ALICE ZDC and TCTTVB Tertiary Collimators

- Zero-degree calorimeters in the heavy-ion experiments (ALICE, CMS, ATLAS) are crucial for physics measurements
  - Measure energy carried away by non-interacting (spectator) beam nucleons
  - D1 separator magnet separates spectator protons and neutrons to two distinct calorimeters 92 m from IP
  - Neutron calorimeter also measures neutrons from electromagnetic dissociation (1 and 2 n)
- Physics measurements affected:
  - The energy mean value and resolution
    - centrality determination
  - The phi azimuthal angle distribution
    - measurement of the reaction plane in nuclear collisions and therefore measurement of the directed flow
- Angular spread of spectator neutrons from nuclear Fermi momentum

Transverse divergence of spectator neutrons

Nuclear radius: $R_A \approx (1.25 \text{ fermi}) A^{1/3}$

Nucleon density: $n \approx \dfrac{A}{\frac{4}{3}\pi R_A^{\,3}}$

Fermi energy: $E_f = \dfrac{\hbar^2}{2m_n}\left(\dfrac{3\pi^2 n}{2}\right)^{2/3} \approx 30 \text{ MeV}$

Fermi momentum: $p_f = \sqrt{2m_n E_f} \approx 240 \text{ MeV}$

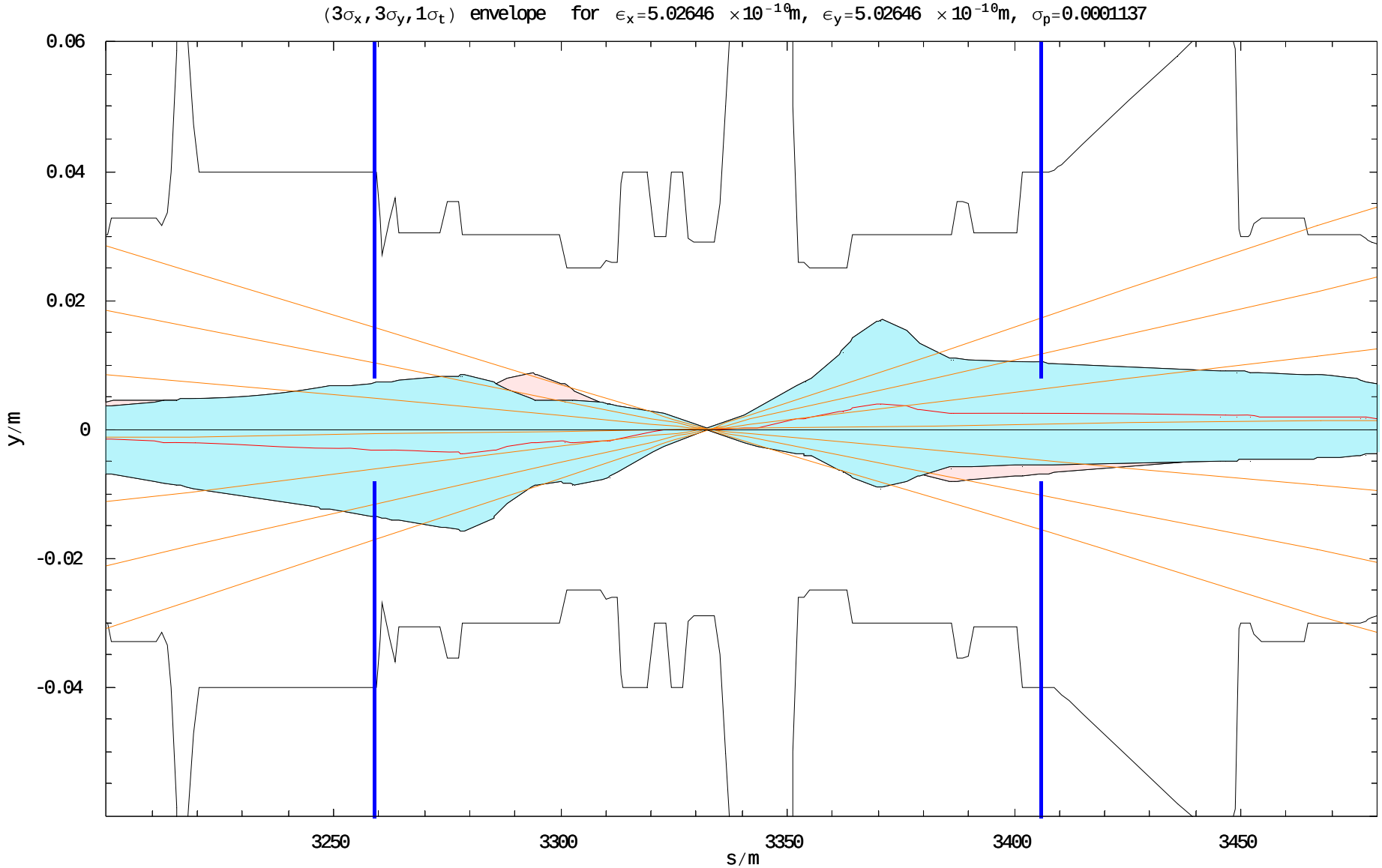
RMS neutron angle: $\sigma_\theta = \dfrac{p_f}{2\,p_{\text{beam}}/A} = 44\ \mu\text{rad}$ (ALICE ZDC Monte Carlo gives 51 μrad)

