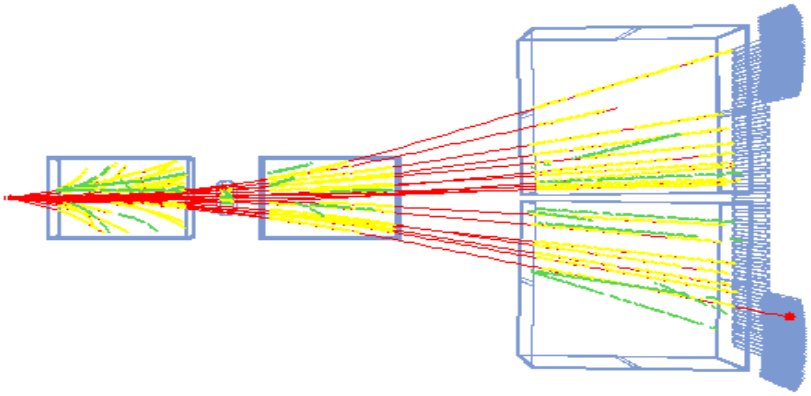
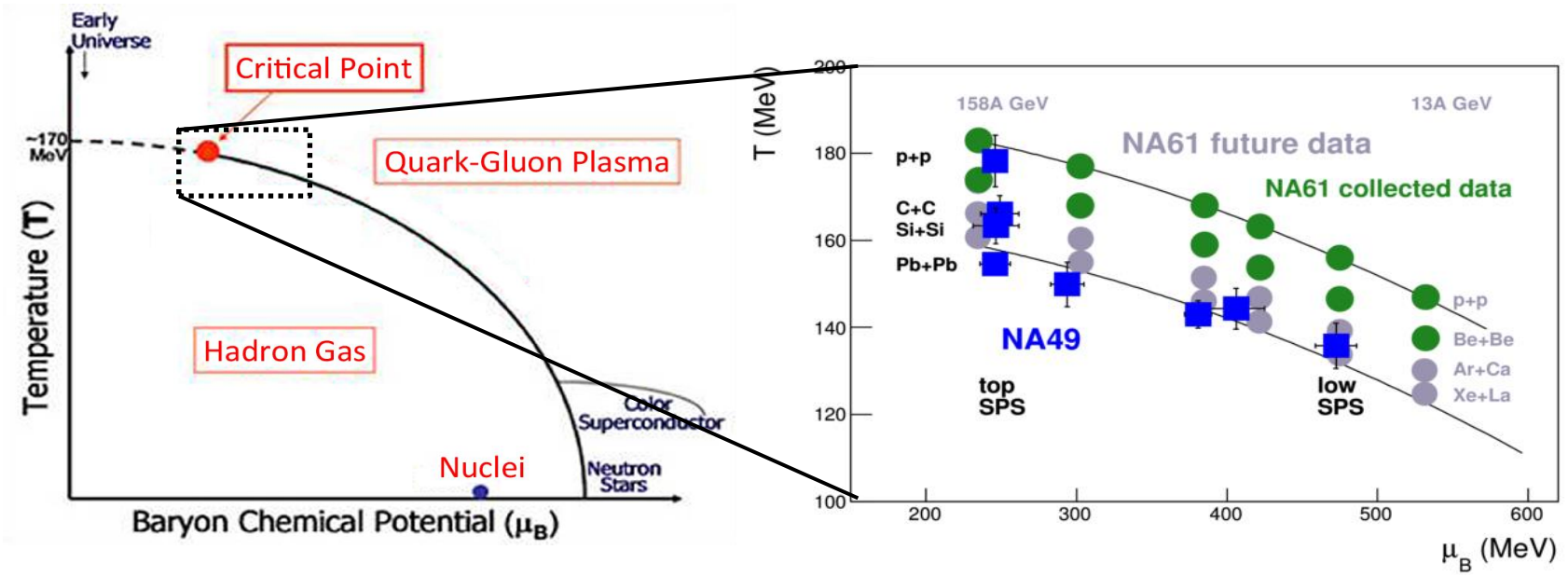


Is Beryllium heavy?
The first results on Be+Be collisions

Emil Kaptur
for the NA61/SHINE collaboration
Department of Nuclear Physics
University of Silesia

Ion physics programme

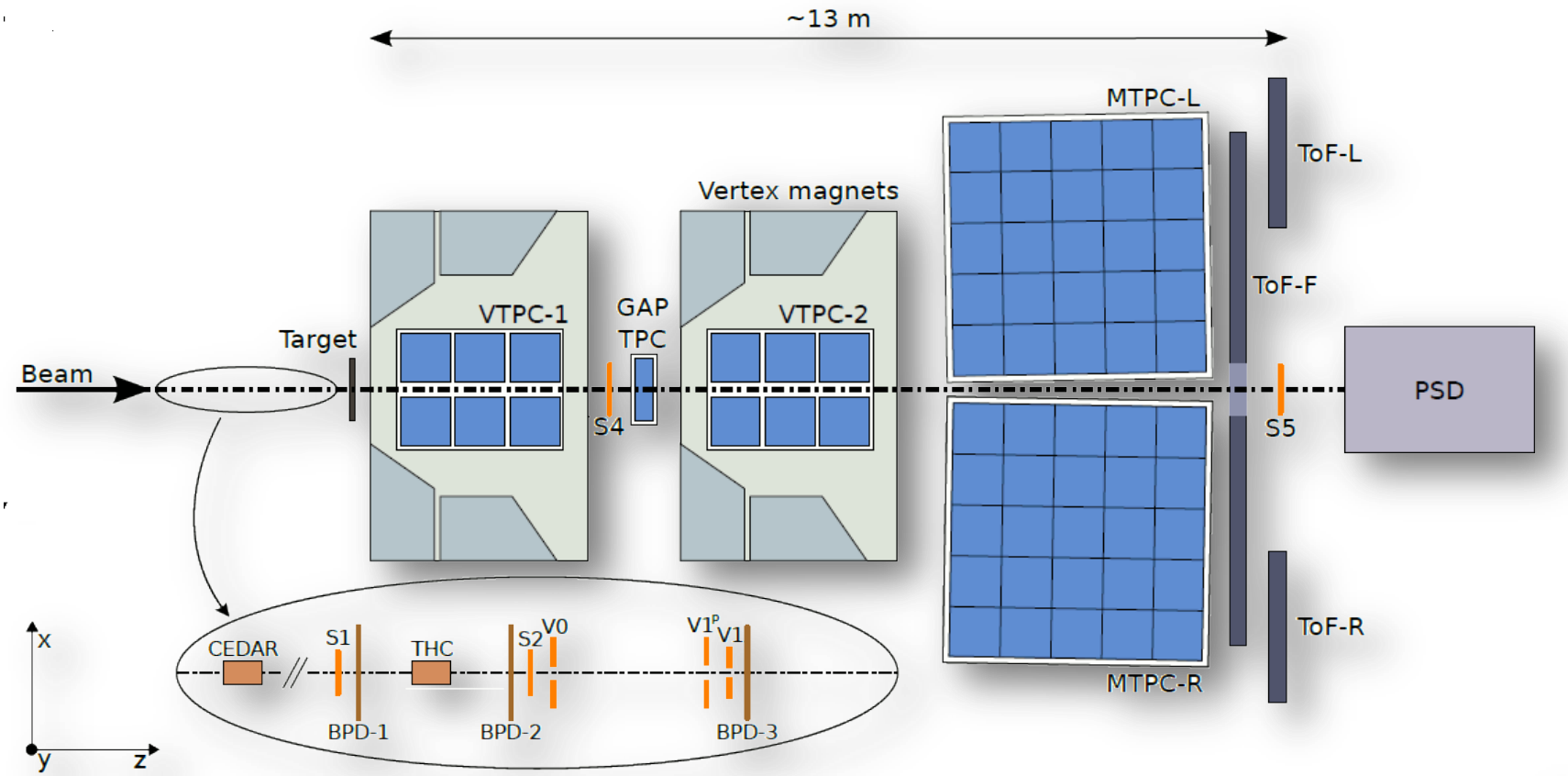


Statistics of taken events (in millions)

	13A GeV/c	20A GeV/c	31A GeV/c	40A GeV/c	80A GeV/c	158A GeV/c
p + p	1.2	1.4	3.5	5.8	5.0	4.0 + 58
	13A GeV/c	20A GeV/c	30A GeV/c	40A GeV/c	75A GeV/c	150A GeV/c
Be + Be	4.6	3.4	4.3	3.4	4.2	3.0

