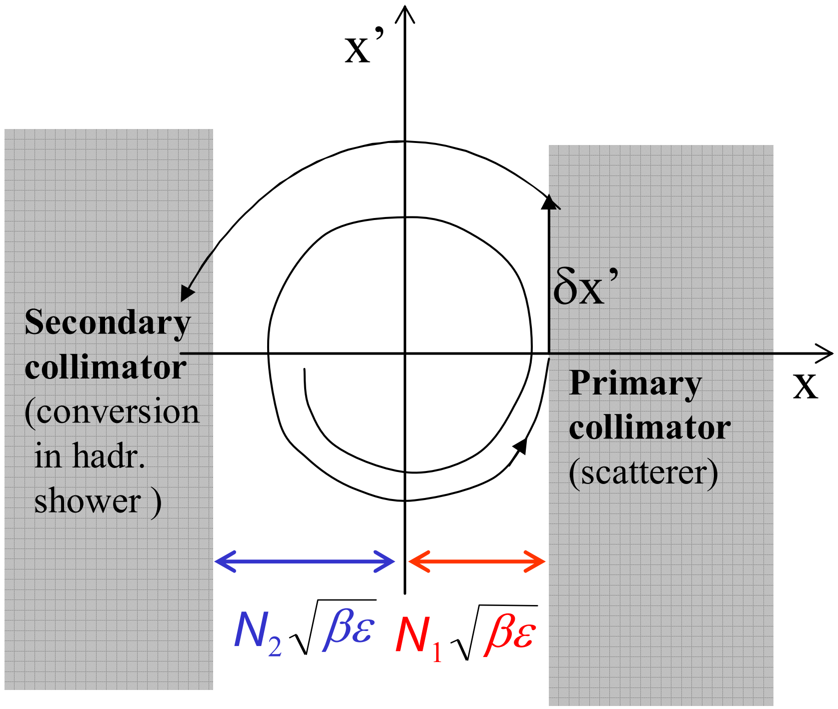
An approach to solve the ion collimation problem

- ***Why does proton two stage collimation not work for heavy ions***
- ***Condition for two stage betatron collimation***
- ***Criterium for optimum material for primary collimators***
- ***Optimum positions for primary collimators***
- ***Conclusions***

Criteria for two stage betatron collimation



Necessary condition :

$$\delta x' > \sqrt{\frac{\left(N_2^{\ 2} - N_1^{\ 2}\right)\varepsilon_N}{\gamma_{REL.}\ \beta_{TWISS}}}$$

scattering at primary collimator *δx'* is mainly due to multiple Coulomb scattering with

$\langle \delta x'^2 \rangle \sim L$

if required $L > L_{INT}$ particle undergoes nuclear reaction.

Thus $\delta x'$ in

$$\delta x' >> \sqrt{\frac{\left(N_2^{\;2} - N_1^{\;2}\right)\varepsilon_N}{\gamma_{REL.}\,\beta_{TWISS}}}$$

can be interpreted as the r.m.s. scattering per interaction length.

To achieve the collimation condition for given ε_N, N_1, N_2 and γ only two variables are available:

- **β_{TWISS} at primary collimator**
- **choice of collimator material to maximise $\delta x'$**

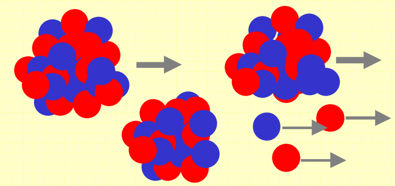
Optimising the material primary collimator material