Compare collisional beam at IP: $\sigma_{p_y} = \sqrt{\dfrac{\varepsilon_n}{2\beta^* \sqrt{2\gamma^2 - 1}}} \approx 22.5\ \mu\text{rad}$

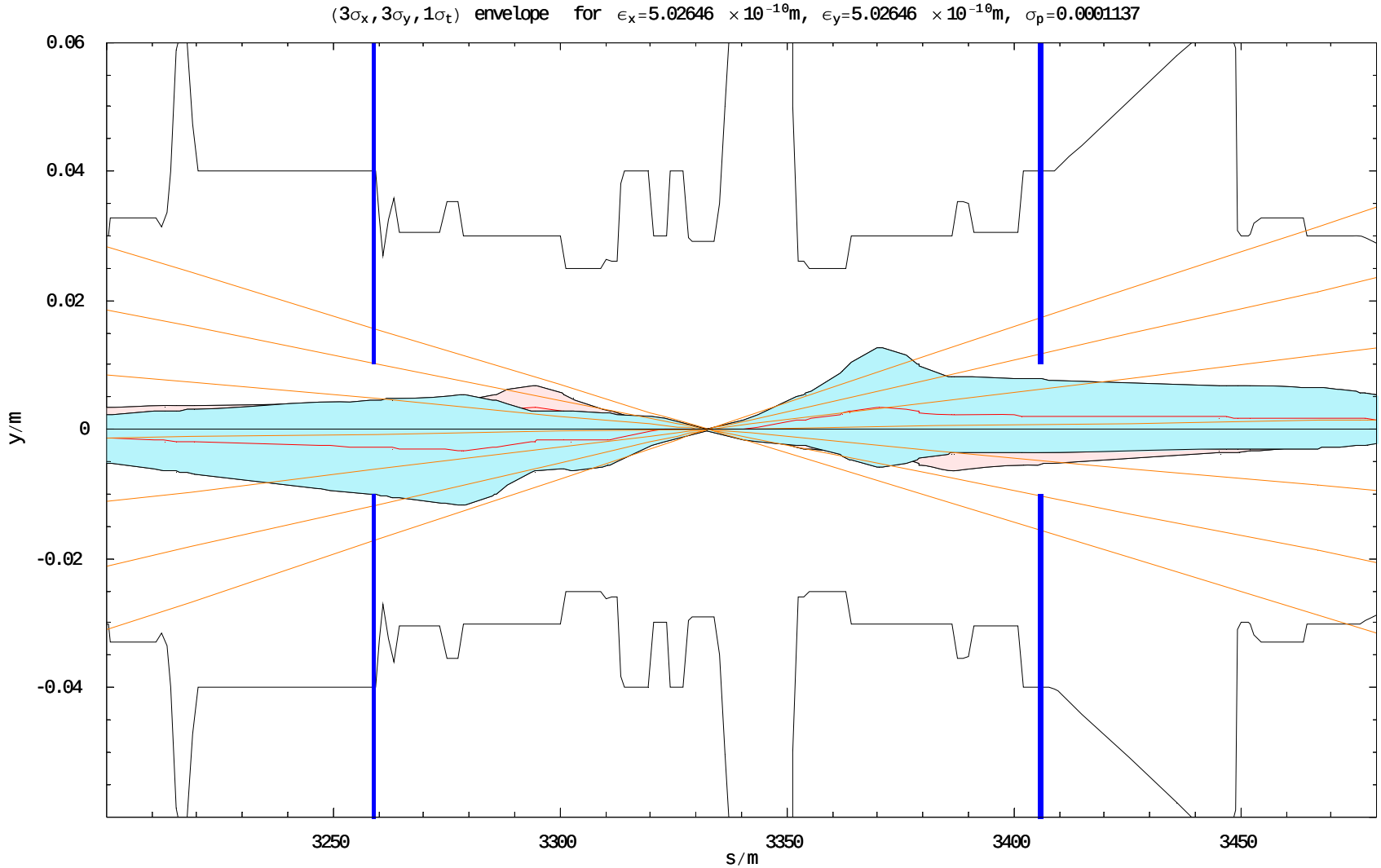
Neutrons are not focussed in straight sections (no strong sextupoles!).

