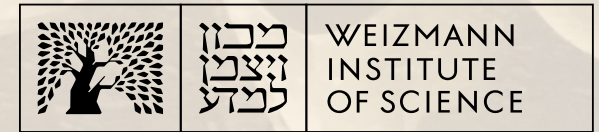


Application of ALPIDE Detectors in a Telescope Configuration in SFQED Experiments

Noam Tal Hod, Roman Urmanov, Nathaly Nofech-Mozes,
Arka Santra, Alon Levi, Oleksandr Borysov



14th Beam Telescopes and Test Beams Workshop

April 13, 2026

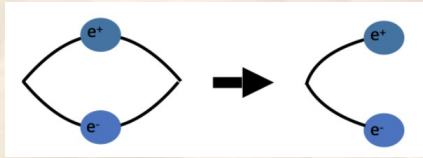
Outlook

- Introduction, E320 setup at FACET-II
- Simulation study with ALPIDE tracking detector
- Tracker prototype installation
- Results from run campaigns in 2025
- Summary

Strong Field QED Physics processes

Strong-field QED regime is defined by so-called Schwinger critical field;

It does work equal to the electron rest mass over a distance of one Compton wavelength.:



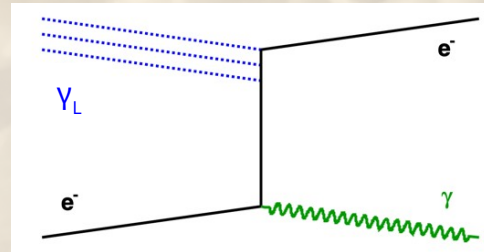
$$\frac{\hbar}{mc} e \varepsilon \geq mc^2$$

$$\varepsilon_s = \frac{m^2 c^3}{\hbar e} = 1.3 \times 10^{18} \text{ V/m}$$

- It is well below terrestrially producible fields;
- For moving charge the field is enhanced by Lorentz factor;
- Thus it can be probed in collisions of electrons with high power laser pulses.

Non-linear Compton Scattering (NCS):

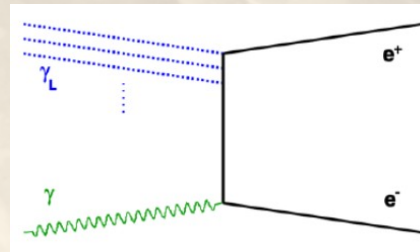
$$e^- + n \gamma_L \rightarrow e^- + \gamma$$



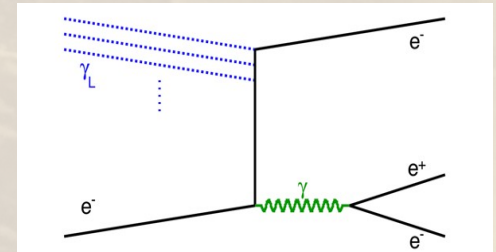
Pair production:

non-linear Breit-Wheeler (NBW) and trident

$$\gamma + n \gamma_L \rightarrow e^+ + e^-$$

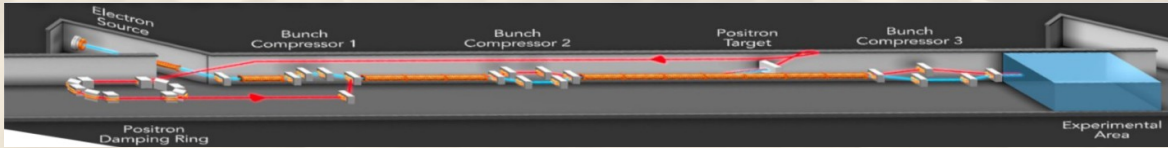


$$e^- + n \gamma_L \rightarrow e^- + e^+ + e^-$$



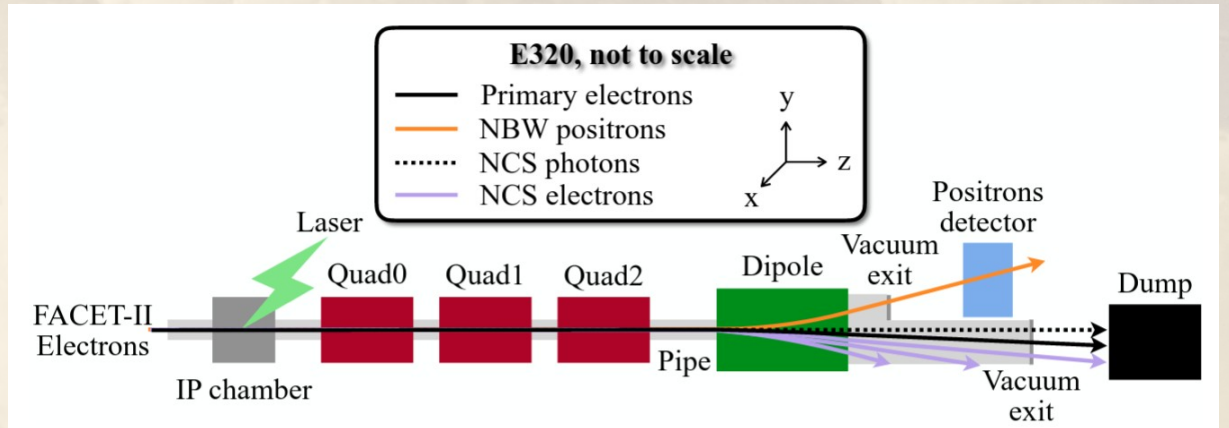
Experiment 320 (E320) at FACET-II (SLAC)

FACET-II: Facility for Advanced Accelerator Experimental Tests at SLAC



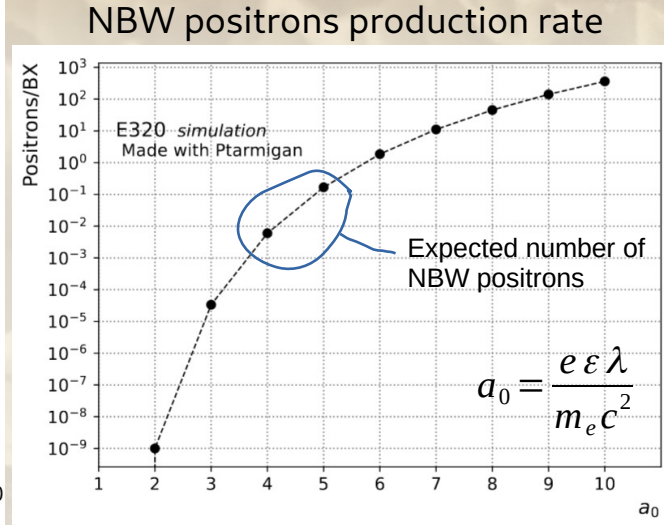
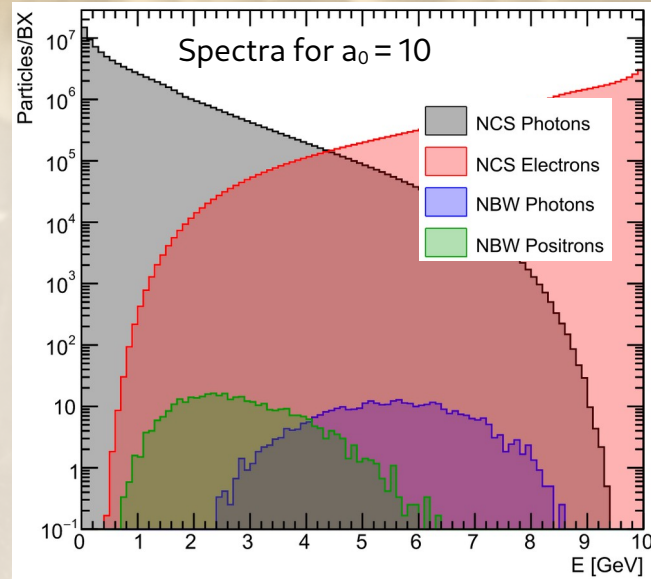
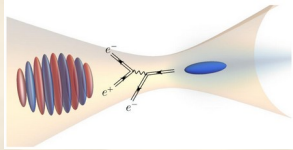
| Parameter | Value | Units |
|------------------------|---------------------|-------------------|
| Laser | | |
| Power | ~ 10 (upgrade: 100) | [TW] |
| Pulse repetition rate | 10 | [Hz] |
| Wavelength | 0.8 | [μm] |
| Pulse spot size (FWHM) | 2-3 | [μm] |
| Pulse duration | $\lesssim 60$ | [fs] |
| Beam diameter | 40 | [mm] |