The important ion/matter interactions for ions in this context are

- **hadronic fragmentation** $\sigma_{HAD} \sim (A_{PROJ}^{1/3} + A_{COLL}^{1/3})^2$
- **electromagnetic dissociation** $\sigma_{EMD} \sim Z_{COLL}^2$
- **Multiple scattering** $\langle \delta x'^2 \rangle^{1/2} \sim Z_{COLL}$
- **Ionisation energy loss** $dE/dx \sim Z_{COLL}$

remark:
angle deflection for hadronic fragmentation and electromagnetic dissociation are negligibly small for LHC conditions

hadronic fragmentation



electromagnetic dissociation

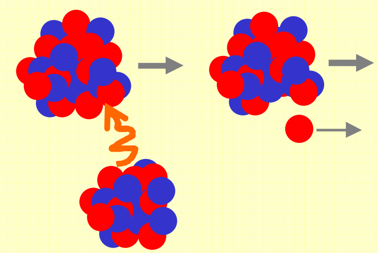
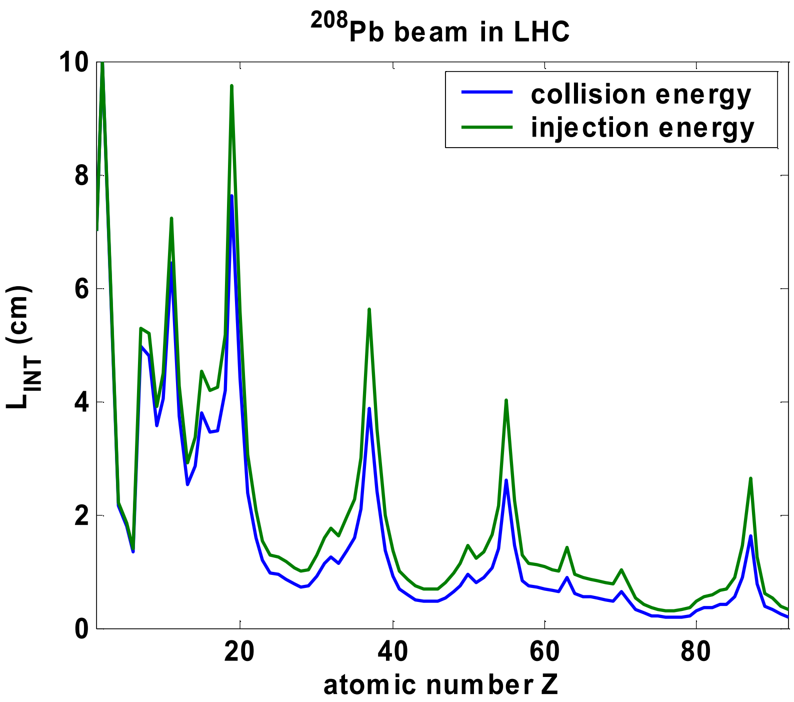
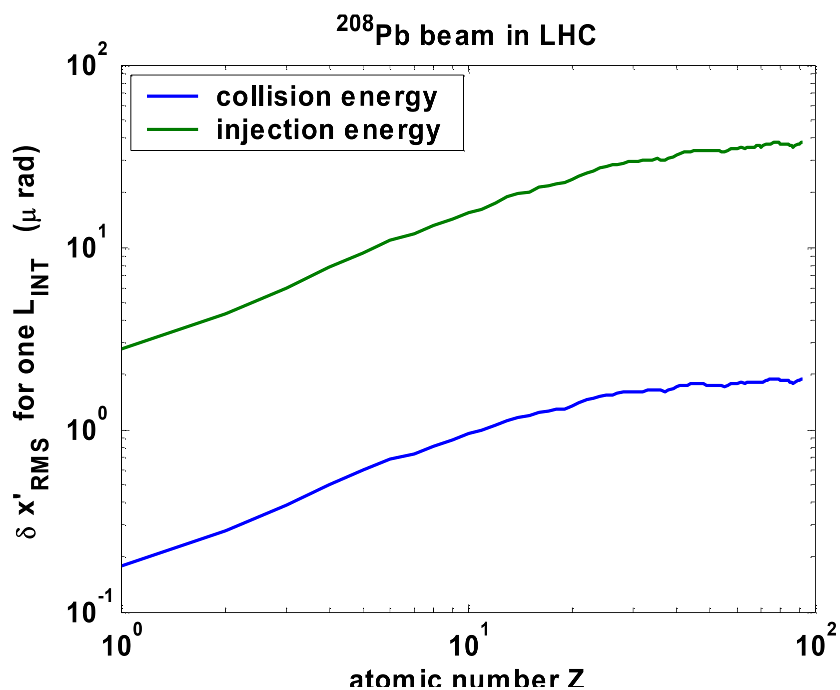


figure of merit for collimator material

$$\sqrt{\left\langle \delta x'^2 \right\rangle}\Big|_{L=L_{INT}}$$

$$\text{with} \quad L_{INT} = \frac{A_{COLL}}{N_A \; \rho \left(\sigma_{HAD} + \sigma_{EMD}\right)}$$



