Ion fragmentation simulation for HERD charge measurement

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Heavy ion fragmentation

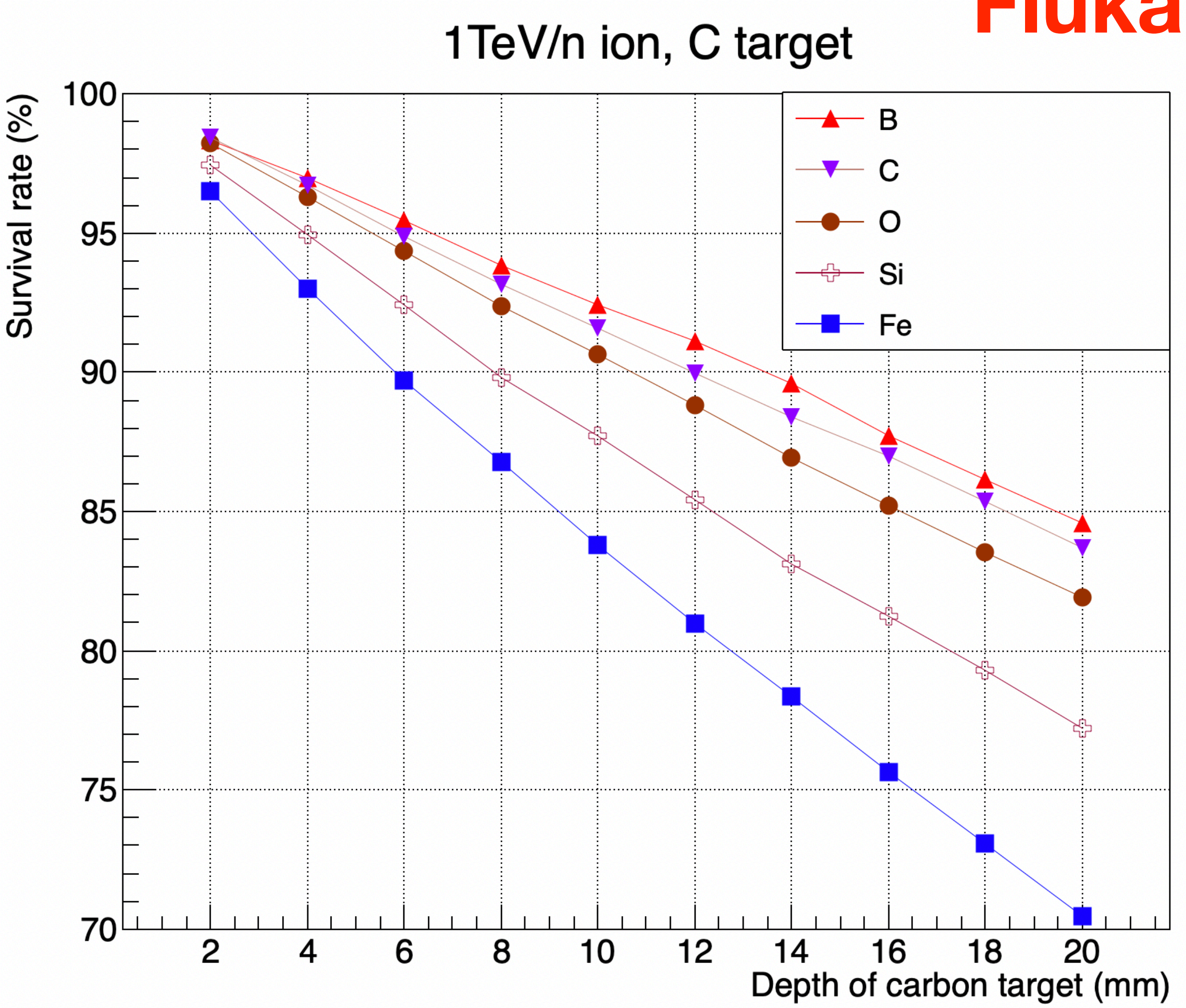
- Projectile fragments: approximately preserve the direction and velocity of the incident particle;
- Target fragments: excite the target nuclei to an excited state, decay via emission of nucleons which have relatively low energy.
- Charge-changed channels of projectile fragments may cause misidentify of ion species.

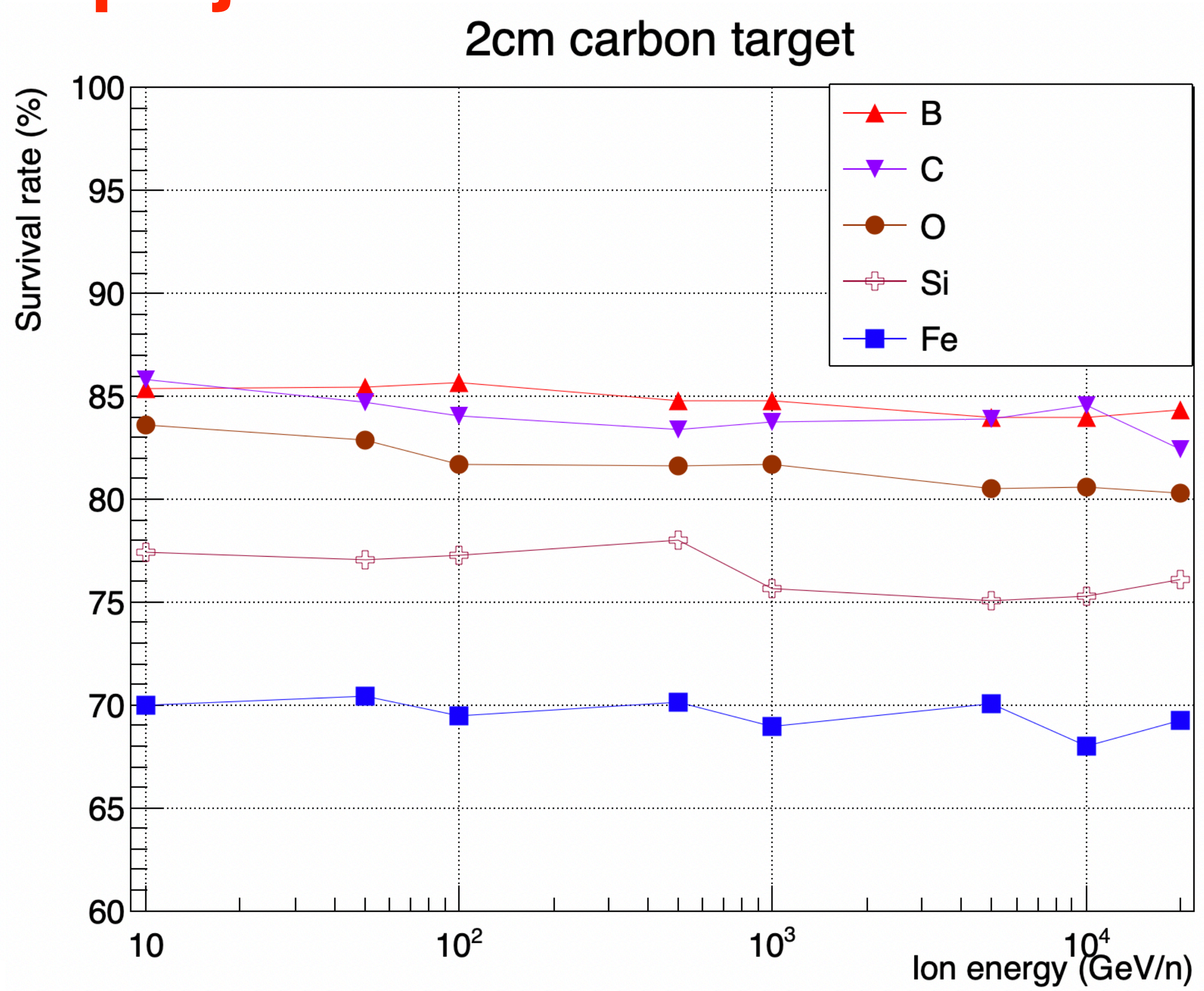
$$\sigma_{cc} = \pi r_0^2 \left(A_{\text{proj}}^{1/3} + A_{\text{targ}}^{1/3} - 0.2 - 1/A_{\text{proj}} - 1/A_{\text{targ}} \right)^2$$