| Parameter | Value | Units |
|-------------------------|---------------|-----------------------|
| Electron beam | | |
| Final beam energy | 10 (8-13) | [GeV] |
| Final rms energy spread | ~ 1 | [%] |
| Bunch charge | 1-2 | [nC] |
| Pulse repetition rate | 10 (1-30) | [Hz] |
| Bunch length | $\lesssim 20$ | [μm] |
| Bunch transverse size | $\gtrsim 30$ | [μm] |
| β^* | 0.5 (0.1-1) | [m] |
| Emittance (normalized) | $\gtrsim 35$ | [$\mu\text{m-rad}$] |

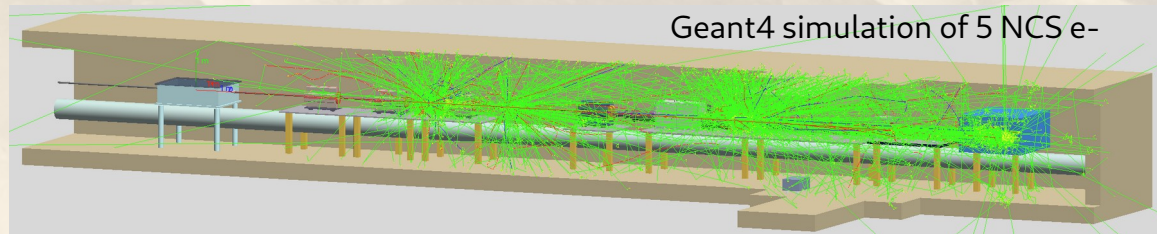


SFQED Signals at FACET-II

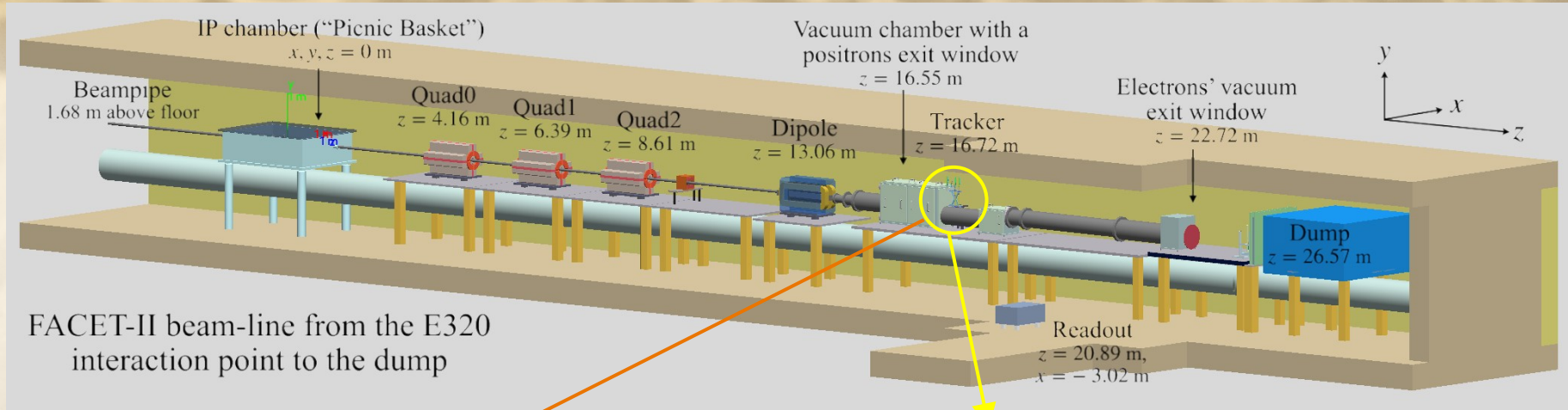
Simulation collisions of FACET-II electron beam with laser pulse using Ptarmigan, [git](#)