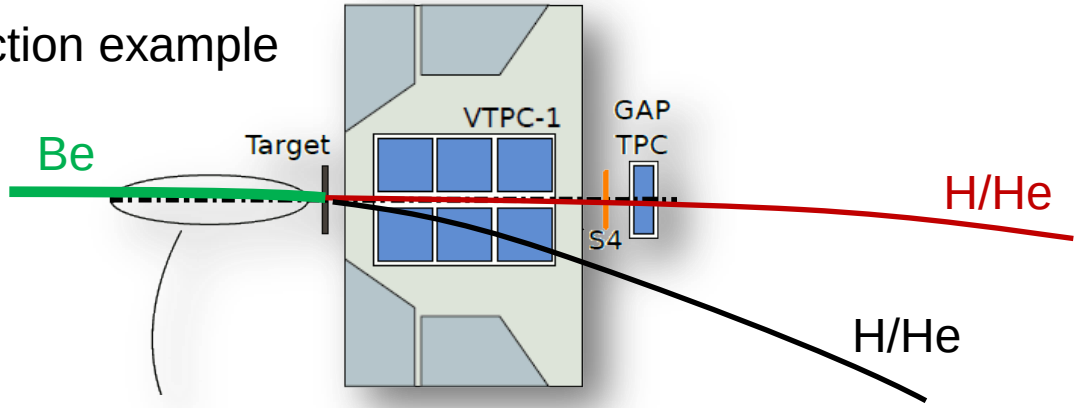
NA61/SHINE facility

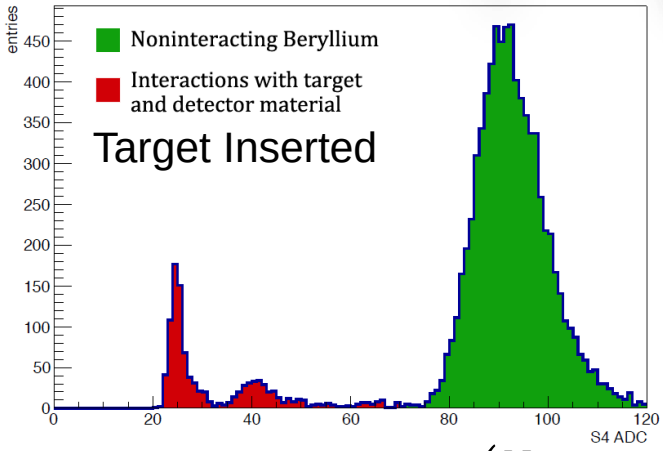
NA61/SHINE (SPS Heavy Ion and Neutrino Experiment)

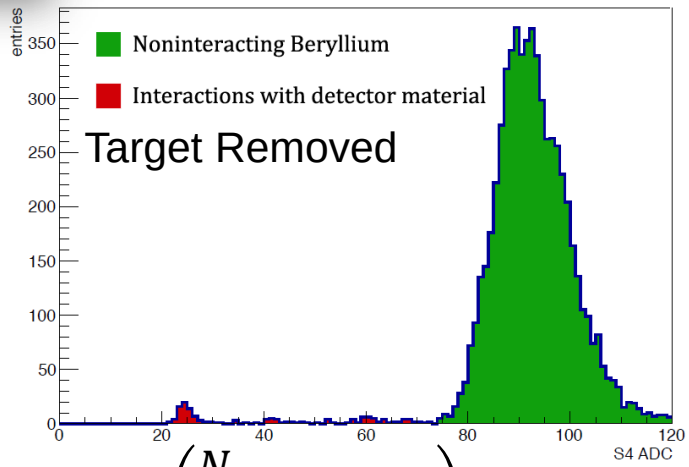


Inelastic cross section ^{7}Be+^{9}Be

Beryllium interaction example





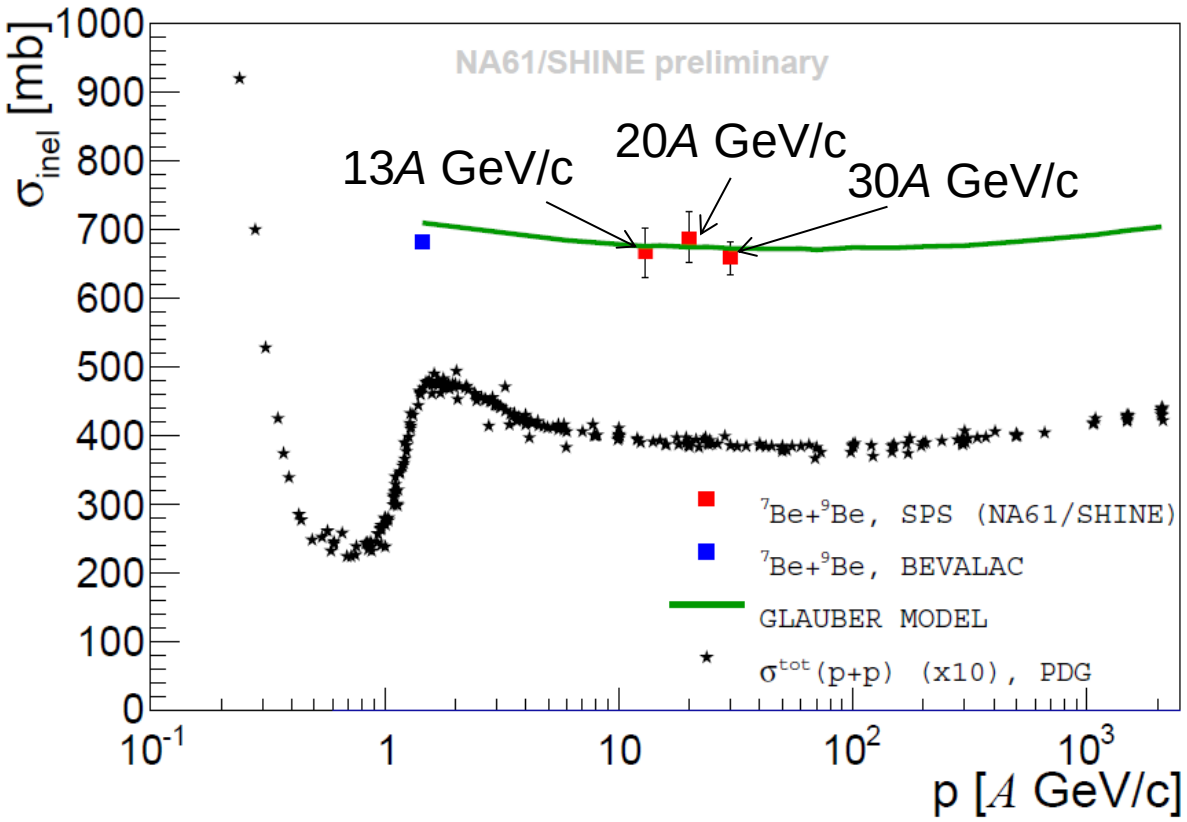


$$P_{\text{int}}^{S4} = \left(\frac{N_{\text{Interactions}}}{N_{\text{beams}}}\right)_I - (1 - P_{\text{int}}^{0}) \left(\frac{N_{\text{Interactions}}}{N_{\text{beams}}}\right)_R$$

P_{int}^{0} – approximate probability of interaction in target

P_{int}^{S4} – total probability of interaction in target

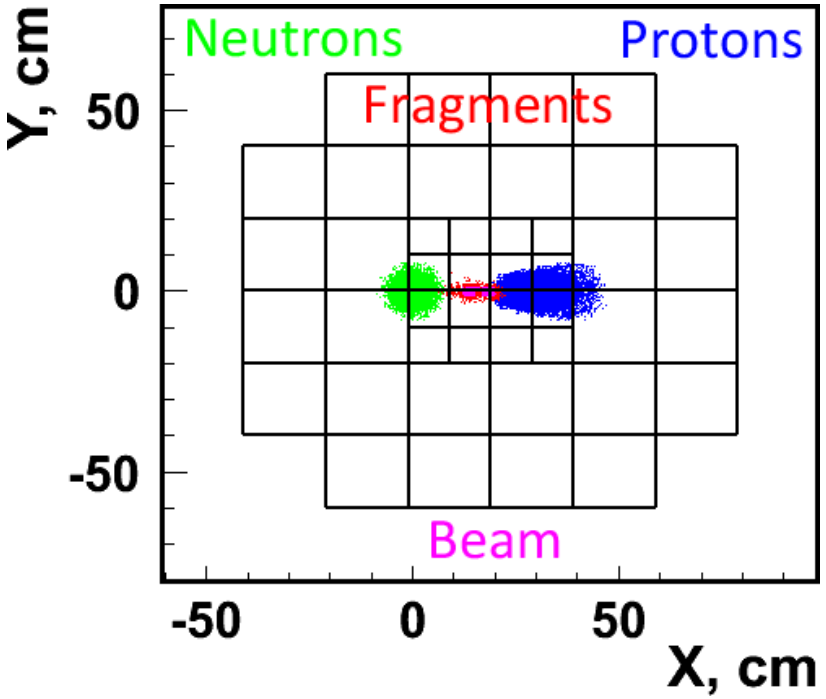
Inelastic cross section ^{7}Be+^{9}Be



Bevalac point, Phys. Rev. Lett. **55** (1985) 2676.
Glauber (GLISSANDO, Kielce) Model, Comput.Phys.Commun. 180 (2009) 69.