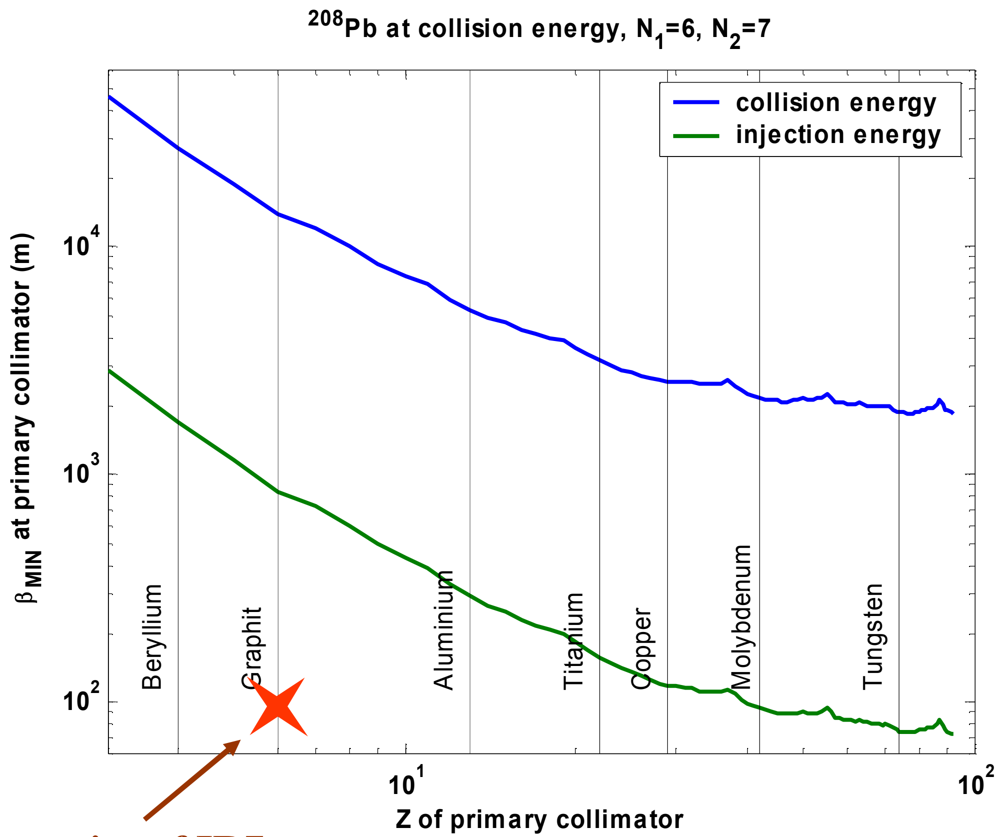


Hans-H. Braun, LHC collimation WG, 23.4.2004

Condition

$$\delta x' \gg \sqrt{\frac{\left(N_2{}^2 - N_1{}^2\right)\varepsilon_N}{\gamma_{REL.}\,\beta_{TWISS}}}$$