An energy independent formula is used to describe charge changed cross-section
Townsend LW & Wilson JW , Radiat Res (1986)

Fragmentations in Carbon target

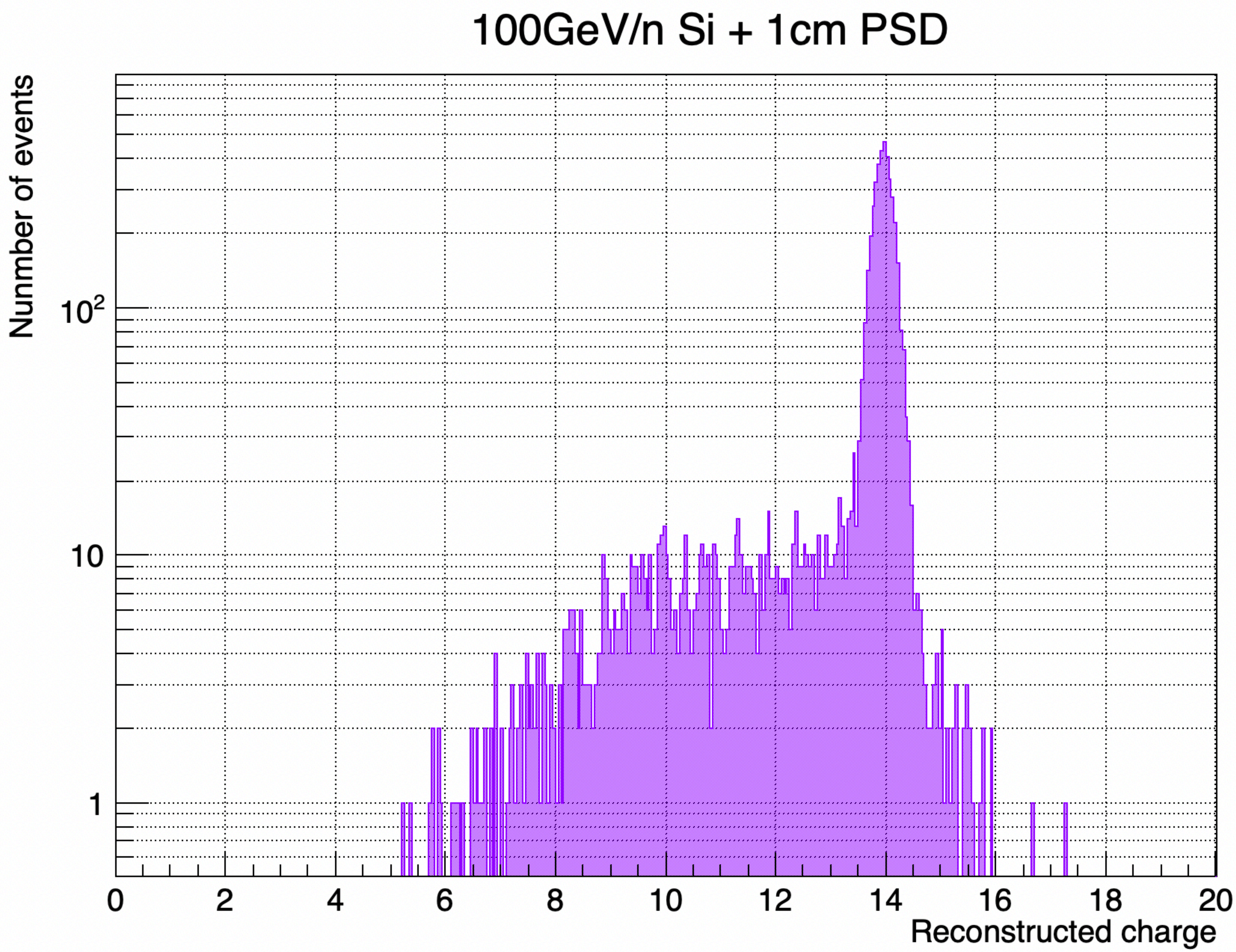
Fluka+dpmjet3



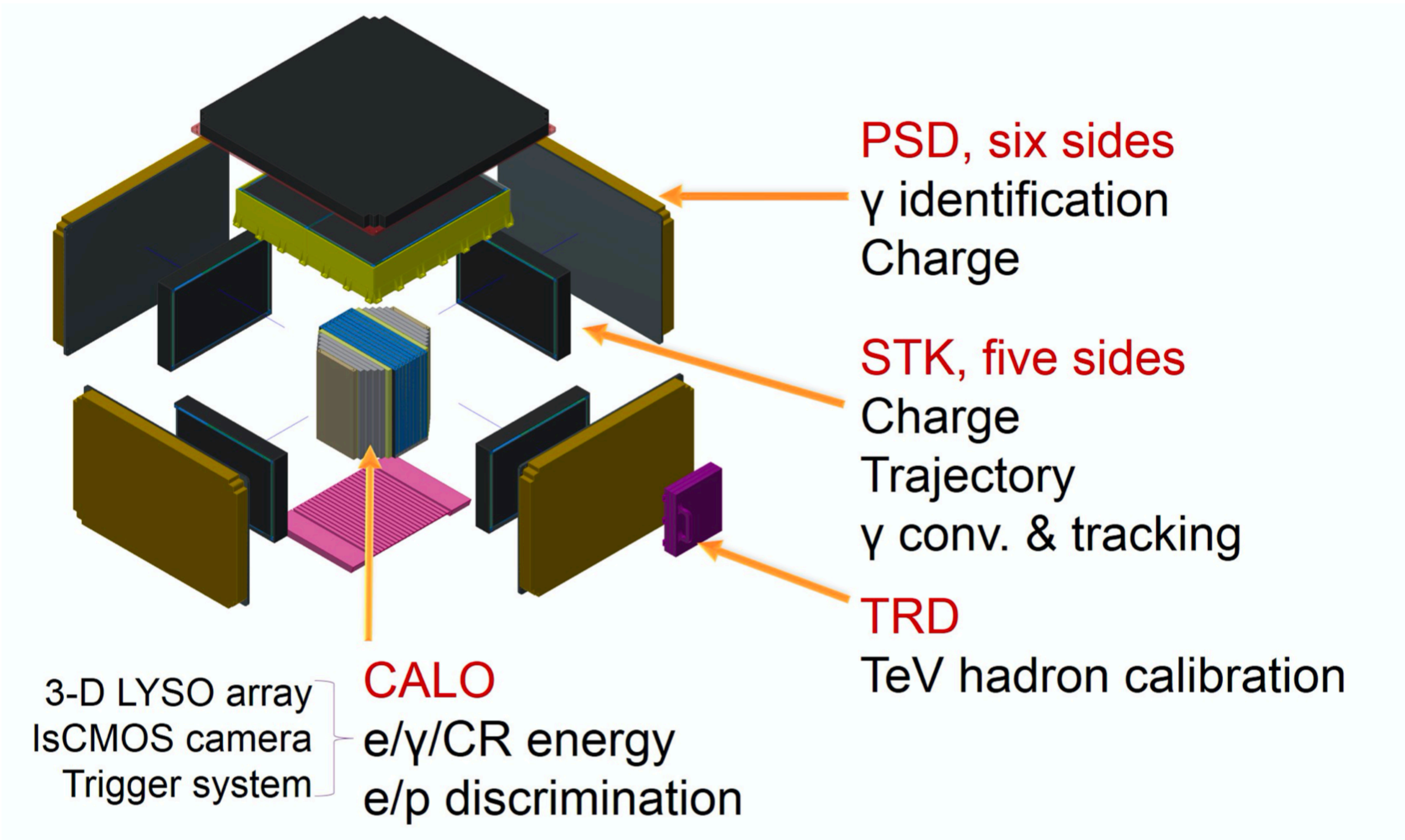


- ✦ Survival probability has an exponential relationship with target depth;
- ✦ Almost energy independent (verified up to several hundred of AGeV)