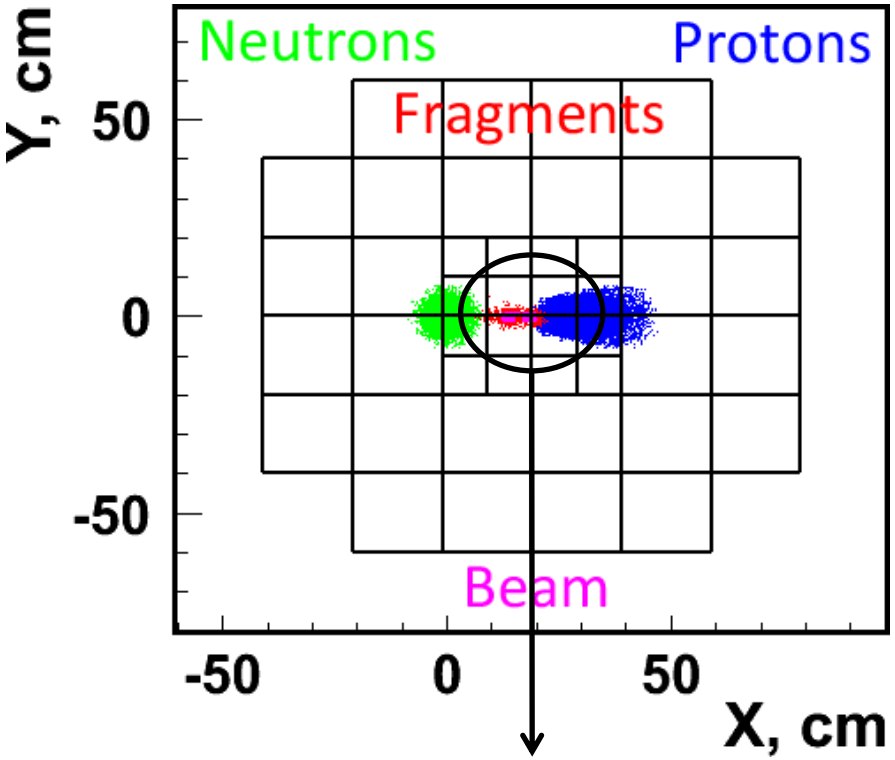
Projectile Spectator Detector

PSD during 2011 data taking
(40*A*, 75*A* and 150*A* GeV/c Be+Be)

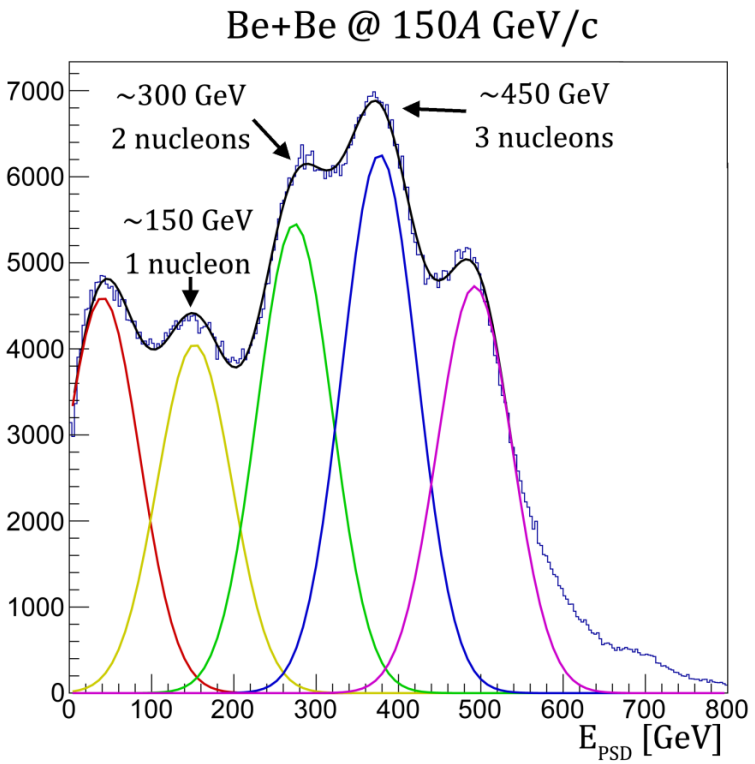


Spectators spatial distribution
on the PSD front face
for Be+Be at 150*A* GeV/c

PSD performance



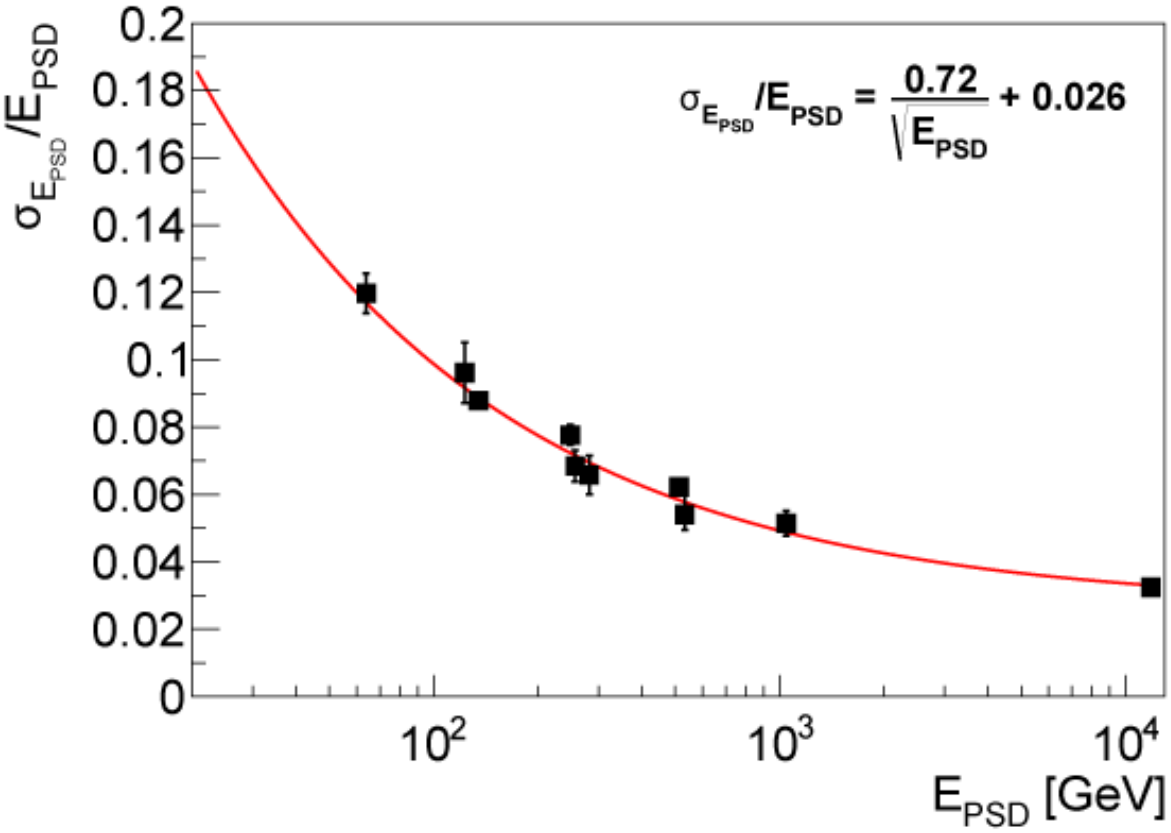
Central modules



Energy spectrum
from PSD central modules

One nucleon resolution!