In electromagnetic dissociation, mean transverse momentum is less, 27 MeV/c.

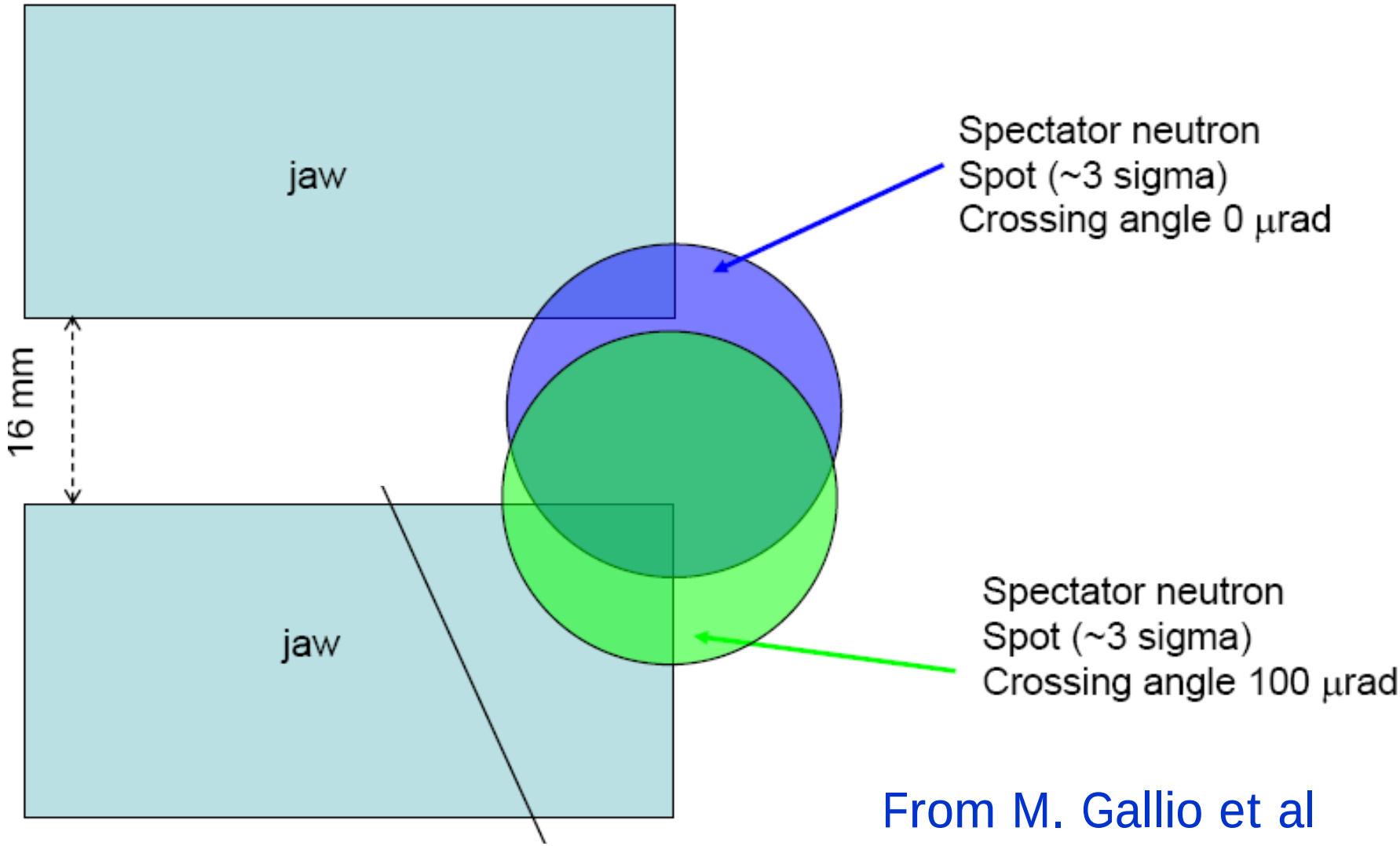
Nominal ion collision optics (with 100 μrad crossing angle)