Fragmentation in PSD



HERD instruments(proposal edition)



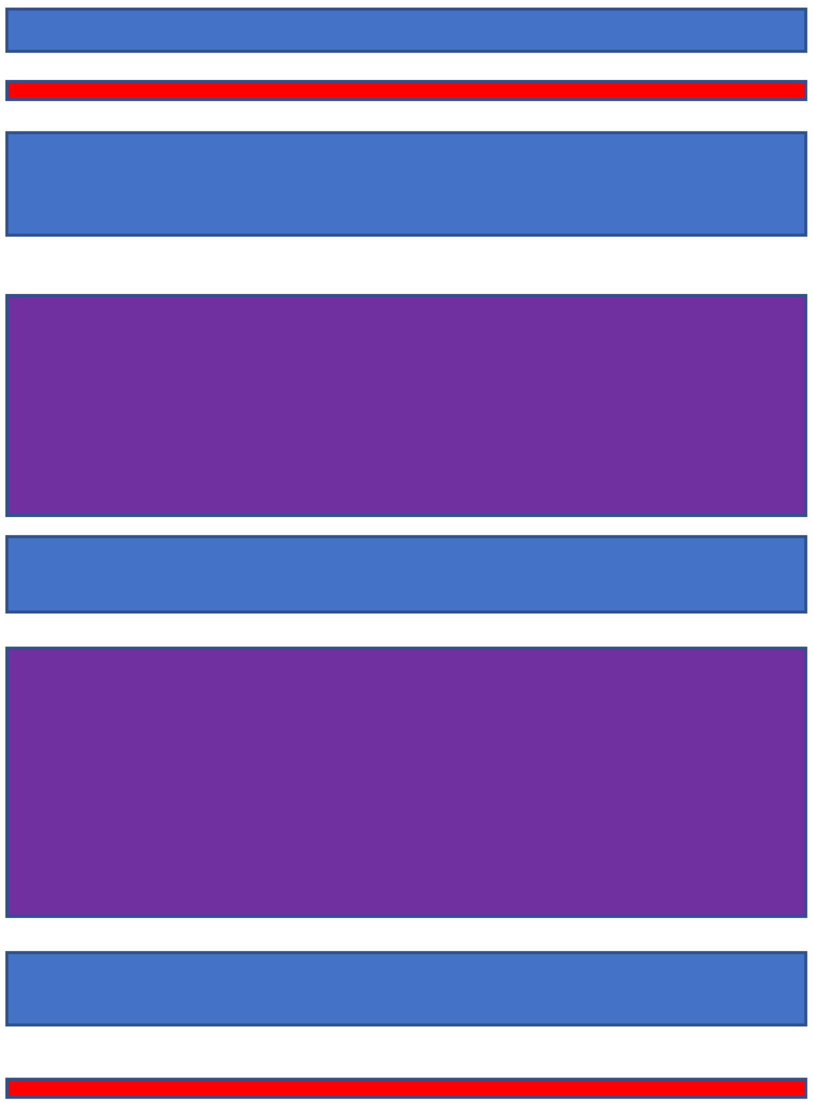
The main charge detector STK has PSD and structure materials on its top.

Motivation

- ✦ To verify the improvement of charge detection when a top charge detection is used;
- ✦ Evaluate ion fragmentation probability on the top of STK;
- ✦ Study the effect of fragmentation on CR spectrum measurement.

