Possible scenarios for stage II ion collimation

G Bellodi

thanks to HBraun and JJowett for slides and information

Recap of current situation:

different physics of ion/material interactions: two stage collimation not optimal

Physics process	Proton	^{208}Pb
$\frac{dE}{Edx}$ due to ionisation	-0.12 %/m -0.0088 %/m	-9.57 %/m -0.73%/m
Mult. Scattering (projected r.m.s. angle)	73.5μrad/m^{½} 4.72μrad/m^{½}	73.5μrad/m^{½} 4.72μrad/m^{½}
Nucl. Interaction length ≈fragment. length for ions	38.1cm 38.1cm	2.5cm 2.5cm
Electromagnetic dissociation length	-	33cm 19cm

$$L \approx L_{\text{int}} = \frac{A_{coll}}{N_A \rho (\sigma_{had} + \sigma_{emd})}$$

$$\frac{\Delta P}{P} = \frac{Z_2}{A_1}\frac{A_2}{Z_2} - 1$$

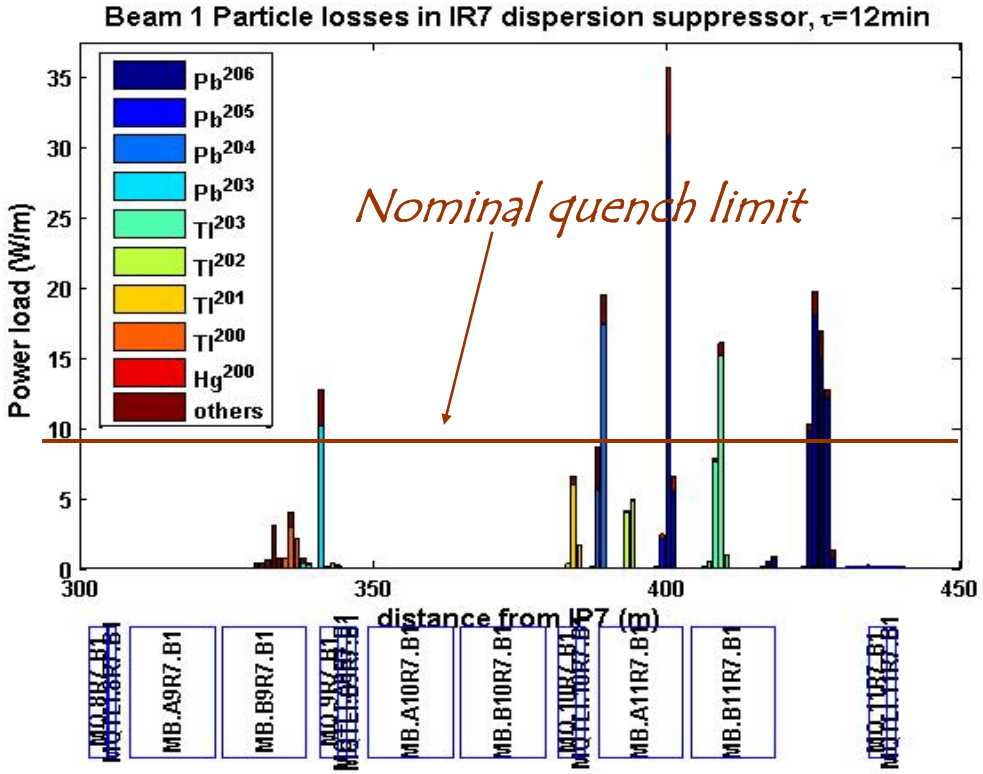
LHC energy acceptance:
- arcs: ~ ±1%
- IR3: ~ ±0.2%

^{204}Pb -1.92%	^{205}Pb - 1.44%	^{206}Pb - 0.96%	^{207}Pb - 0.48%	^{208}Pb 0.0%
^{203}Tl -1.2%	^{204}Tl - 0.71%	^{205}Tl - 0.23%	^{206}Tl 0.26%	^{207}Tl 0.75%
^{202}Hg - 0.46%	^{203}Hg 0.04%	^{204}Hg 0.53%	^{205}Hg 1.02%	^{206}Hg 1.51%