Early Ion Collision optics (with 100 μrad crossing angle)



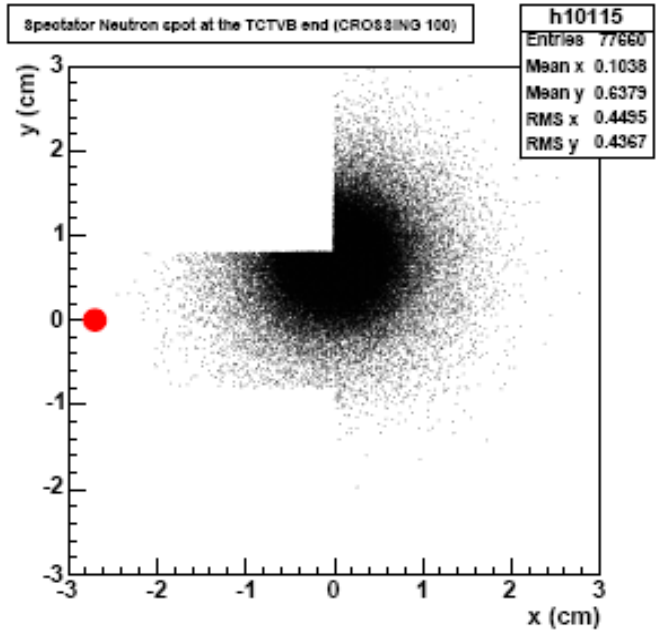
Drawing of neutron spot on a cross section of TCTVB