MC setup

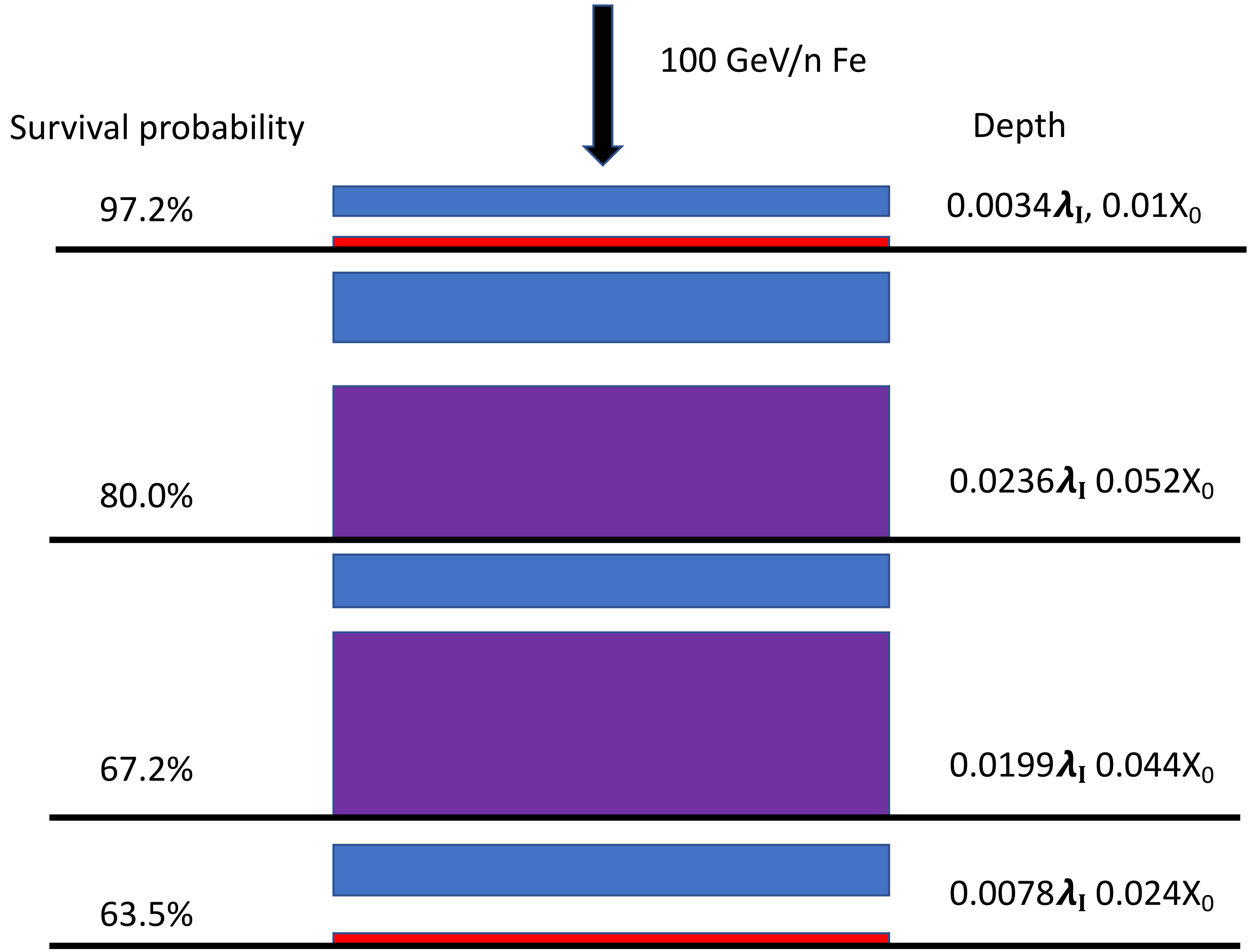
Fluka 2011.2x with DPMJET3



Some configurations of input card:

DEFAULTS		CALORIME
PHYSICS	3.0	EVAPORAT
PHYSICS	1.0	COALESCE

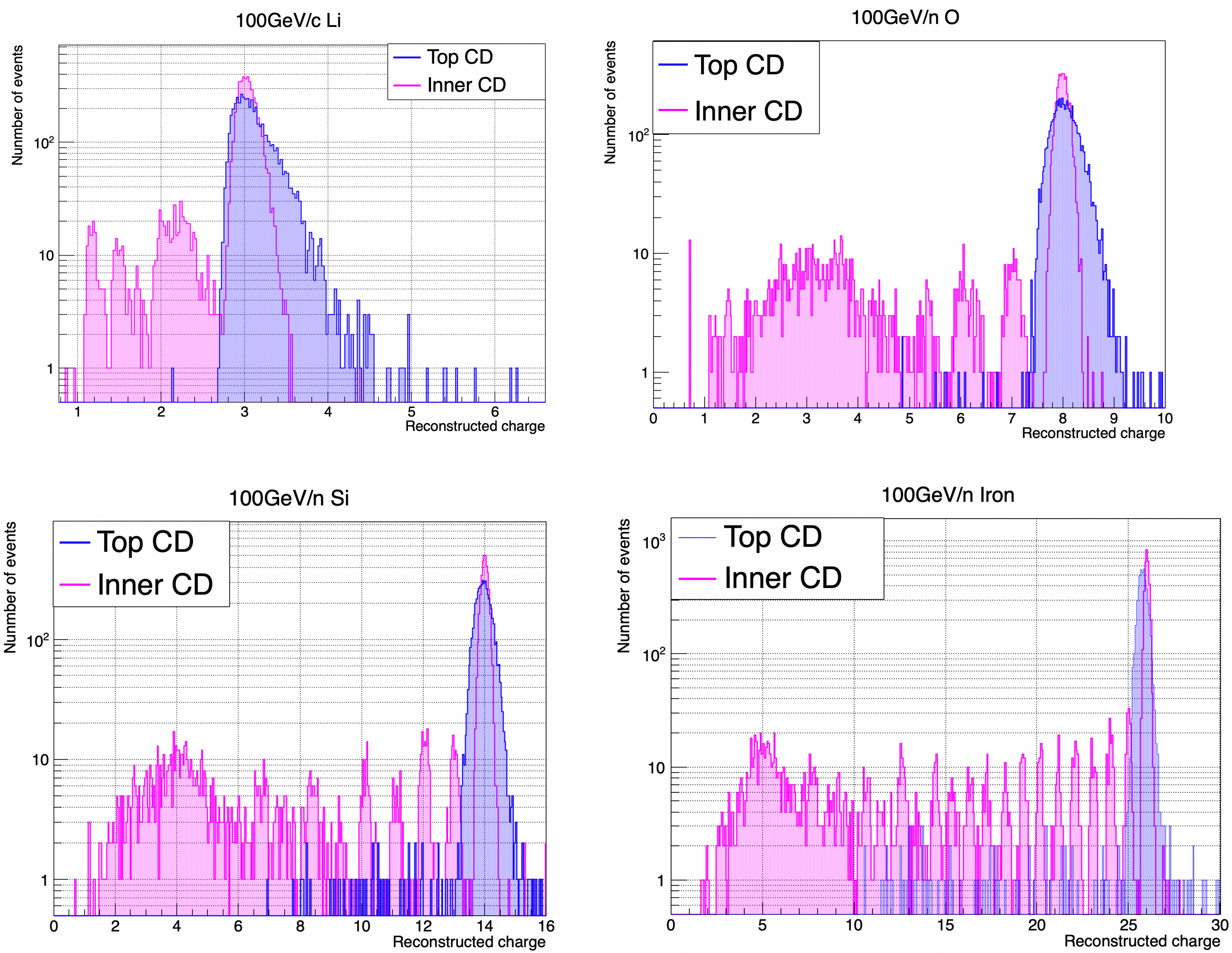
Iron fragmentation



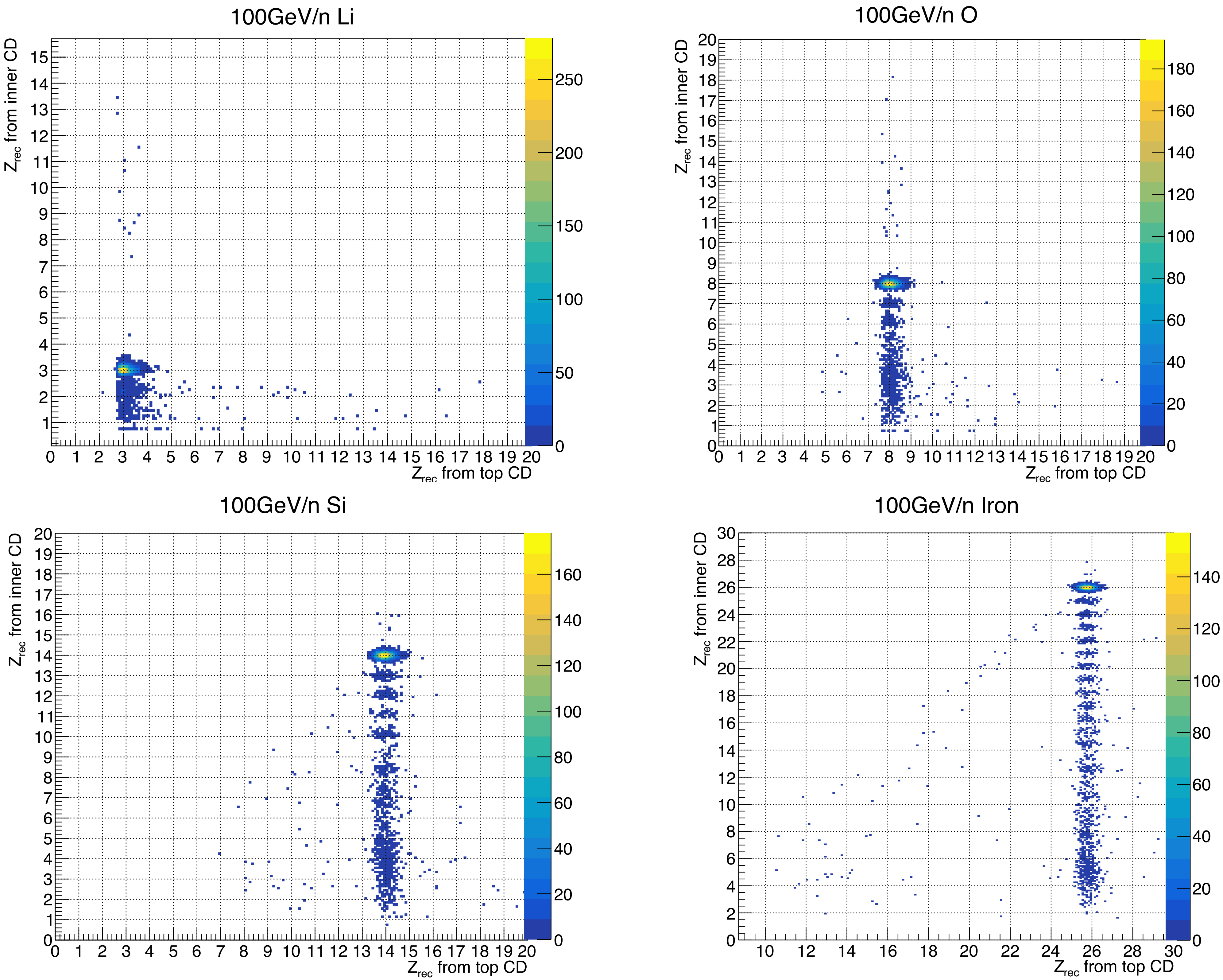
Totally 0.051λ_I and 0.13 X_0 from top CD to inner CD

Using USRBDX to check if the primary particle is changed when crossing the boundary