ICOSIM simulations: beam1 at collision

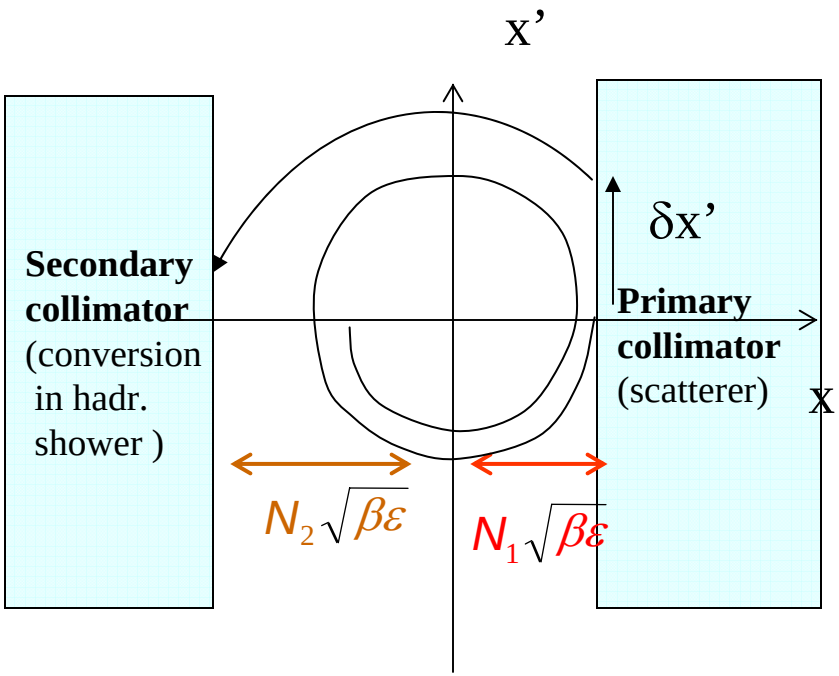
Most particles stopped in primaries..

Losses on IR7 dispersion suppressor aperture: 30% - 50% current limit



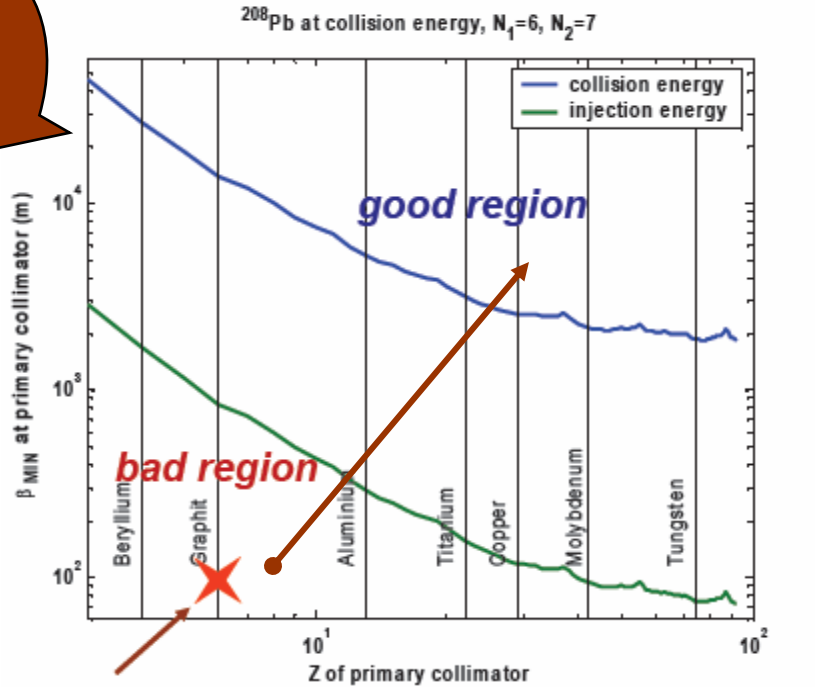
Two stage coll. : Necessary condition:

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



δx' mainly due to multiple Coulomb scattering, with

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



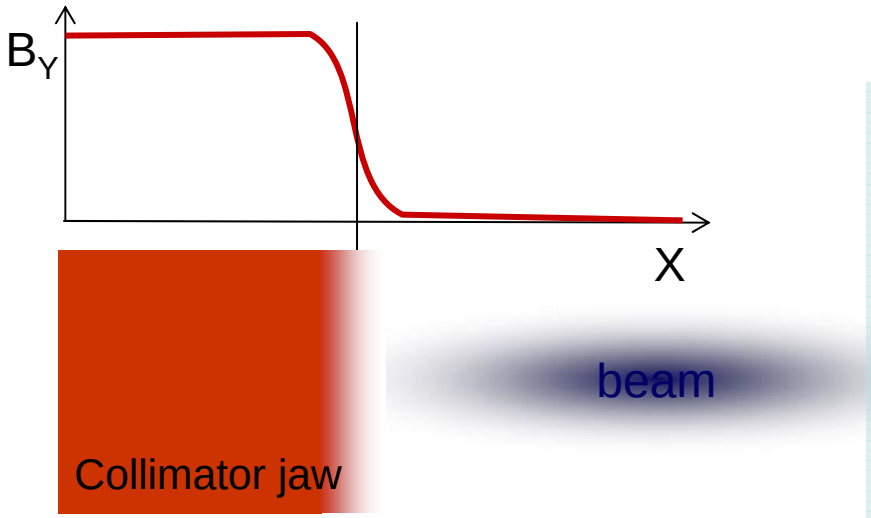
Option # 1:

Add high Z scrapers at high β locations

Other ideas to increase deflection…

#2: Magnetic fringe fields

(first proposed by P Bryant et al in 1993 for CLIC)



Condition to bend particle sufficiently to hit secondary collimator

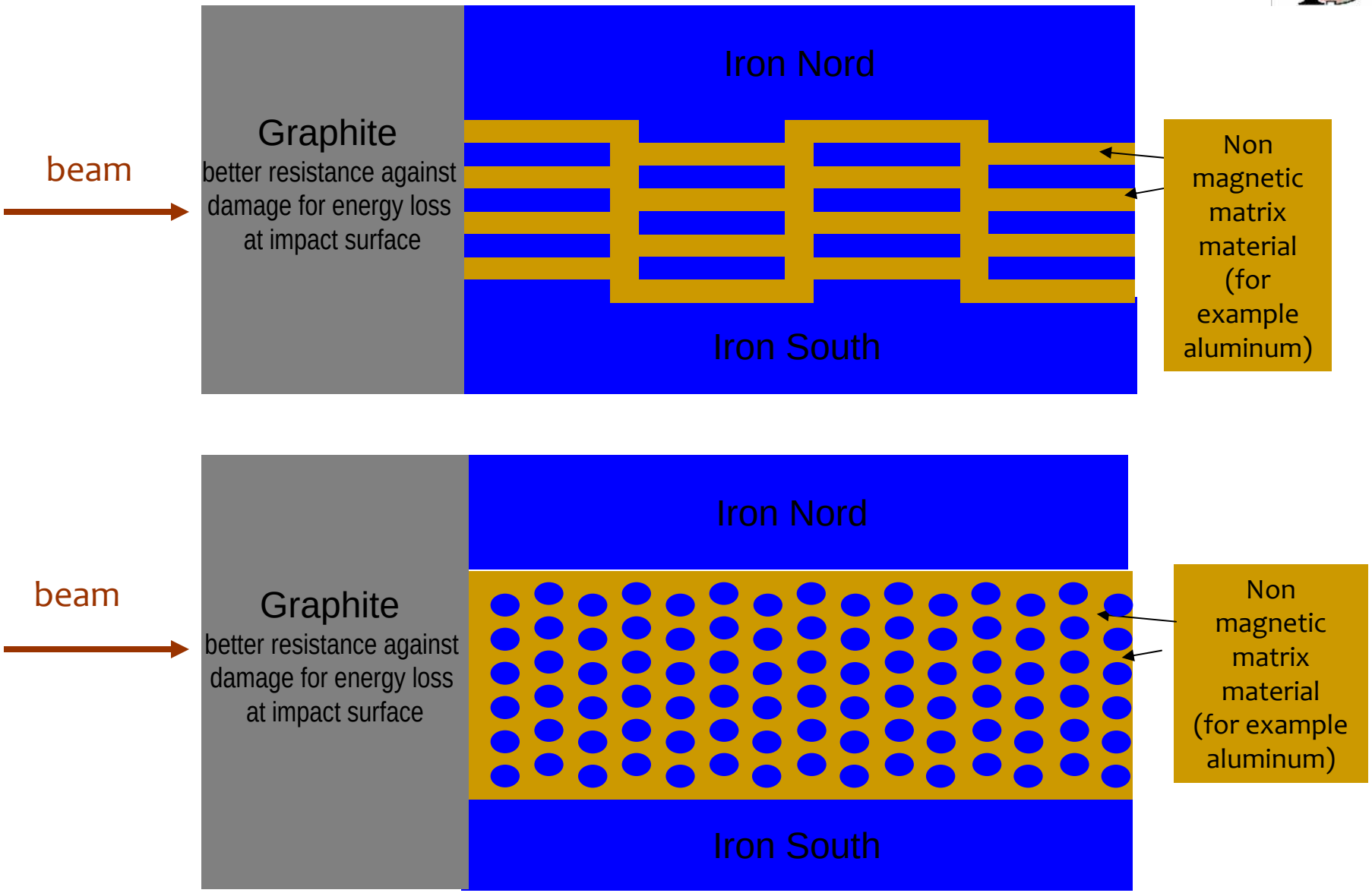
$$\delta x' > \sqrt{\frac{\left(N_2^{\,2} - N_1^{\,2}\right)\varepsilon_N}{\gamma_{REL.}\,\beta_{TWISS}}}$$

