-ion experiments)
 - Plan to study in detail with Roderik Bruce (in Lund)
- Need to verify situation for lighter ions
 - Not simulated so far but we have the “tools”
- Magnetised collimators could be an alternative.