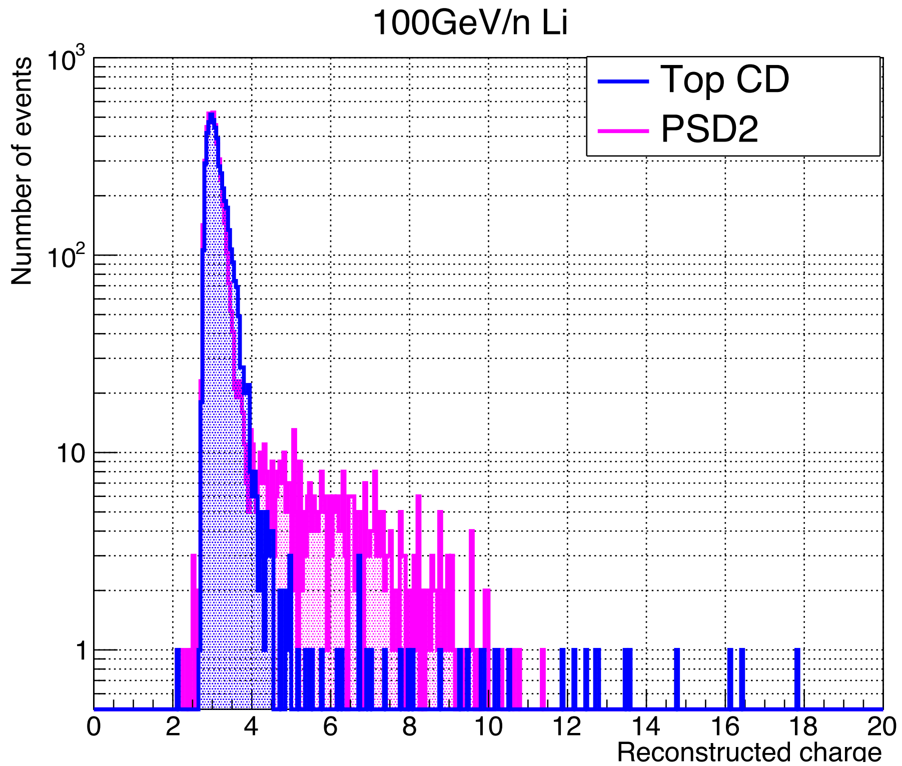
Inner CD vs Top CD

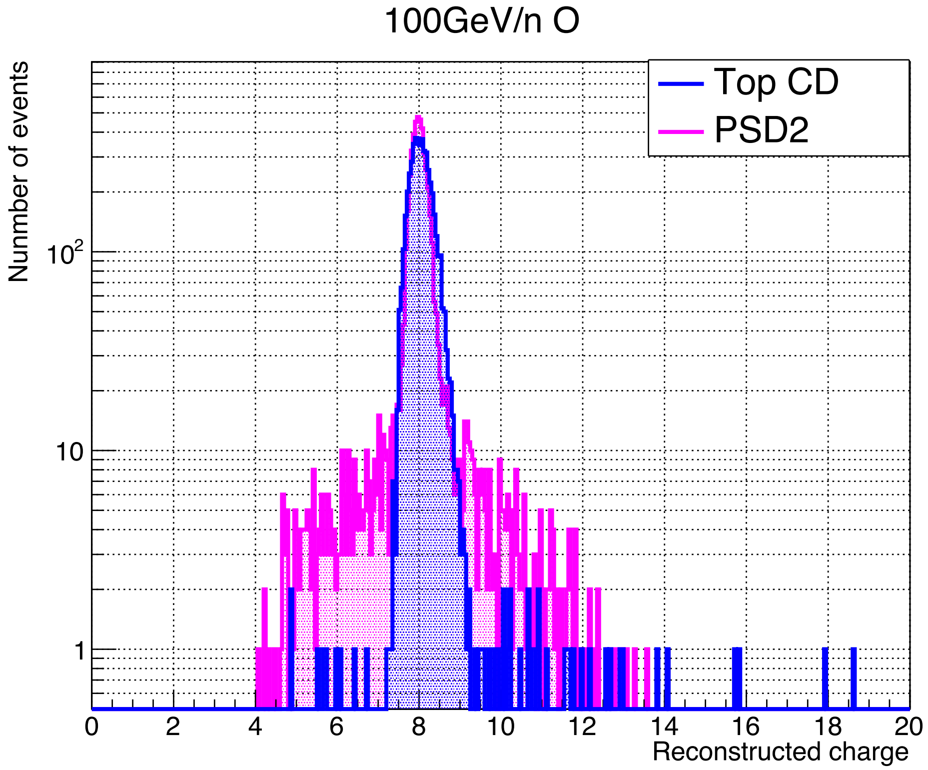


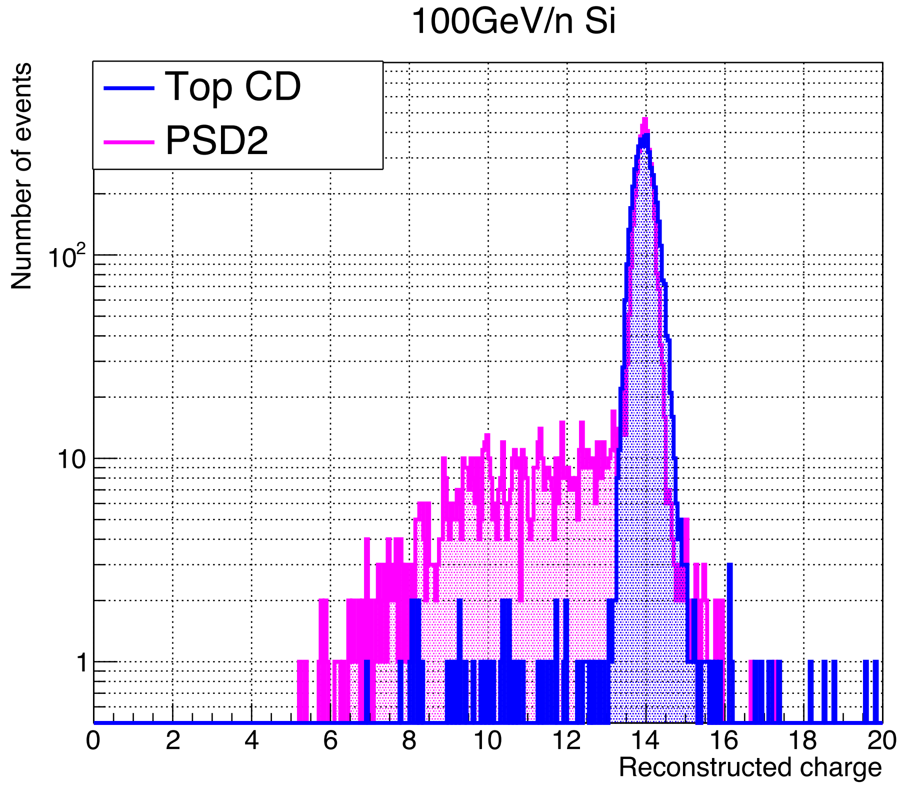
Inner CD vs Top CD

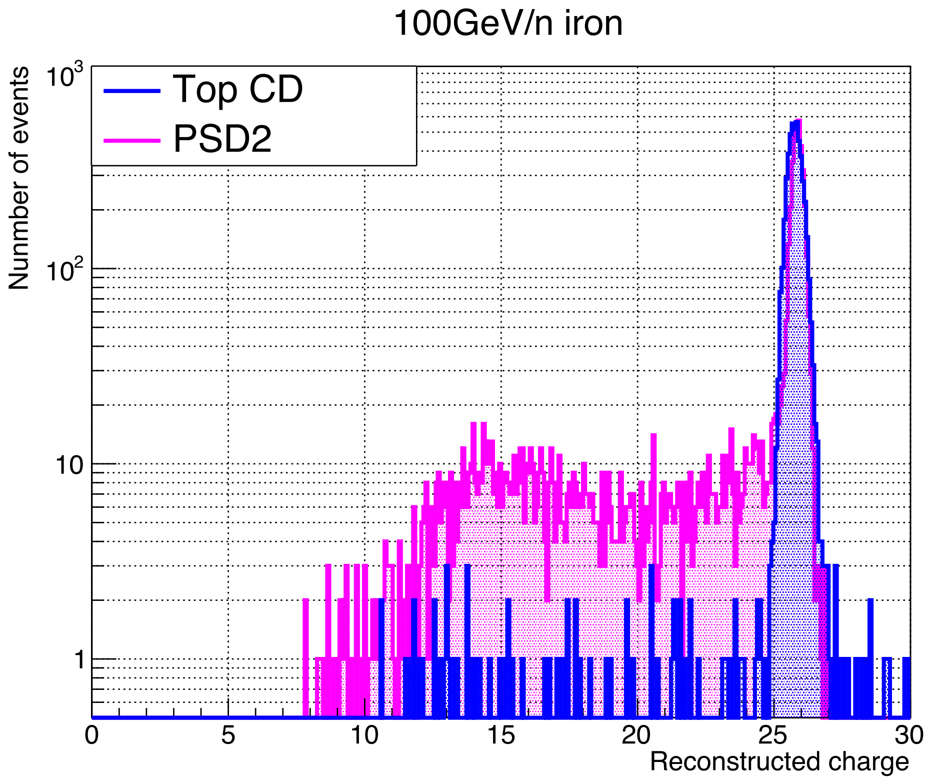


PSD2 vs top CD





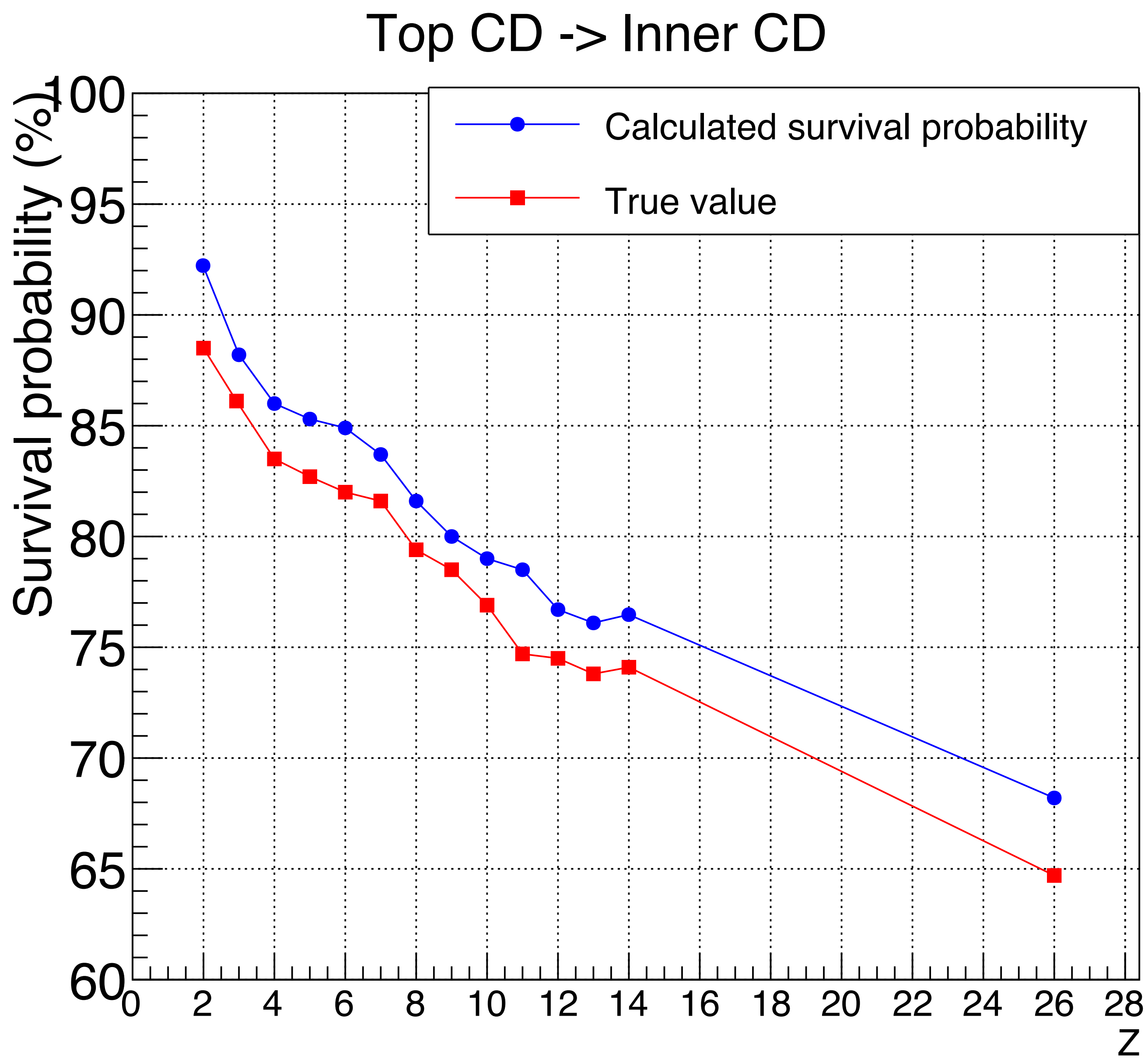




Calculate survival probability

Selection: 2-σ, efficiency>90%

