Simulation of ZDC detector at SPD-NICA

START program results on behalf of the SPD collaboration.

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Outlook

Motivation

Motivation

- ZDC detector is needed for neutral particle detection and it serves from luminosity and time measurements to local polarimetry.
- Detector description should be modular and agnostic from implementation of simulation and reconstruction tasks.
- InSTEC participation under the frame of JINR and Havana University collaboration agreement.
- Conclusion of START program by my self.

ZDC Geometry Setup

ZDC Geometry Setup

Located symmetrically outside of the detector barrel at 0° wrt. the beam line (Z axis) at $\approx 13m$ from IP.

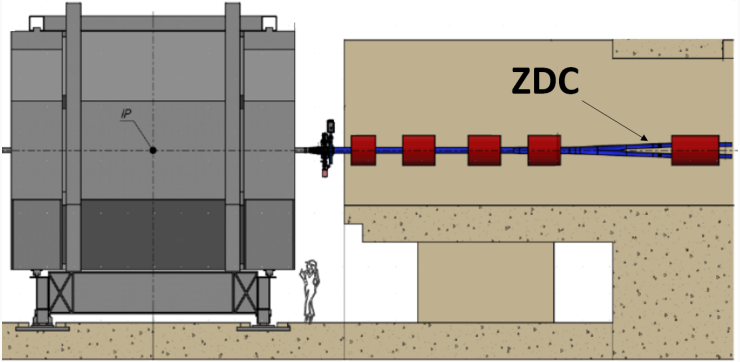


Fig. 1: ZDC position relative to main detector.

ZDC Geometry Setup

A small gap between the beam pipes inside the cryostat will host the ZDC in the shape of a trapezoid.
(74mm x 50mm - 126mm x 50mm - 611mm)

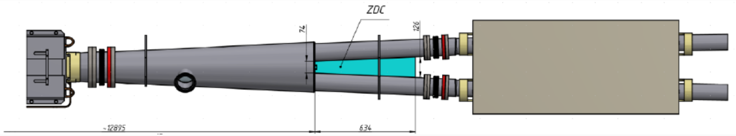


Fig. 2: Available space between beam pipes.

ZDC Geometry Setup

The detector is made of planes with increasing length according to the available space.

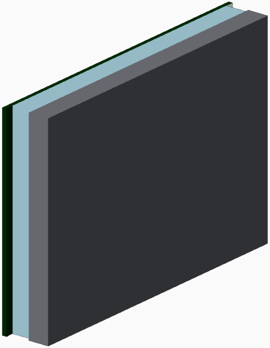


Fig. 3: ZDC detection plane composition. W absorbent plate (Grey), Plastic Scintillator Tiles (Blue), PCB (Dark Green).

ZDC Geometry Setup

When fully assembled with 30 planes, it consist of two main parts: Electro-Magnetic(8) and Hadronic(22).
Material thickness differentiates both parts. 5mm vs. 10mm.

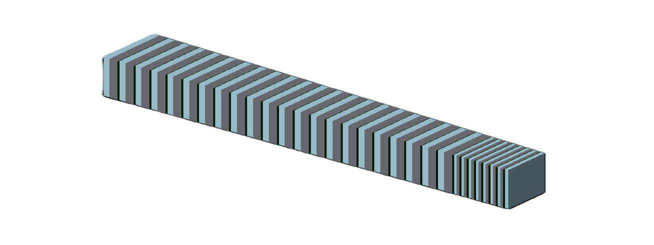


Fig. 4: ZDC full assembly.

ZDC Geometry Setup

- Geometry description was developed using GeoModel.
- A binary format for general geometry persistence (GeoFlat) was developed as alternative to GeoModel's SQLite approach.
- There are also efforts to integrate CAD systems into the toolchain for geometry.

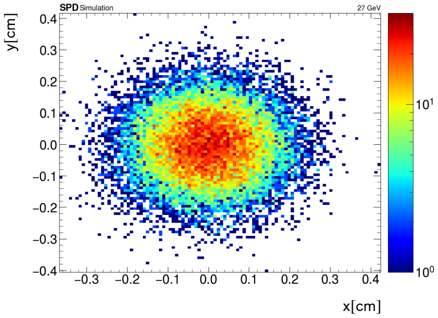
Event generation

Event generation

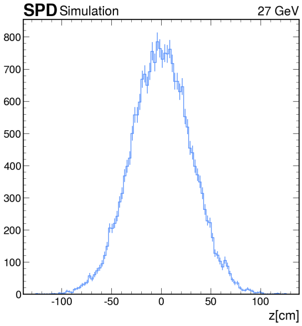
- Event generator: PYTHIA8, p+p collisions at $27\,GeV$.
- Selection cuts based on neutral particles with $\eta > 4.1$, region seen by the ZDC.
- Future studies will include d+d collisions from FTF(Fritiof) event generator.