can be used to define boundaries in $Z - \beta_{TWISS}$ plane

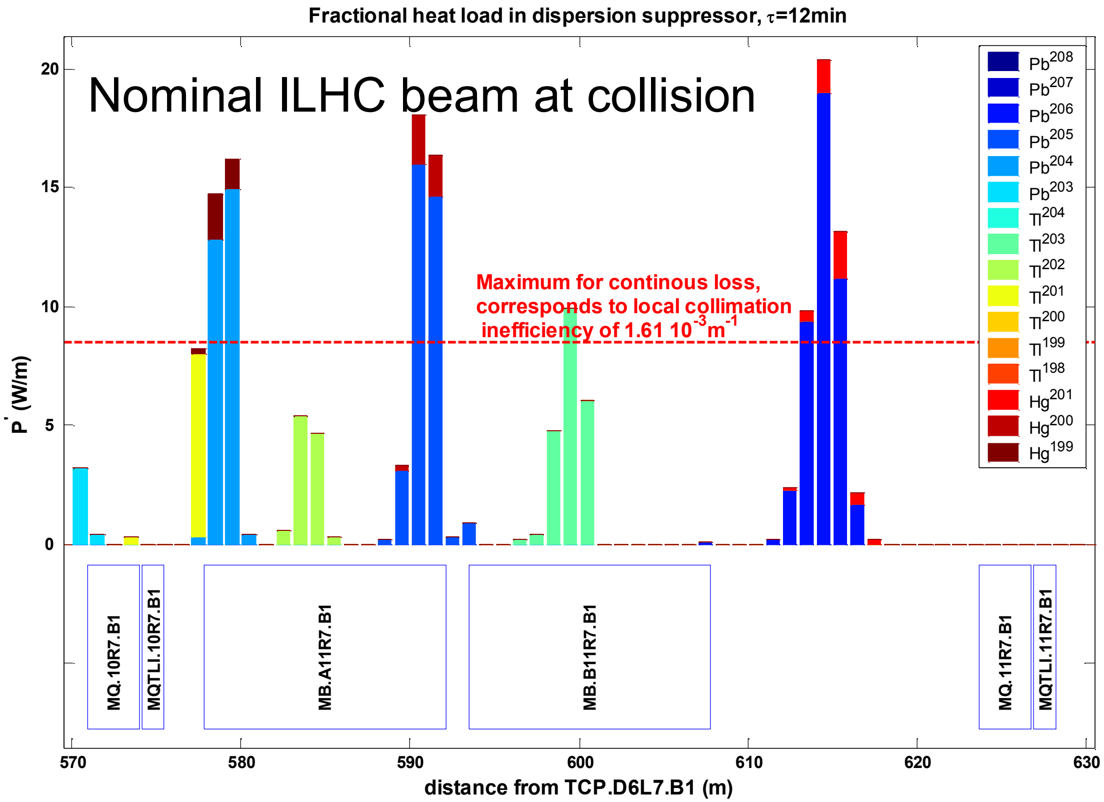


working point of IR7 primary collimators

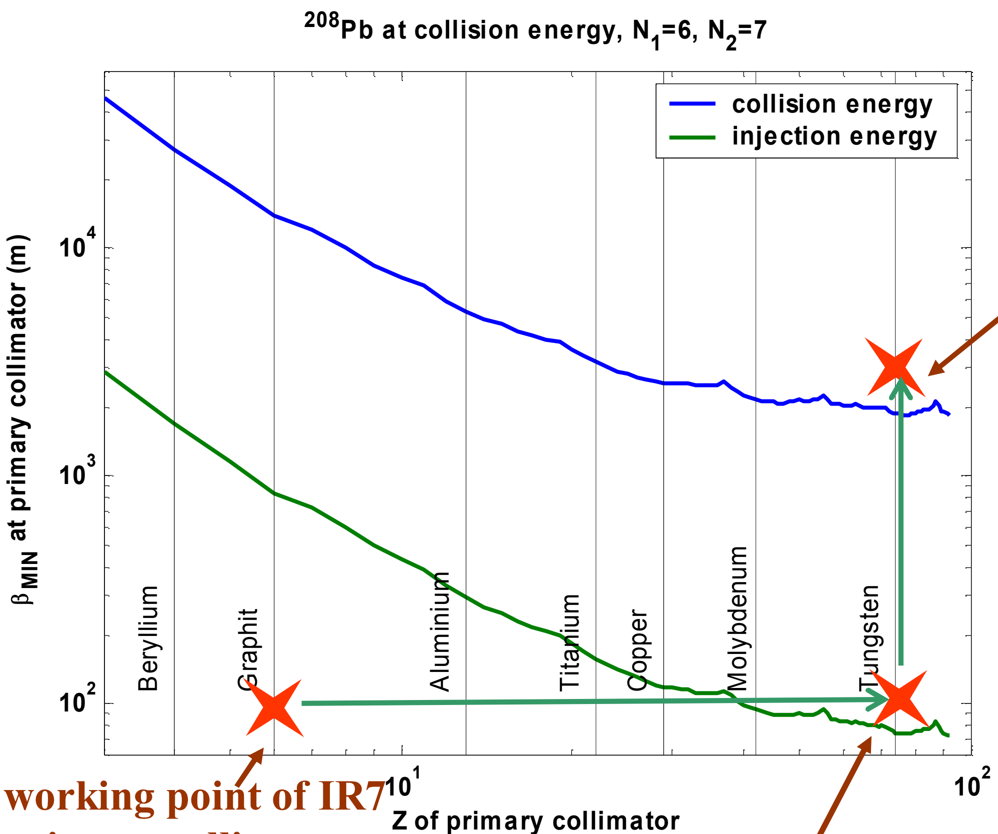
Hans-H. Braun, LHC collimation WG, 23.4.2004