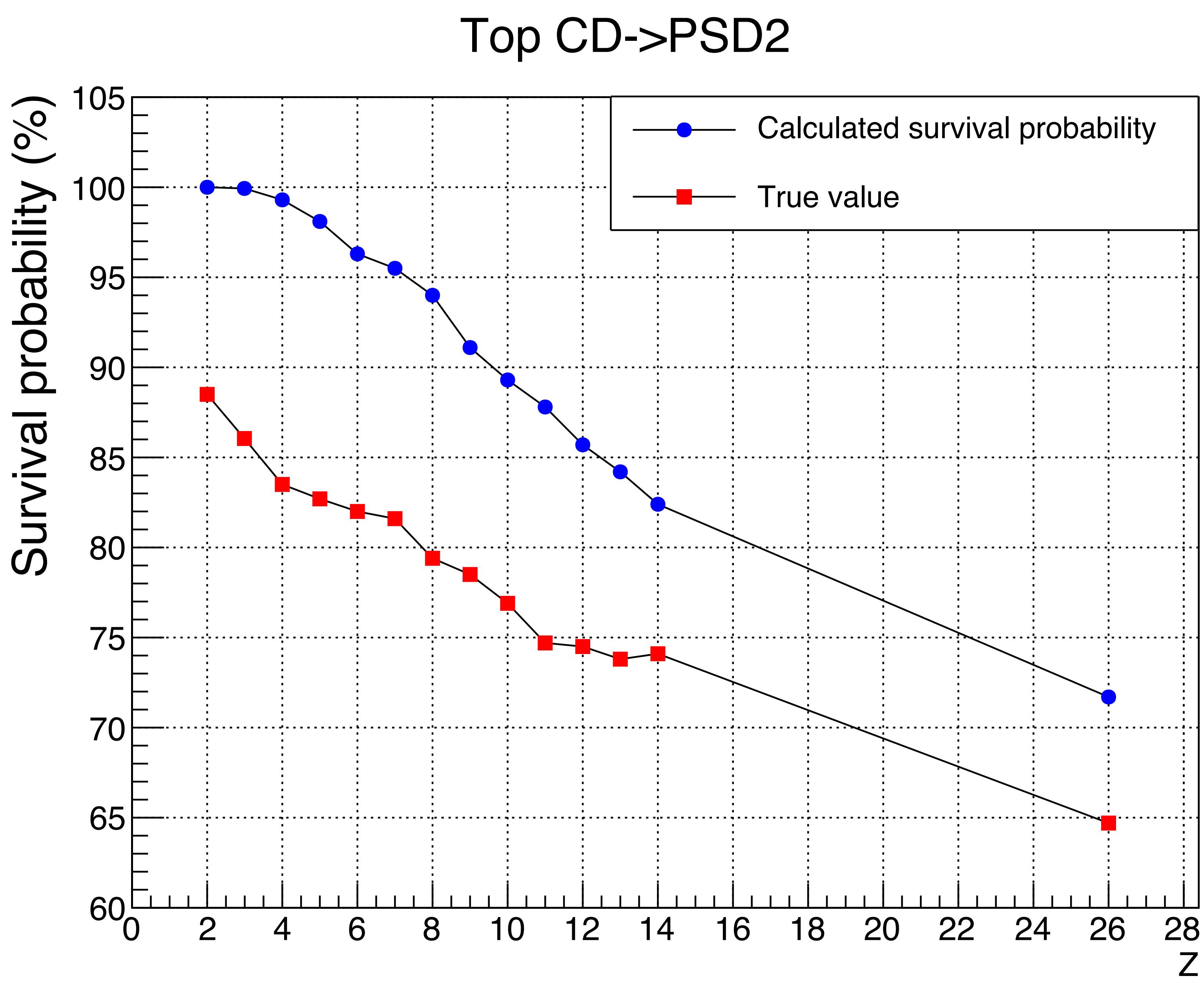
$$\epsilon_{sur} = 1 - N_{inner}(Z < \tilde{Z} - 2\sigma)/N_{top}(2\sigma)$$



Survival probability is always overestimated:

- ✦ Bias from event selection;
- ✦ Charge resolution;
- ✦ Inelastic cross section has isotope channels in which the charge is not changed.