PSD performance



Resolution calculated
for p, d, t, He, Be and Pb beams
at 40*A*, 75*A*, 80*A* and 150*A* GeV/c

Centrality Classes

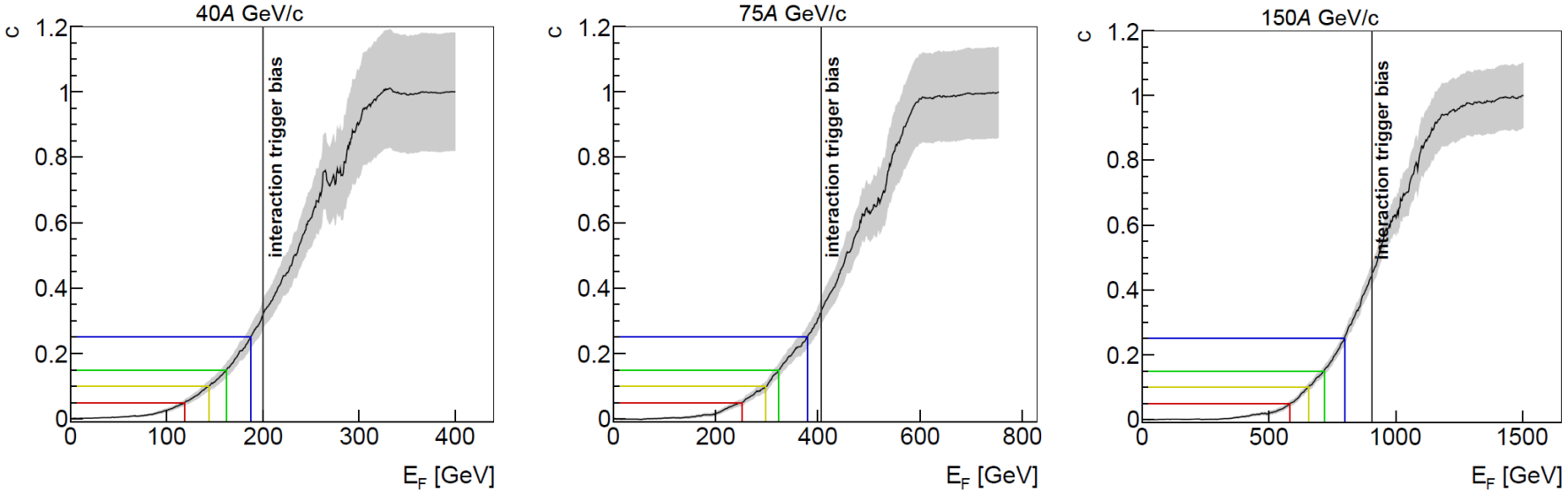
Semicentral collisions chosen by interaction trigger

- based on the energy deposited in the PSD,
- four centrality classes:

0 - 5% **5 - 10%** **10 - 15%** **15 - 25%**

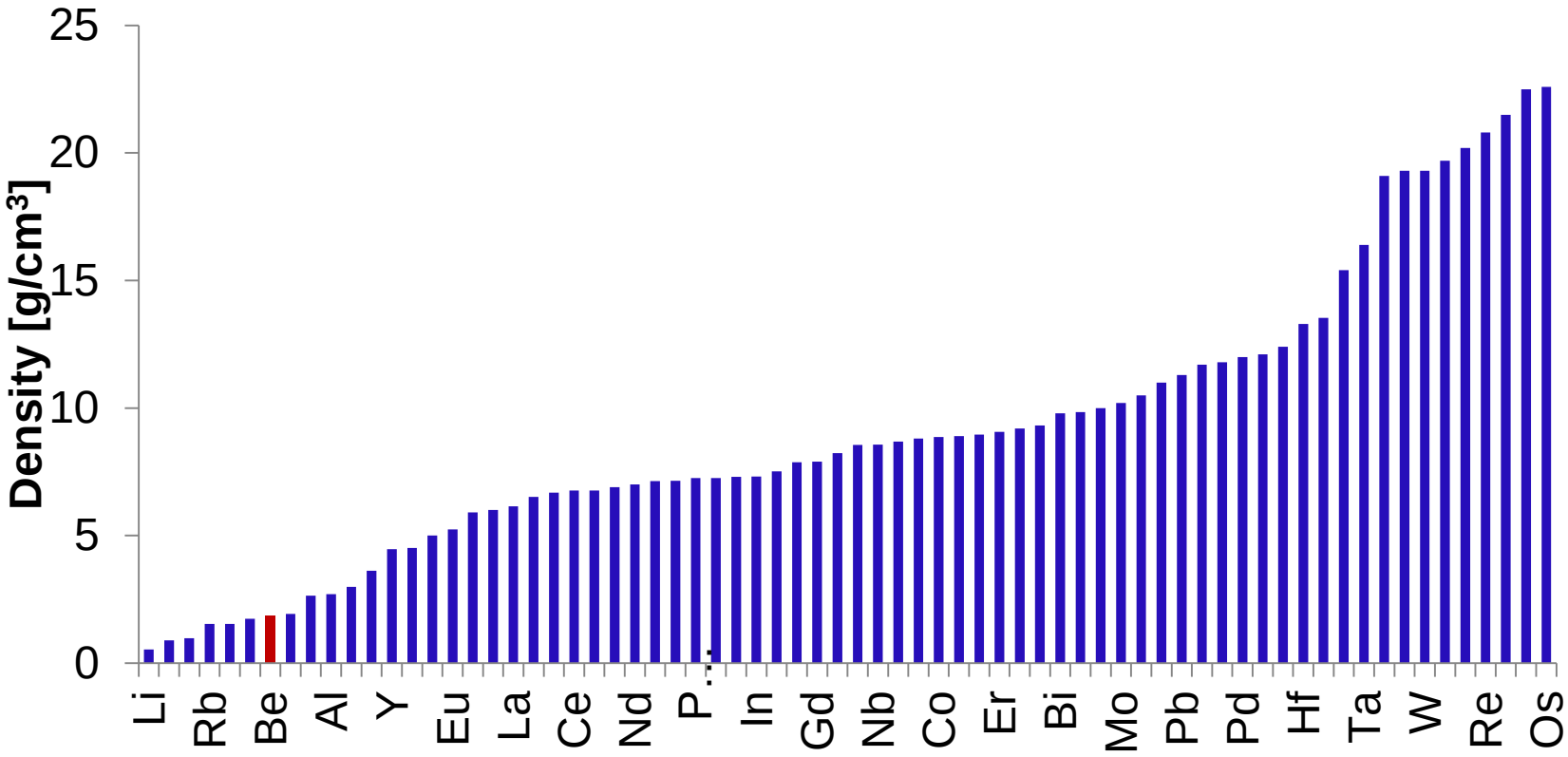
- centrality defined as percent of total inelastic cross section:

$$c(E_{\mathrm{F}}) = \frac{1}{P_{\mathrm{int}}^{S4}} \int_0^{E_{\mathrm{F}}} P_{\mathrm{int}}(E'_{\mathrm{F}})\, \mathrm{d}E'_{\mathrm{F}}.$$



P_{int}^{S4} – total probability of interaction in target

Is Beryllium heavy?