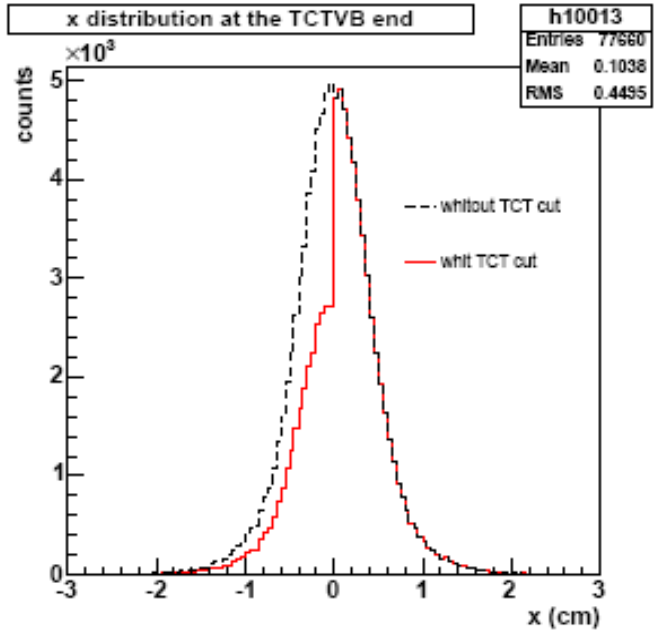


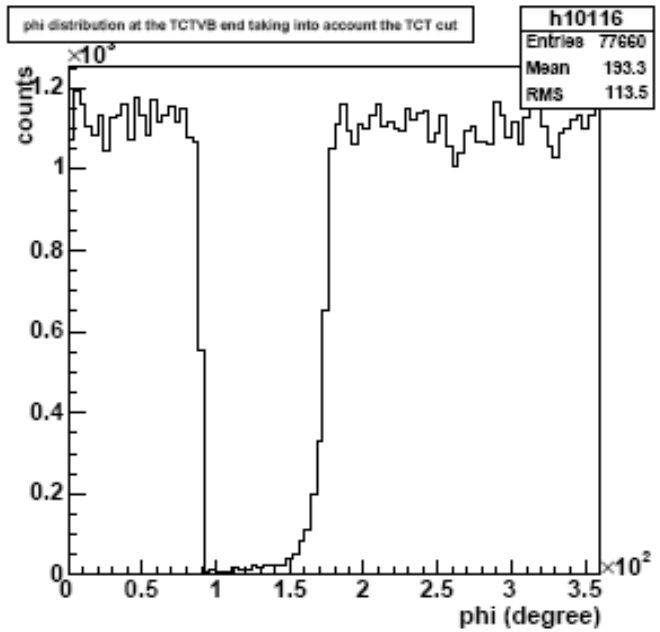
From M. Gallio et al

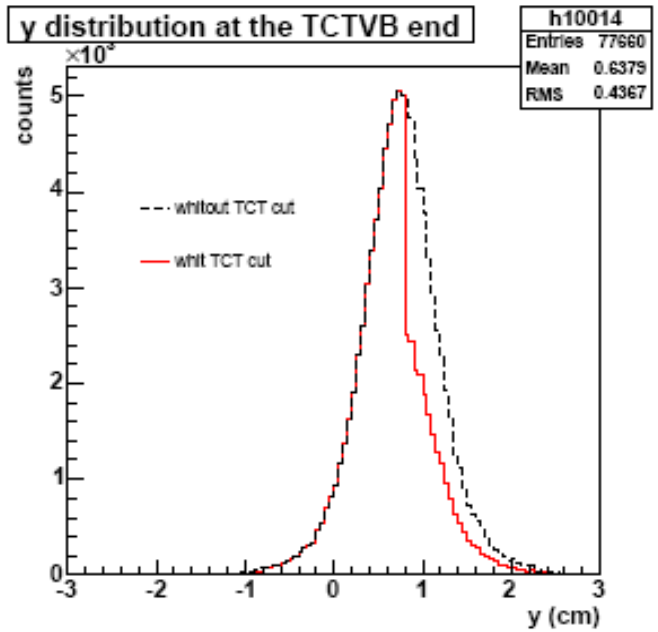
TCTVB neutron shadow on ZDC for 100 μrad crossing angle

This is larger than we are likely to use in heavy-ion operation.