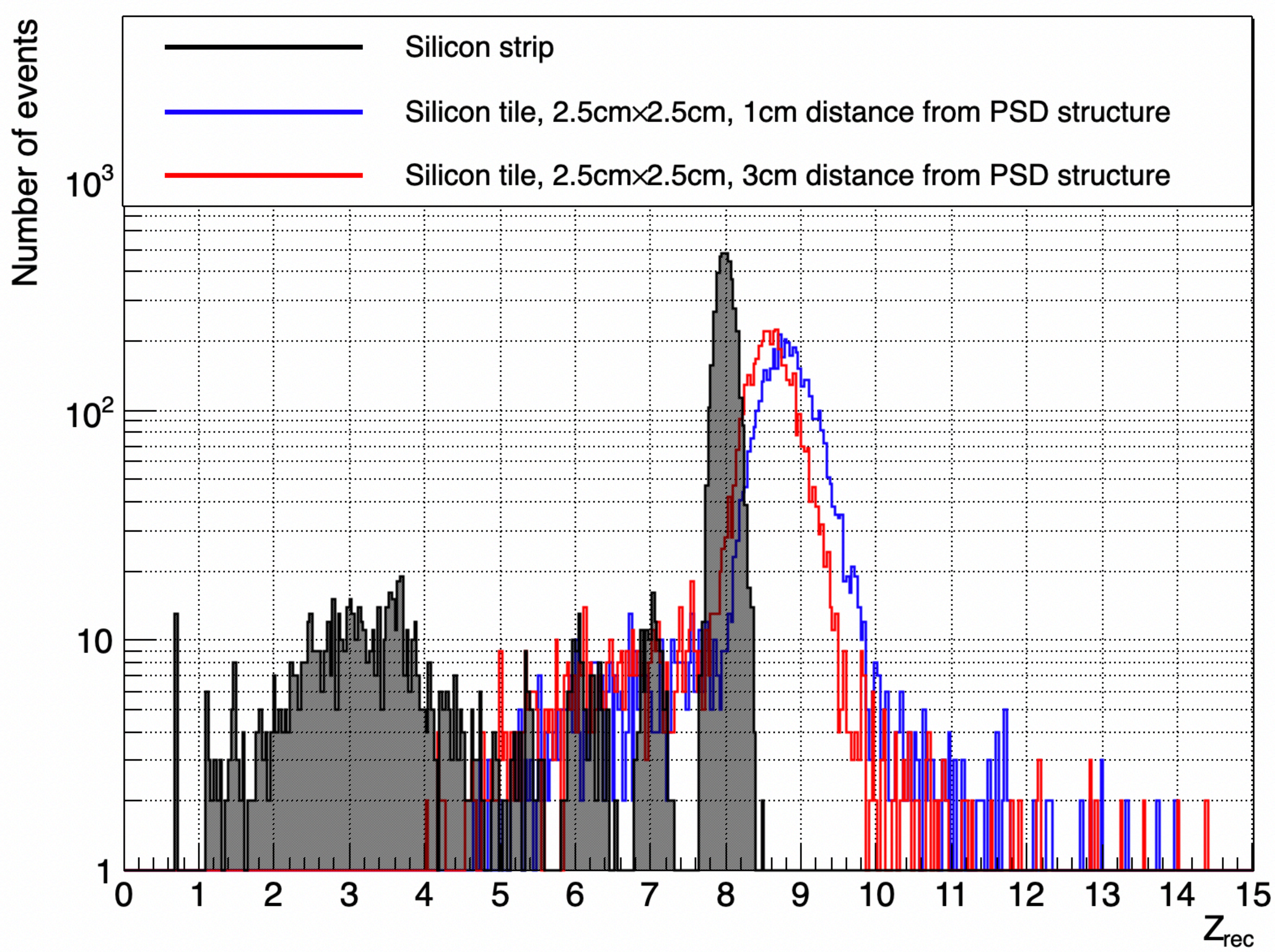
Survival probability (Top CD->PSD2)



Large deviation from the true value:

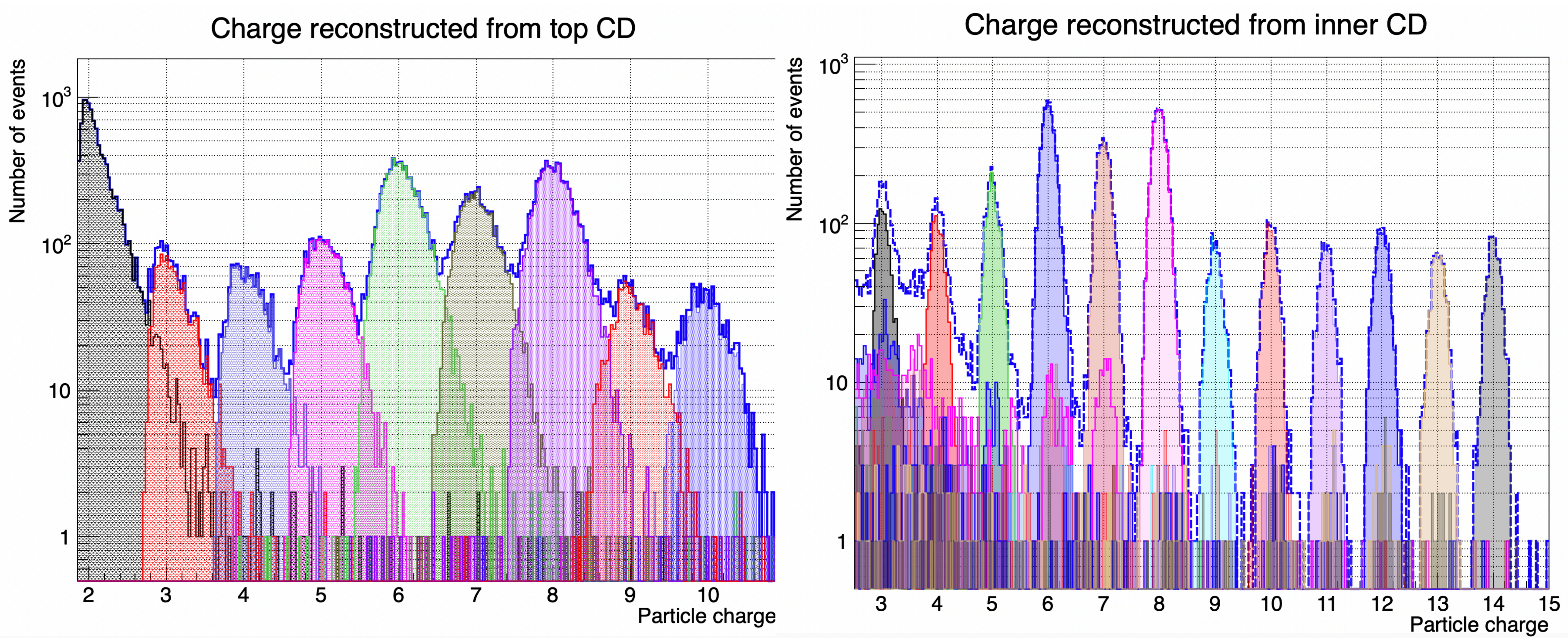
- Fragmentation occurs inside the PSD (0.013 nuclear interaction length)
- Large size, cannot distinguish the primary ion from many secondary particles produced when crossing the pre-material, energy deposition is smeared.

Using 2.5cm×2.5cm Si tile as inner CD



More energy deposition in Si tile, lost fragment information. 3cm distance is not enough.

Backgrounds evaluation of CR



- The amount of background depends both on charge resolution and relative abundance of nuclear species in CR.
- The selection sample would have contamination from heavier ion fragments.

Backgrounds evaluation

In 2-σ selection:

$$BKG_2(Z) = N(\tilde{Z} > \tilde{Z})/N(\tilde{Z} = Z)$$

Z	BKG2 top CD	BKG2 inner CD
3	0.1%	56.1%
4	1.0%	48.6%
5	1.5%	18.9%
6	0.4%	6.1%
7	1.0%	7.7%
8	0.3%	2.4%

- A top charge detector is necessary to reject the background from heavy ion fragmentation.

Conclusion

- ✦ Using Fluka+Dpmjet3 to study the behavior of high energy ions passing through materials, a top charge detector can be used for evaluating the fragmentation probability;
- ✦ It’s hard for PSD (180cm×3cm×1cm) to detect all the fragments;
- ✦ A highly segmented charge detector with good charge resolution is needed for precise measurement of produced fragments and relative inelastic cross sections.

Future work:

➡Geometry update;

➡Digitization of charge detector signal;

➡Study the details of nuclei productions by recording the information of all secondary particles;

➡Study the requirement of geometrical acceptance of charge detector.

Thank you