$$\Downarrow$$

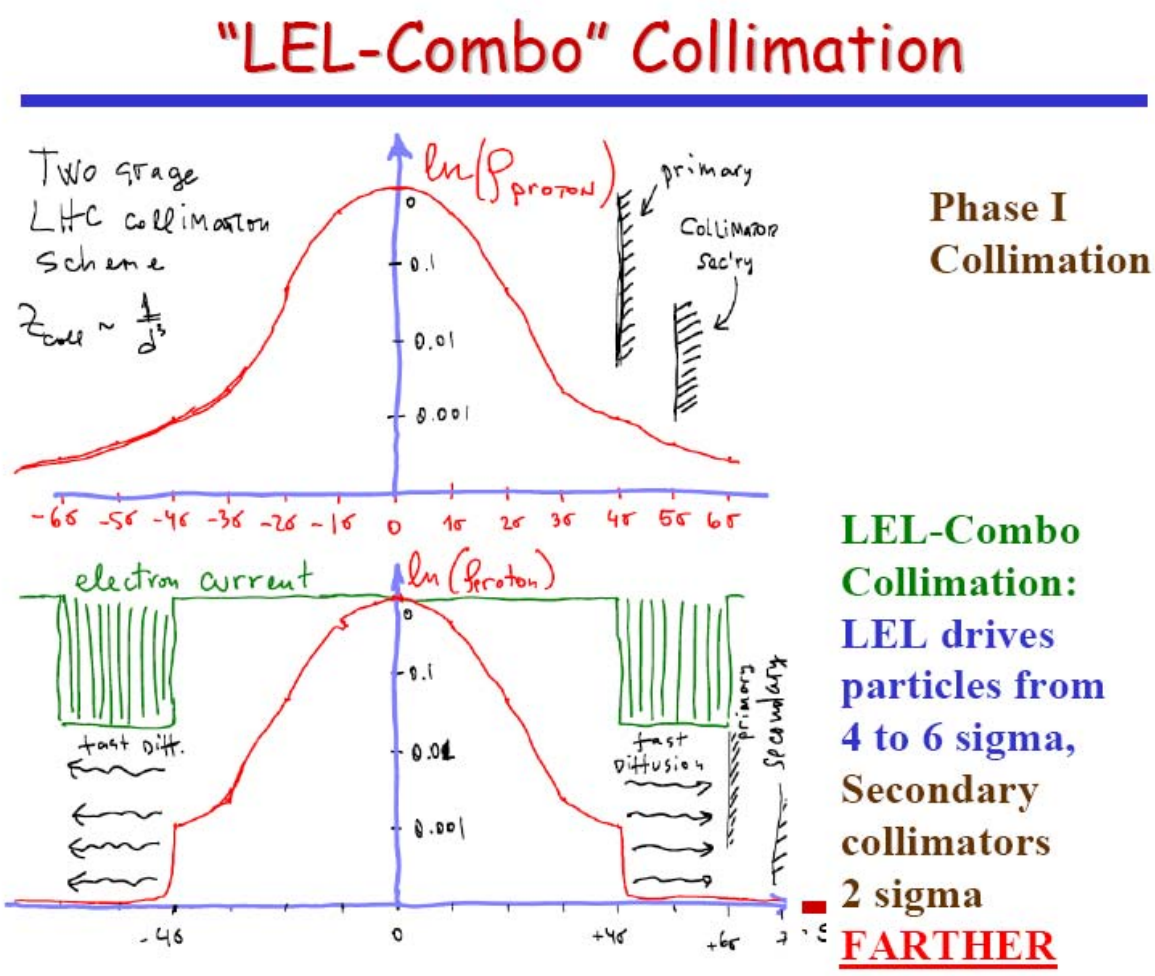
$$B\,L > \sqrt{\frac{\left(N_2^{\,2} - N_1^{\,2}\right)\varepsilon_N}{\gamma_{REL.}\,\beta_{TWISS}}}\,\frac{P}{Z\,e} \approx 0.2\ \mathrm{Tm}$$

- Required "magnetic field skin depth" in the order of 100 μm
  - Minimize or linearize residual field at beam core
  - 3D magnet code simulations needed

Sandwich structure for field modulation



#3 Electron lenses (→ V Shiltsev, BEAM'07)



- Clean method (only e.m., no nuclear interactions)
- Fast cleaning time (resonance driven)
- No material damage concerns
- No mechanical systems involved
- Technology tested at Tevatron (abort gap cleaning)

#4 Crystal collimation

Channelling

- may benefit from suppression of fragmentation and EMD of ions
- long history of experiments, not always conclusive (single pass/multipass, SPS/RHIC → see talk given at CARE-HHH workshop last year)

Volume reflection

- more efficient, smaller deflection
- does not benefit from suppression of nuclear electromagnetic interactions

Open questions about operational stability, robustness, machine protection…

Physics of ion interactions?