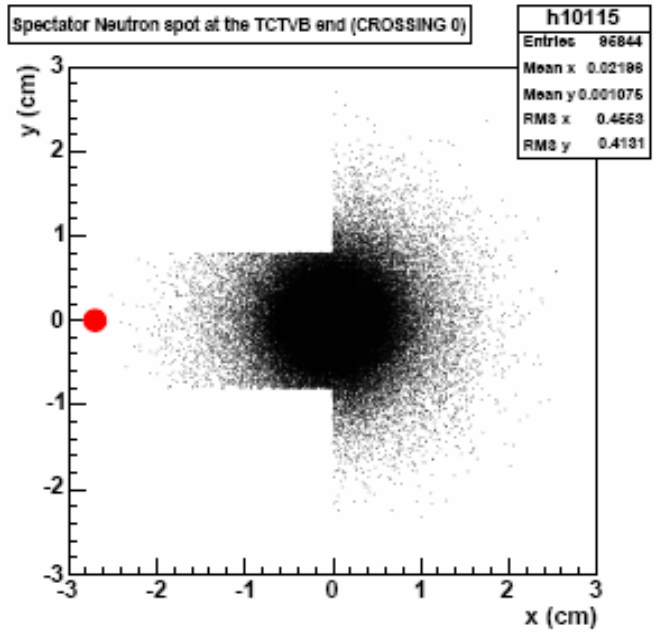


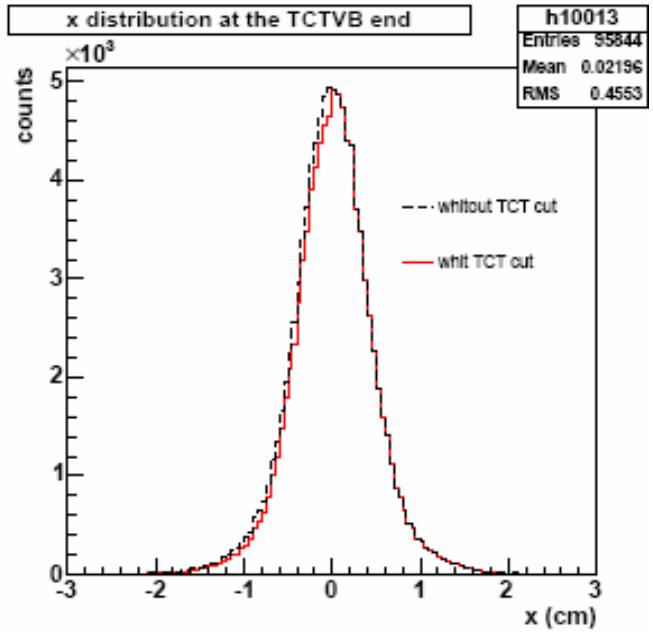


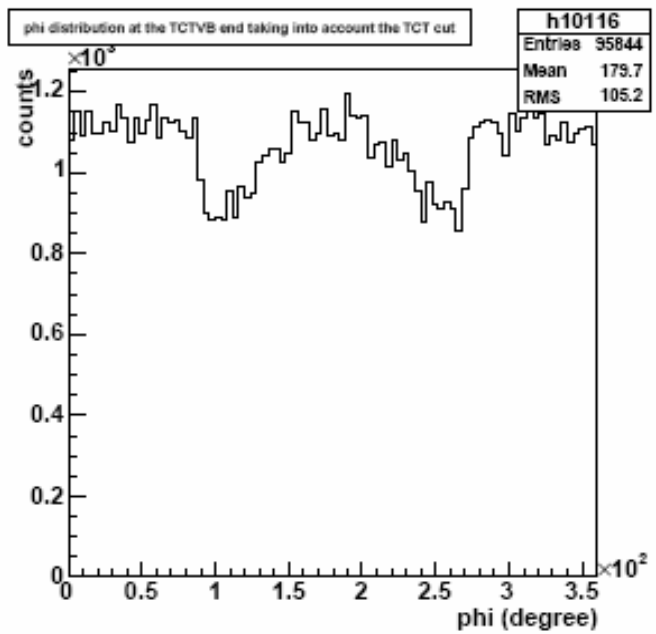
From M. Gallio et al

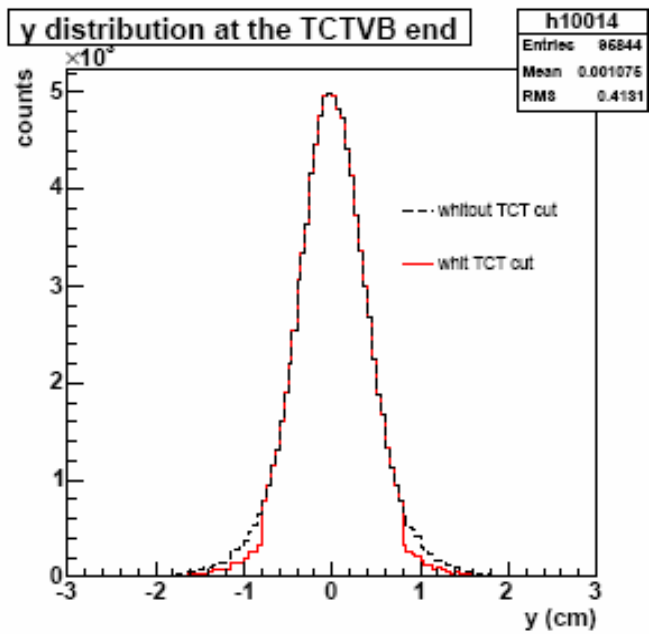
TCTVB neutron shadow on ZDC for zero crossing angle

However even zero crossing angle is a problem.