Event generation

Following expected primary vertex smearing for SPD.



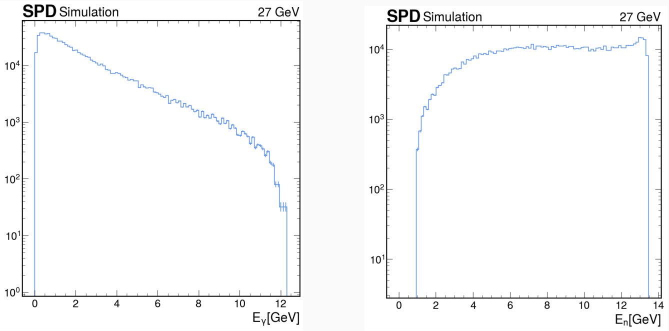
(a) Transversal Plane $\sigma = 0.1cm$



(b) Beam axis $\sigma = 30cm$

Fig. 5: Primary vertex distribution.

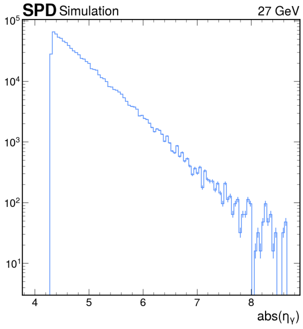
Event generation



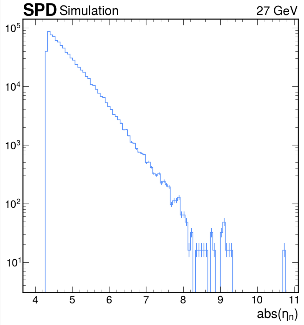
(a) gammas **(b)** neutrons

Fig. 6: Energy distribution of accepted particles.

Event generation



(a) gammas



(b) neutrons

Fig. 7: Pseudorapidity distribution of accepted particles.

Detector response simulation

Detector response simulation

Geometry description was developed in C++ while the rest used python bindings (PYTHIA8, GEANT4) or native python libraries (Analysis).

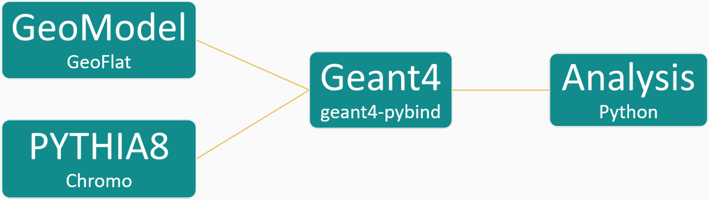


Fig. 8: Simulation workflow.

Detector response simulation

Event snapshots for different primary particles.

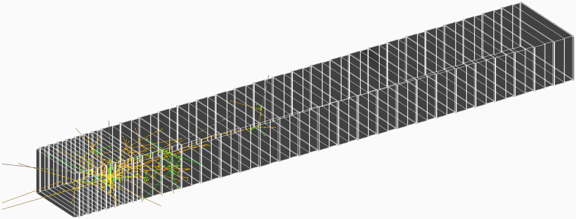


Fig. 9: Gamma event sample.

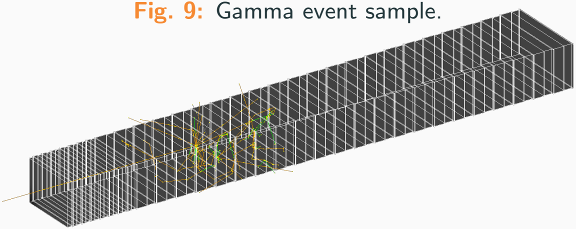
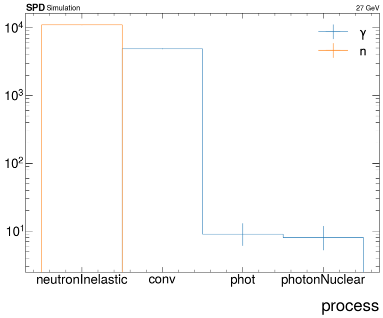


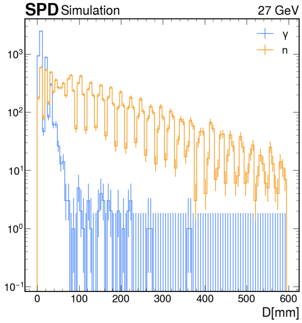
Fig. 10: Neutron event sample.