Consequence of this working point:

Ions loose nucleons in primary collimator due to interactions, but do not get sufficient angle kick to hit secondary collimator. The fragments get mainly lost in superconducting magnets downstream of IR7 due to their modified Z/A ratio



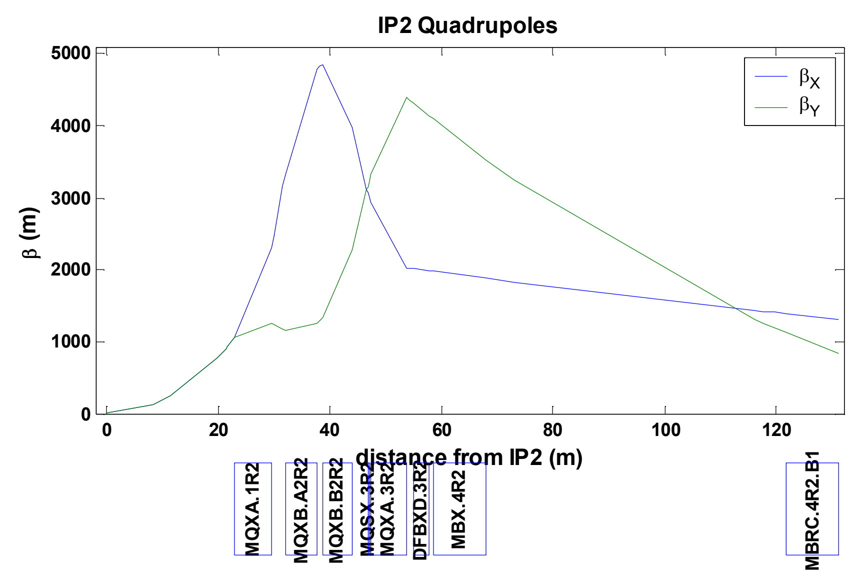
- Even highest Z material is insufficient to fulfil two stage collimation conditon for maximum β_{TWISS} available in IR7 region (~100 m).
- The only possibility two fulfil two stage condtion are thin, high Z collimators next to IP triplets where β_{TWISS} is maximum.