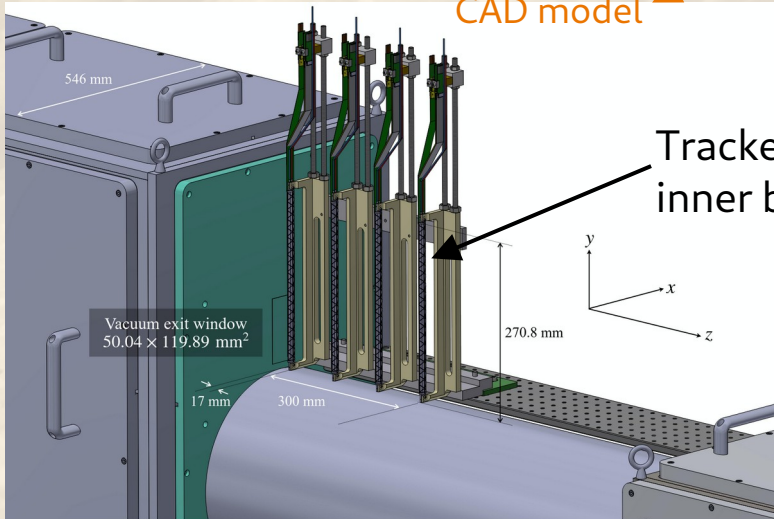
- Expected number of NBW positrons: **0.1 - 0.01** per bunch crossing (BX);
- Number of NCS electrons and photons 0.1-1% of primary electron beam: **10^6 - 10^7** ;
- NCS electrons and photons create substantial level of the background for positron detection $\sim 10^3$ - 10^4 hits per BX;
- Use tracking detector with high position resolution to be able to:
 - reconstruct path to production position and reject background particles
 - measure energy with 1% uncertainty