Detector response simulation

The formation of an EM/Hadronic shower was studied per primary particle.



(a) Process



(b) Depth

Fig. 11: EM/Had shower formation.

Detector response simulation

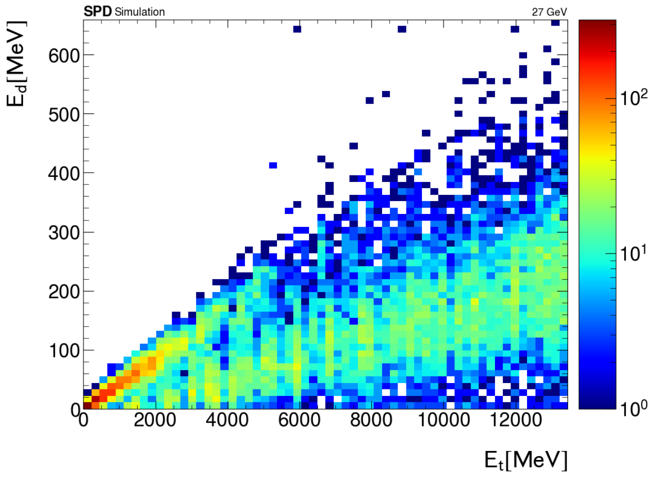


Fig. 12: Deposited Vs. Total energy. Less than 7% efficiency.

Detector response simulation

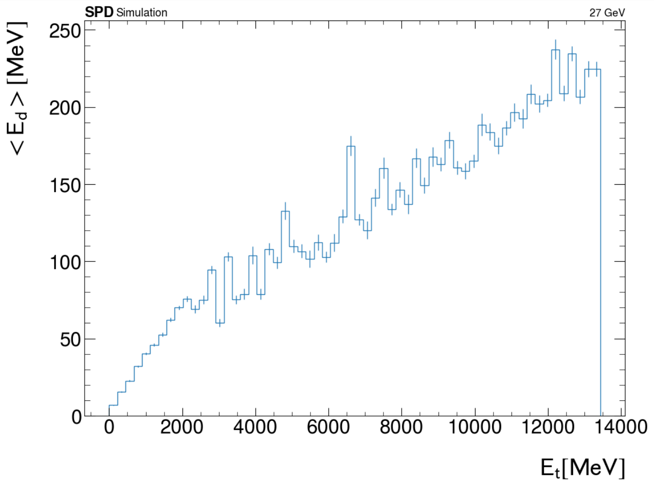


Fig. 13: Deposited energy profile. Less than 7% efficiency.

Detector response simulation

- Basic centroid reconstruction of primary particle was attempted from energy deposition in scintillators.

$$\vec{r} = \frac{\sum_i dE_i \vec{r_i}}{\sum_i dE_i} \tag{1}$$

- Same information was extracted from truth particle tracking for comparison.