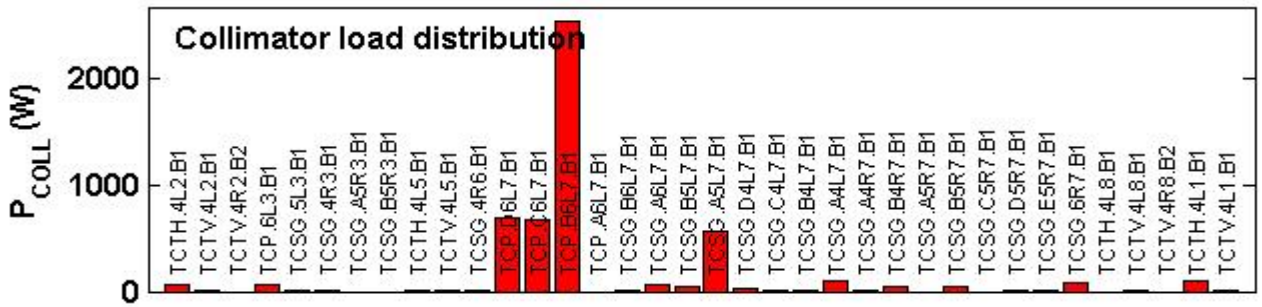


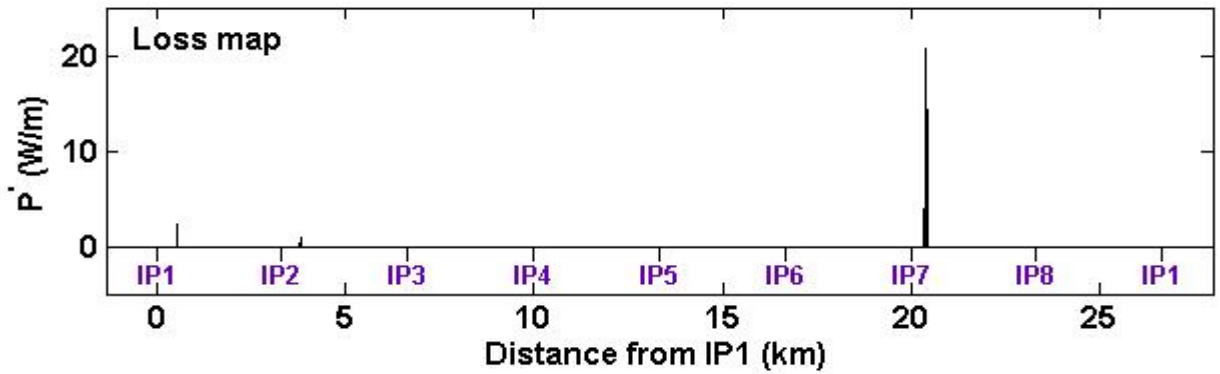
From M. Gallio et al

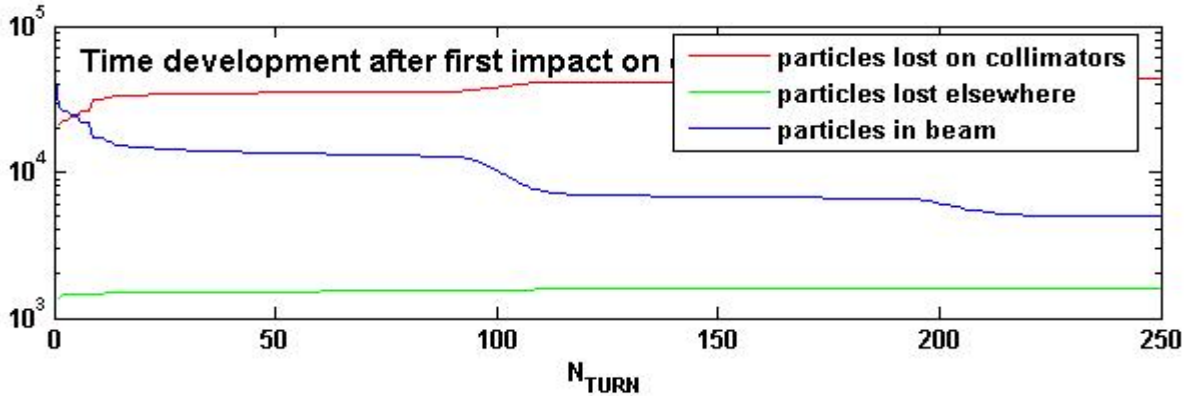
Simulations of collimator load

ICOSIM simulations for LHC lead ion collisions, betatron collimation in IR7.

From G. Bellodi







Possible solutions

- Confirm details and assumptions made so far
- Adjust lateral position of TCTVB
  - Probably does not help
- See what is possible with optics
  - ZDC position cannot change
  - Check jaw apertures and beam positions
- Confirm need for tertiary collimators in ion runs?
- Install new collimators further away from IP ?
  - Daniela Macina has identified possible locations