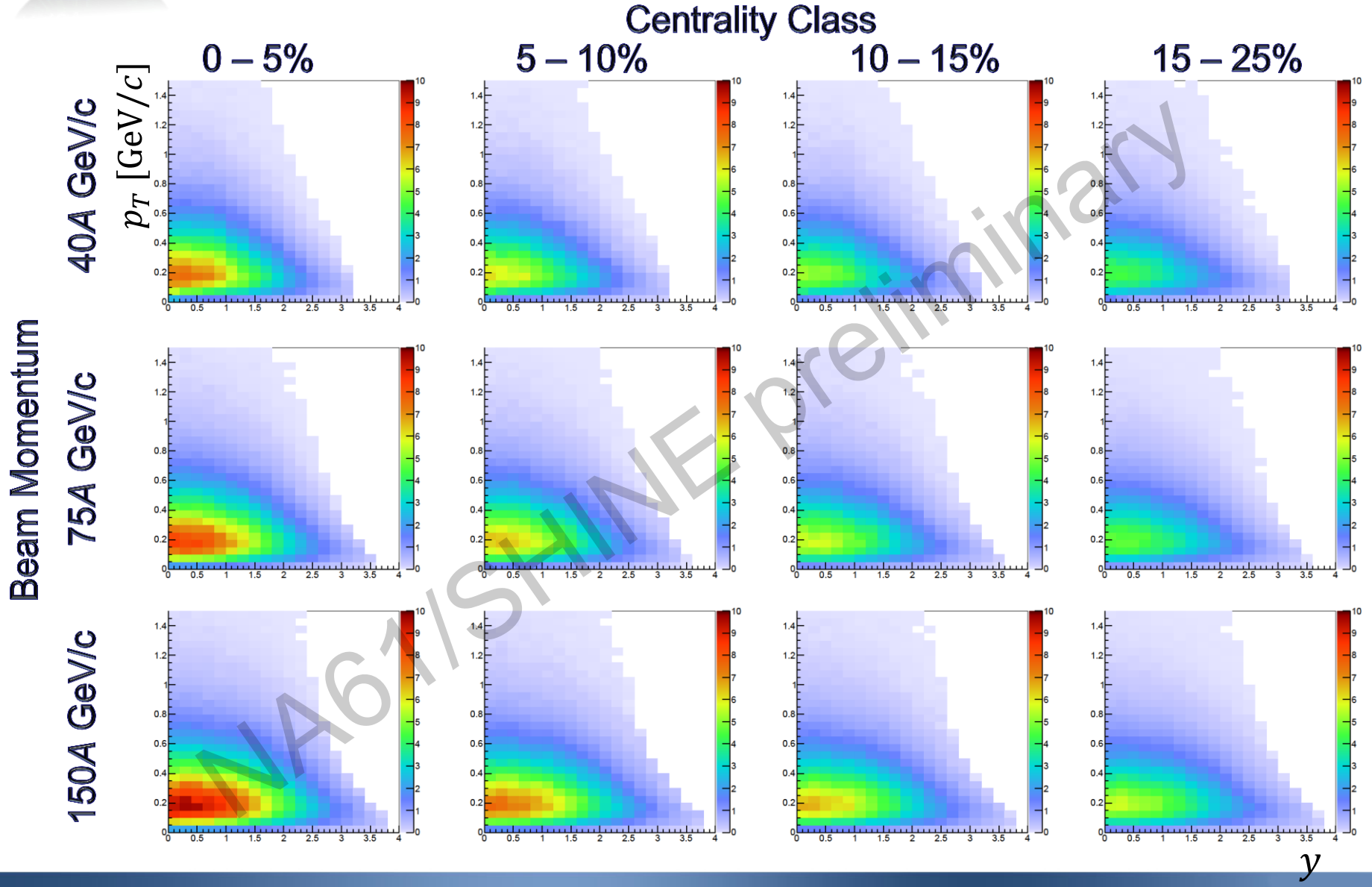
Compared to other metals by the density of the solid state
Beryllium is quite light

h^- method of π^- spectra determination

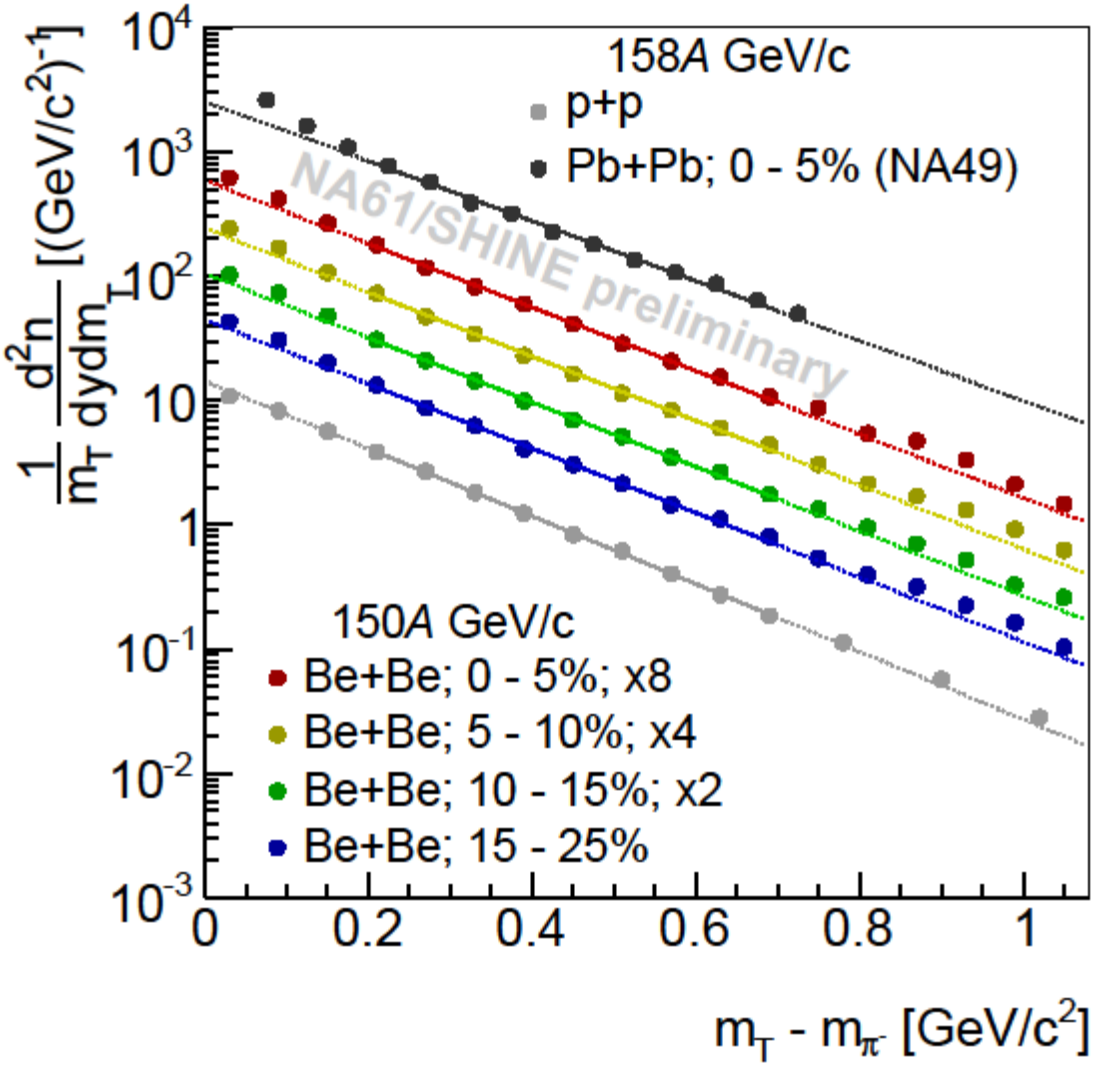
- Determination of negative hadrons spectra, corrected for geometrical acceptance, feed-down and detector effects,
- Correction of small (<10%) contribution from non-pion hadrons based on Monte-Carlo models (EPOS),
- The h^- method covers much larger region of phase-space than dE/dx or ToF identification.

- Details about the method were presented by Antoni Aduszkiewicz

Transverse momentum vs. rapidity spectra of π^- mesons



Transverse mass spectra of π^- mesons



Convex shape of
Pb+Pb and Be+Be spectra

p+p spectra exponential

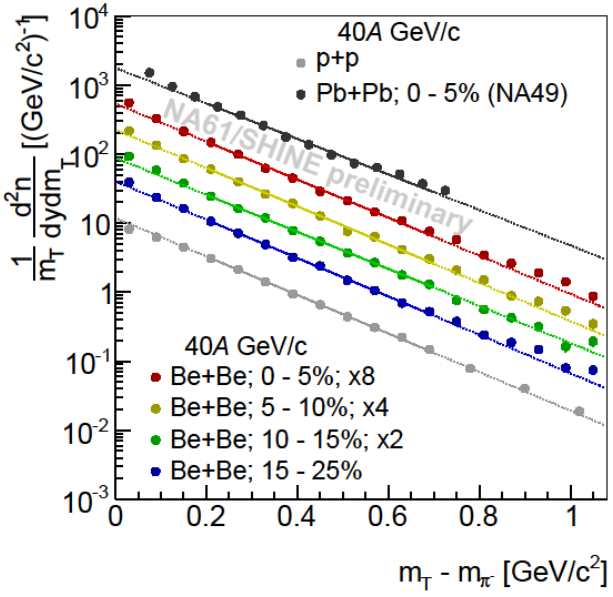
$$\frac{\mathrm{d}n}{\mathrm{d}m_\mathrm{T}} = A\, m_\mathrm{T} \exp\left(-\frac{m_\mathrm{T}}{T}\right)$$