Detector response simulation

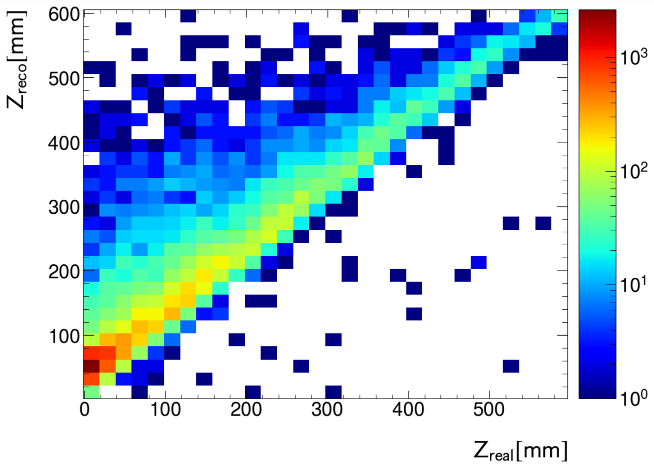


Fig. 14: Reconstructed Vs. Real Z of primary particle. $RMSD = 74.99mm$

Detector response simulation

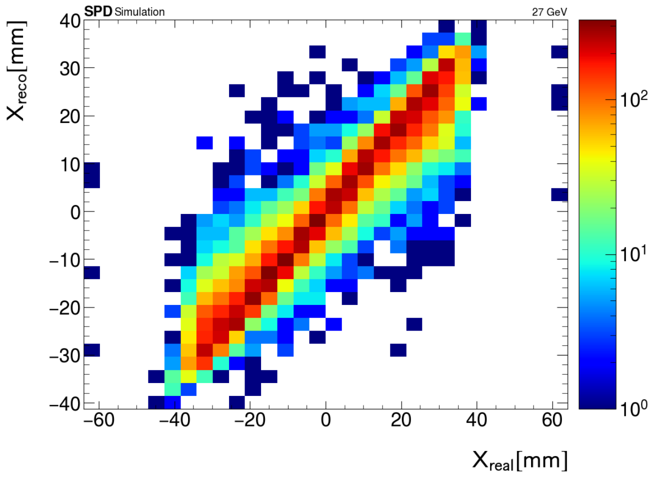


Fig. 15: Reconstructed Vs. Real X of primary particle. $RMSD = 6.829mm$

Detector response simulation

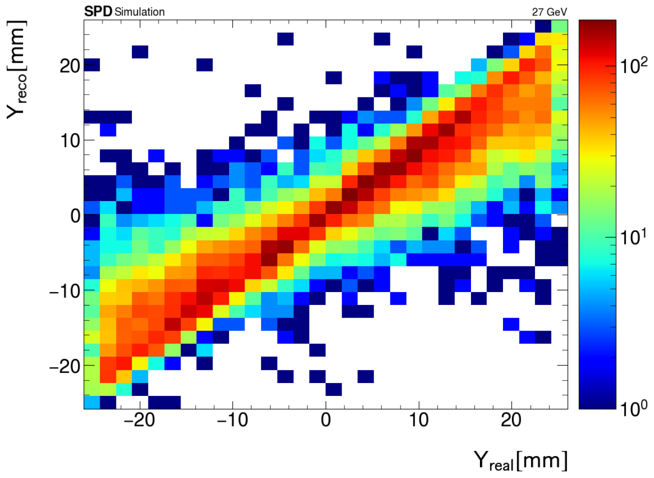


Fig. 16: Reconstructed Vs. Real Y of primary particle. $RMSD = 6.216mm$

Detector response simulation

Using x and y reconstruction the azimuthal angle can be observed.

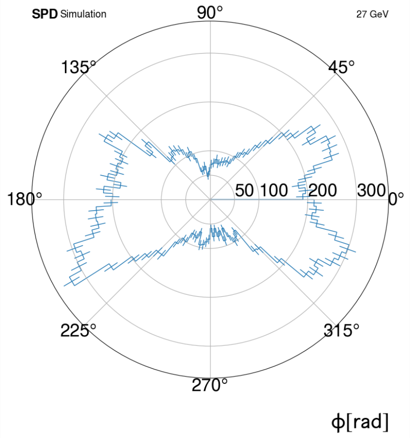


Fig. 17: Reconstructed azimuthal distribution.

Summary and Conclusions

Summary and Conclusions

- Using the Technical Report and the Conceptual Design of SPD experiment we created a functional simulation of the ZDC detector.
- Energy deposition is bellow 7% due to leakage, which reduces the chances of precisely tag incoming particles.
- The centroid reconstruction algorithm yields reasonable accuracy in the transversal plane but needs further adjustments to achieve the desired resolution along the z axis.

Future Work

Future Work

- Collect more details about the experimental assembly from Moscow's Kurchatov Institute beyond the TDR.
- Test different configurations for material distribution (Scintillator/Absorbent) and shielding for better efficiency in energy deposition inside the detector and therefore redice leakage.
- Apply corrections for the COM movement in laboratory system to reconstruction.
- Using the response matrices for x, y and z, unfold the reconstructed distributions to better reflect the detector effect and increase accuracy.

Contact Information

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