E320 Geant4 geometry

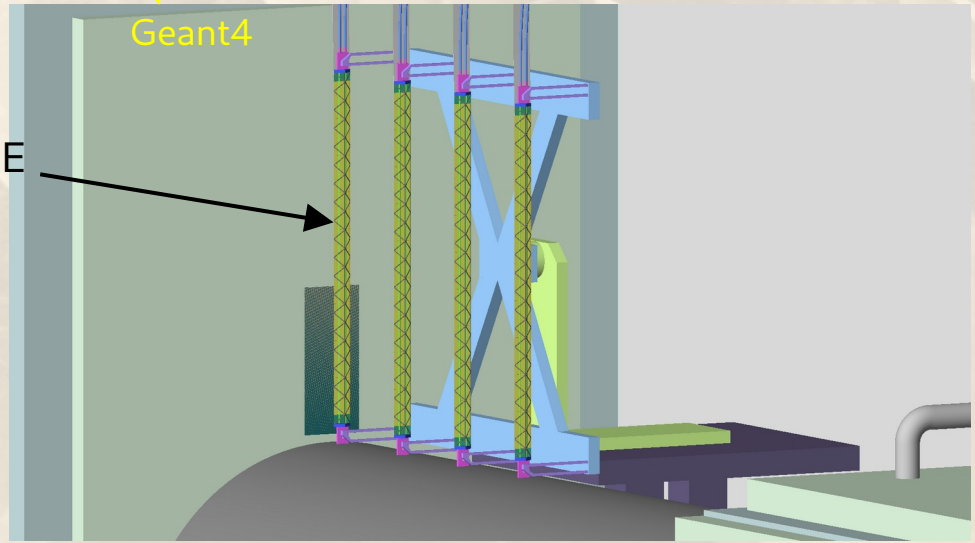


CAD model



Tracker built of 4 ALICE inner barrel staves

Geant4



Results from the simulations

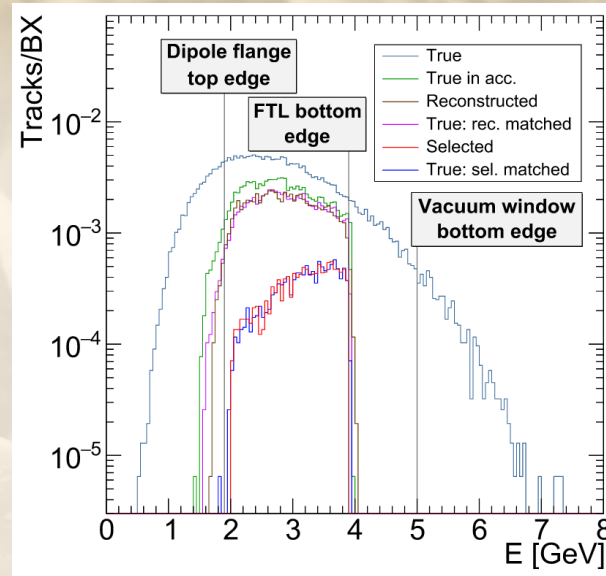


Event reconstruction is performed using the ACTS (A Common Tracking Software) framework.

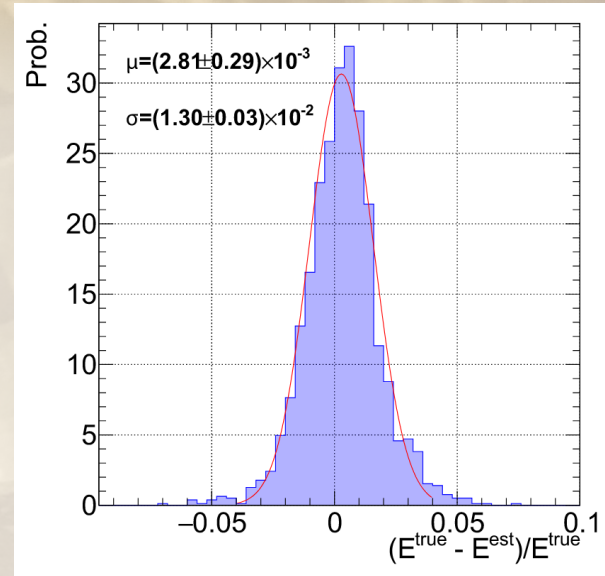
- ACTS detector geometry is based on Geant4 model;
- Magnetic field maps are also imported from Geant4;
- Track finding with Kalman Filter (KF) and Combinatorial KF with propagation to IP.

- Rate for signal positrons (per BX): $(1.280 \pm 0.004) \times 10^{-2}$;
 - ~71% positrons hit at least one sensor
 - ~65% reconstructed
 - ~15% selected
- Estimated energy resolution: ~1.33%
- Rate for background tracks (per BX): $(1.87 \pm 0.13) \times 10^{-4}$;