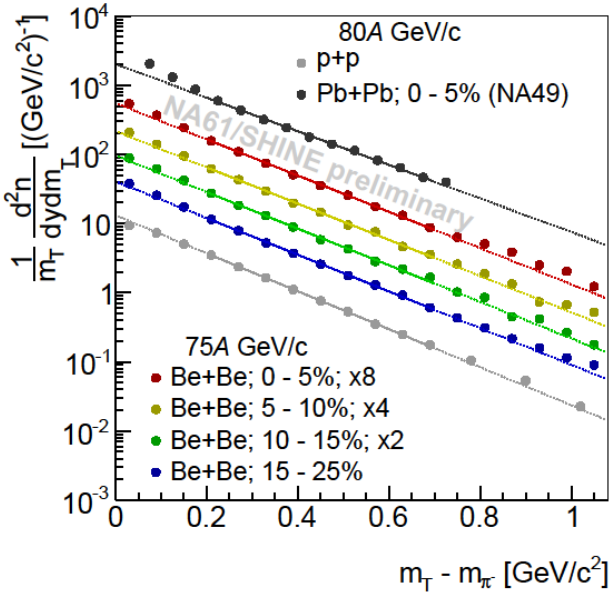
fitted in range
$0.2 < m_T - m_\pi < 0.7$ GeV/c^2

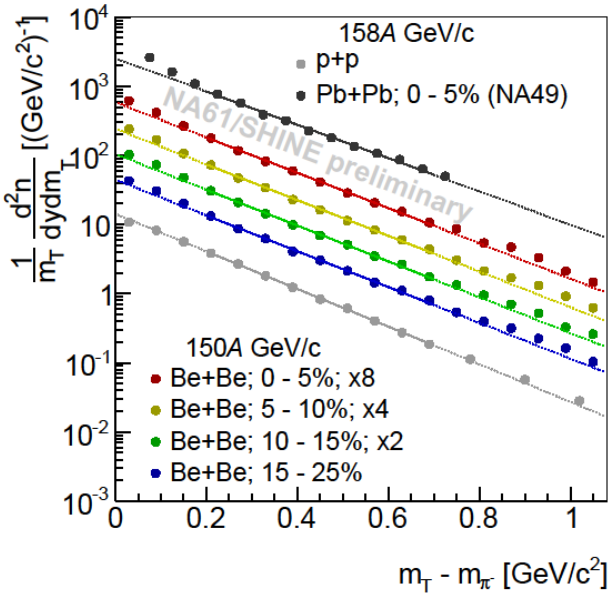
mid-rapidity $(0.0 < y < 0.2)$

Transverse mass spectra of π^- mesons

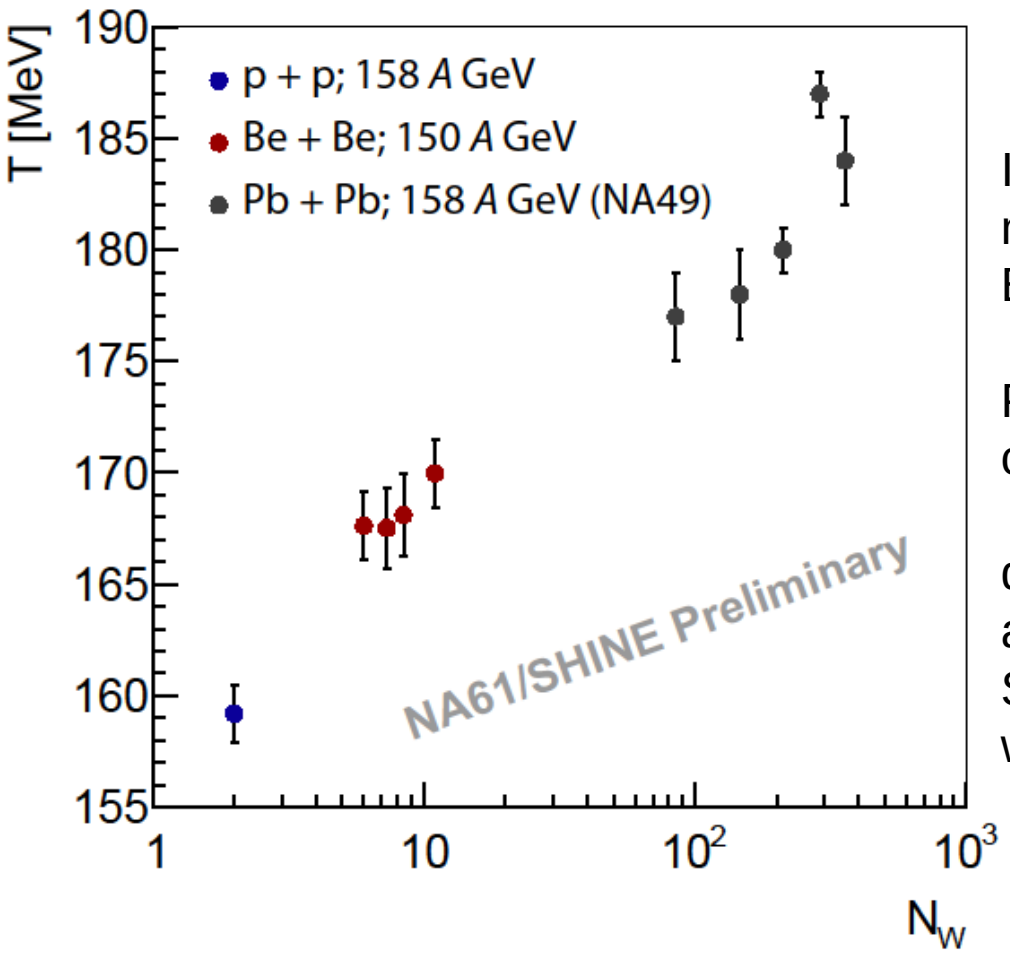
mid-rapidity *(0.0 < y < 0.2)*







Transverse mass spectra of π^- mesons
Inverse slope parameter T



Fitted in range
$0.2 < m_T - m_\pi < 0.7$ GeV/c^2

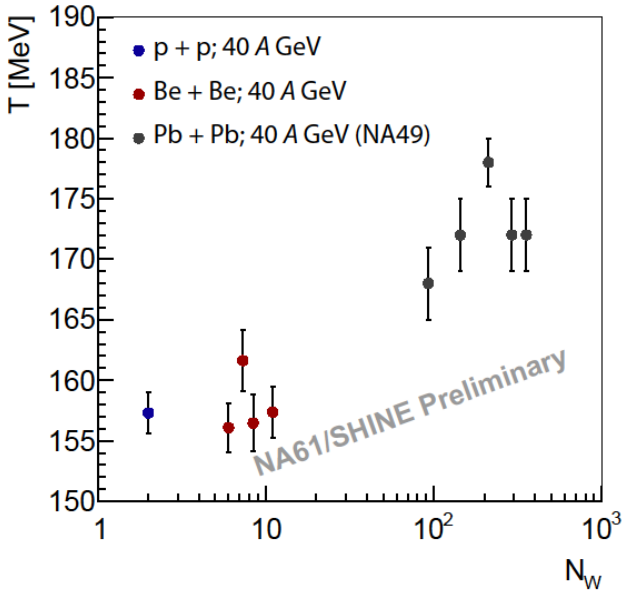
Inverse slope parameter of transverse mass spectra is significantly larger in Be+Be than in p+p

Possible evidence of transverse collective flow in Be+Be collisions

dE/dx identification will provide Kaon and Proton results soon.
Simultaneous fit to three particles types will give better answer regarding flow.

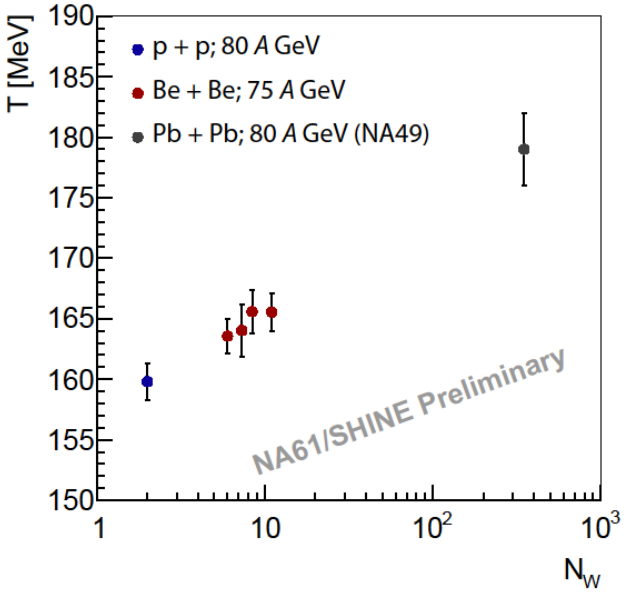
Number of wounded nucleons in Beryllium obtained by Glauber (Glissando) Model (not final)