place high Z primary collimators close to IP triplet

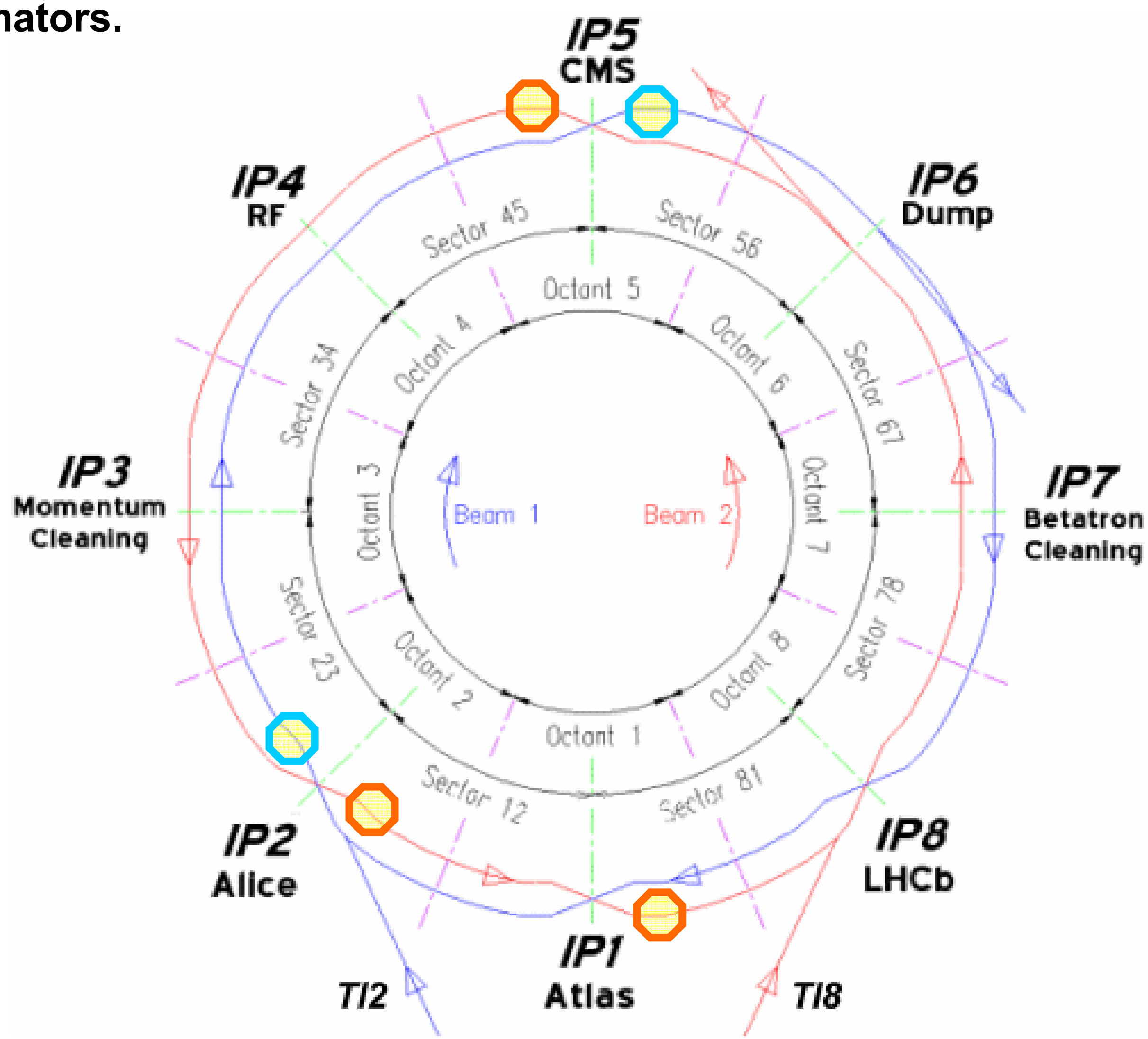
working point of IR7 primary collimators for protons

change of material of primary collimators



Hans-H. Braun, LHC collimation WG, 23.4.2004

Potential locations for Ion beam high Z primary collimators, assuming that IR3 and IR7 TCS's are retained as secondary collimators.



Hans-H. Braun, LHC collimation WG, 23.4.2004

All this is work in progress.

Much more work required to verify these concepts.

- **Is there any space available for short collimators close to the triplets**
- **Tracking simulation all around the ring for**
  - **collimation efficiency, loss maps and heat loads in SC magnets**
  - **optimimum collimator length**
- **Can high Z collimator withstand beam impact (with FLUKA)**
- **What happens before beams are squeezed**

However, if we want to keep this as an option to overcome the ion collimation problems we have to reserve space close to the triplets now !
The only other option I see for the moment is to reduce the luminosity for ions.