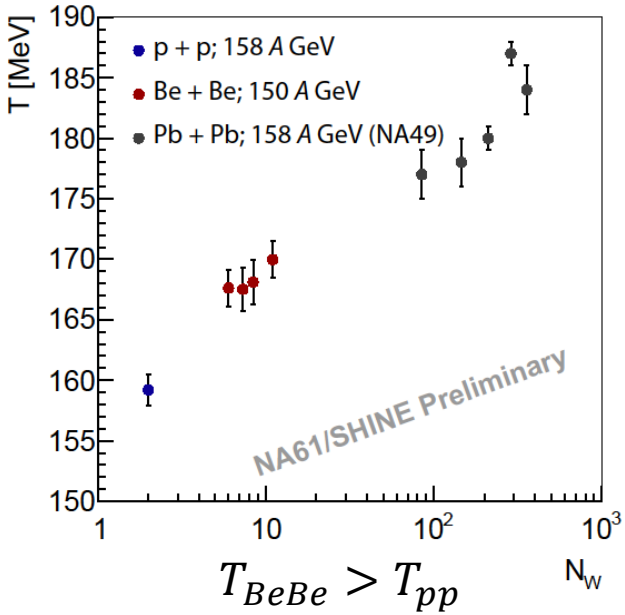
Transverse mass spectra of π^- mesons
Inverse slope parameter T



$T_{BeBe} \approx T_{pp}$

Inverse slope parameter in Be+Be changes with beam momentum

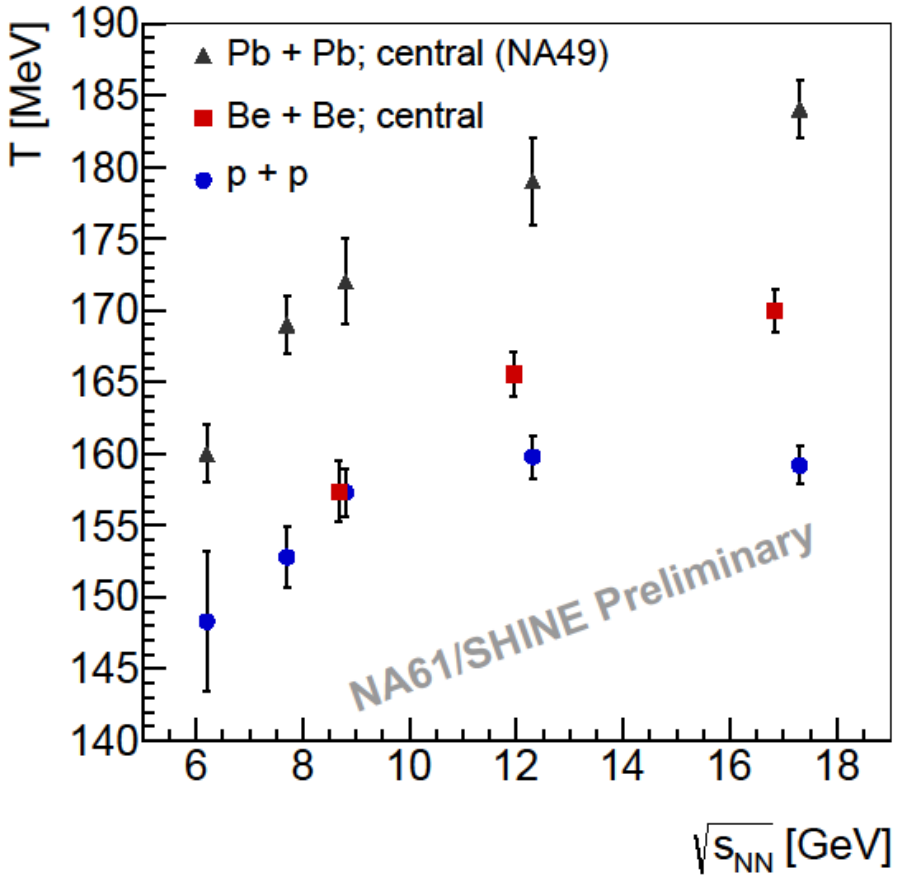




$T_{BeBe} > T_{pp}$

Number of wounded nucleons in Beryllium obtained by Glauber (Glissando) Model (not final)

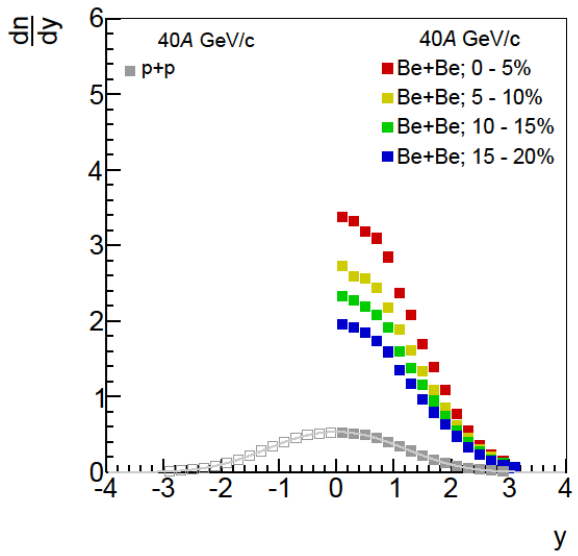
Transverse mass spectra of π^- mesons
Inverse slope parameter

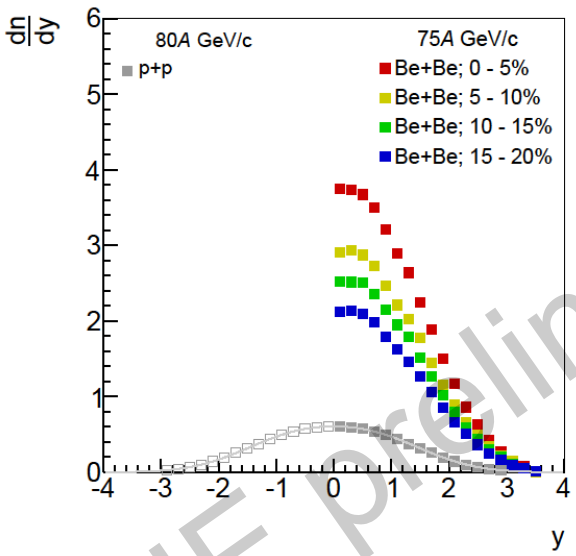


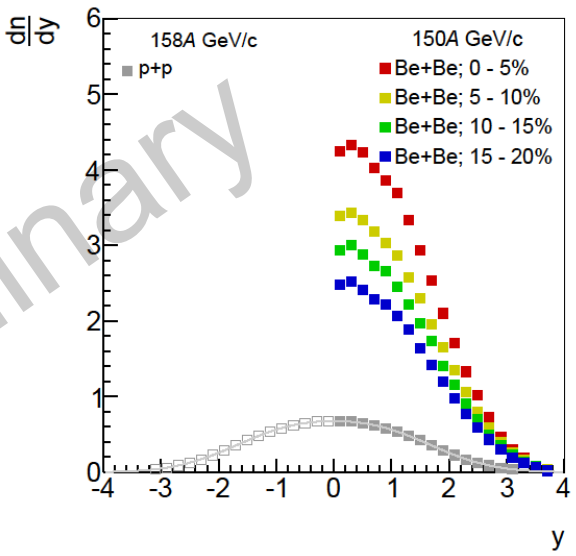
Beryllium looks heavy at 150*A* GeV/c!

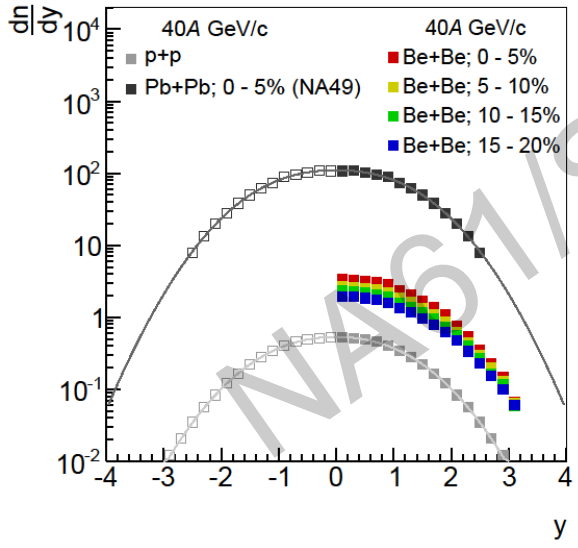
Energy dependance of T parameter in Be+Be simillar to Pb+Pb

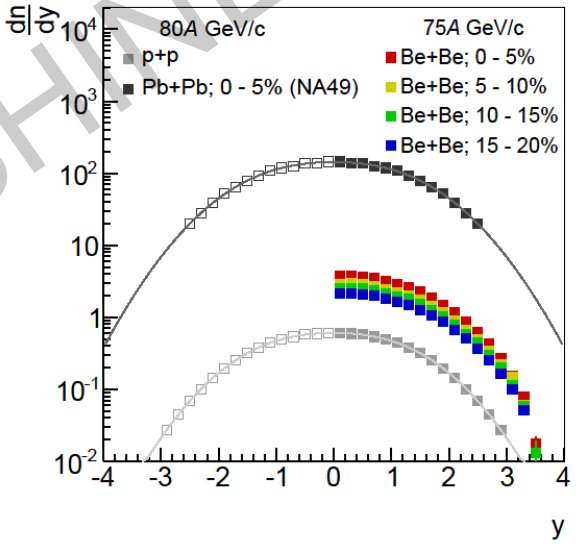
Rapidity spectra of π^- mesons

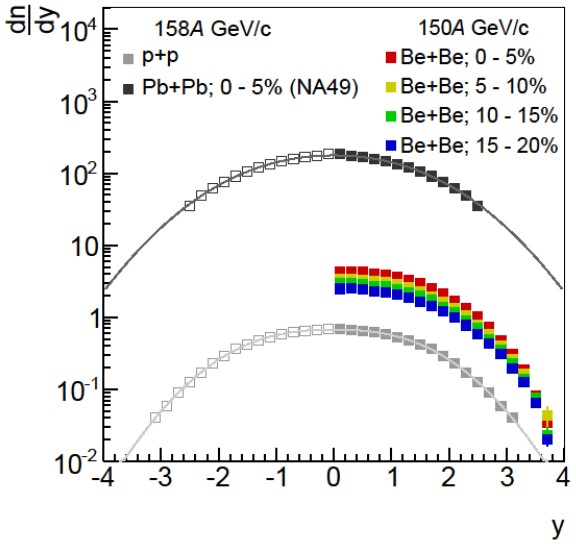












NA61/SHINE preliminary

Mean of rapidity distribution Asymmetric system

The rapidity distribution is shifted to the backward rapidity values due to target being heavier than projectile.

Based on EPOS Monte-Carlo simulations

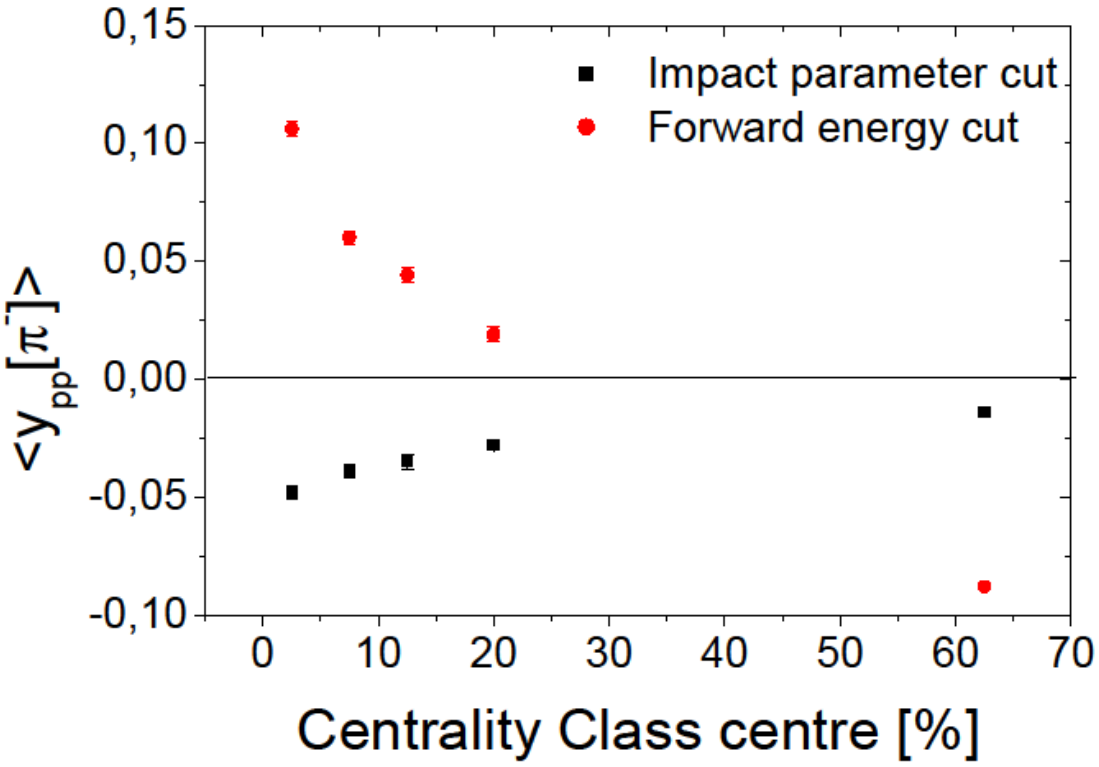
Mean value of rapidity distributions
Centrality classes based on impact parameter

	7Be+9Be
0 – 5%	-0.048(3)
5 – 10%	-0.039(3)
10 – 15%	-0.035(3)
15 – 25%	-0.028(2)
25 – 100%	-0.014(2)

Mean of rapidity distribution Forward energy trigger bias

Centrality classes based on forward energy.
Restriction on wounded nucleons from projectile but not from target.
The mean of the rapidity distribution shifted to the forward region.

Based on EPOS Monte-Carlo simulations



Summary

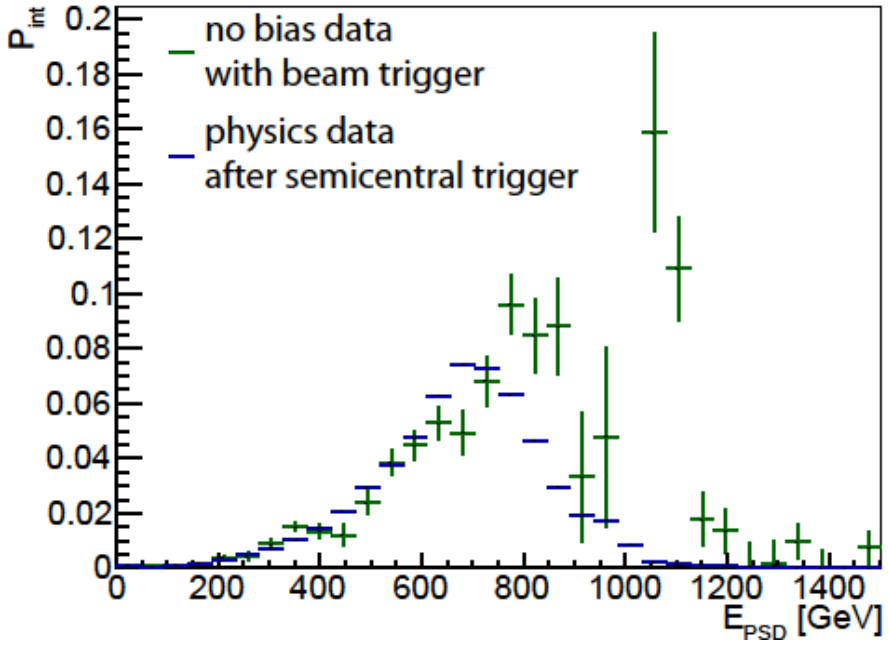
- First results from Be+Be collisions measured by NA61/SHINE were presented,
- Determination of inelastic cross-section for 7Be+9Be collisions at 13A to 30A GeV/c,
- Negative pion spectra in central 7Be+9Be collisions at 40A to 150A GeV/c,
- Interesting behaviour of inverse slope parameter of transverse mass spectra in 7Be+9Be,
- Extrapolation to 4π yields under investigation (although not obvious due to forward energy trigger bias).

THANK YOU

emil.aleksander.kaptur@cern.ch

Centrality Method

Calculation of probability of interaction as in cross section determination, but in every PSD energy bin (green points).
Integral of $P_{\mathrm{int}}(E_{\mathrm{PSD}})$ is the percent of cross section.



Centrality classes defined by percent of total inelastic cross section based on forward energy. Edges of classes determined as:

$$(5 \pm 0.9)\% - (10 \pm 1.2)\% - (15 \pm 1.5)\% - (25 \pm 2.1)\%$$