Positrons energy spectra



Energy resolution

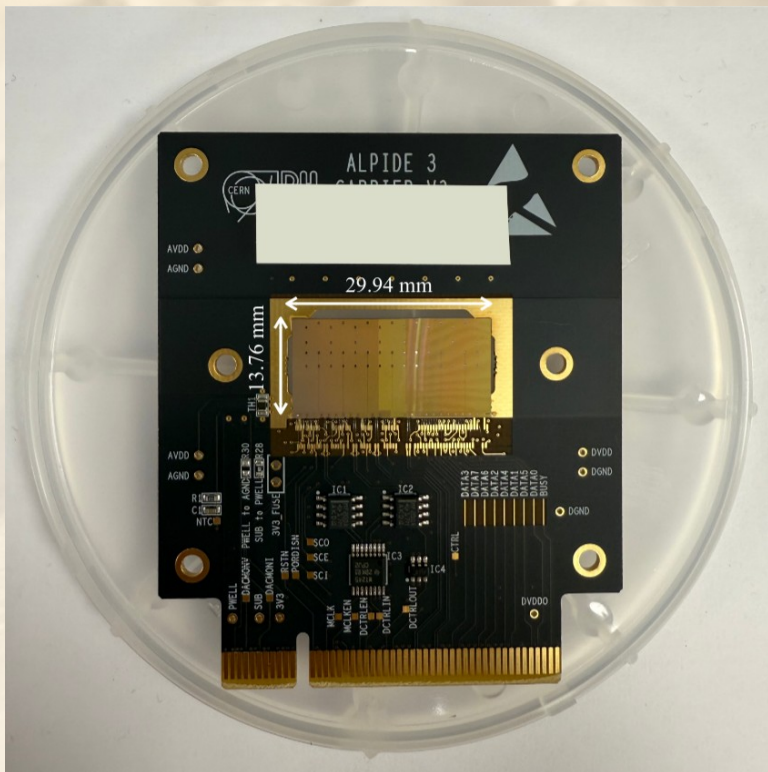


[Nucl.Instrum.Meth.A 1083 \(2026\) 171144](#)

NBW signal positrons can be reliably detected

E320 tracker prototype

Single ALPIDE chip on the carrier board



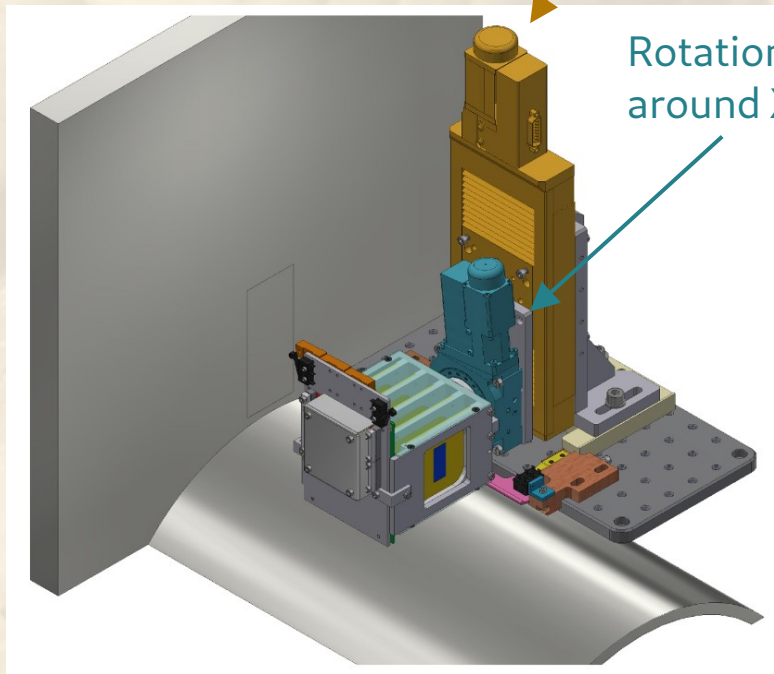
9-chip adapter board with one mounted carrier board



5 layers with ~20 mm distance between layers, every second PCIe in 9-chip adapter is used.

E320 Tracker Prototype

CAD Model

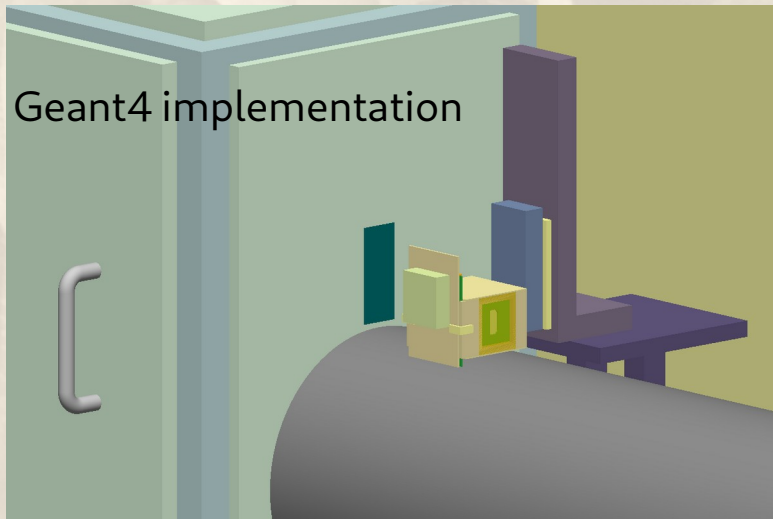


Moving stage in Y direction

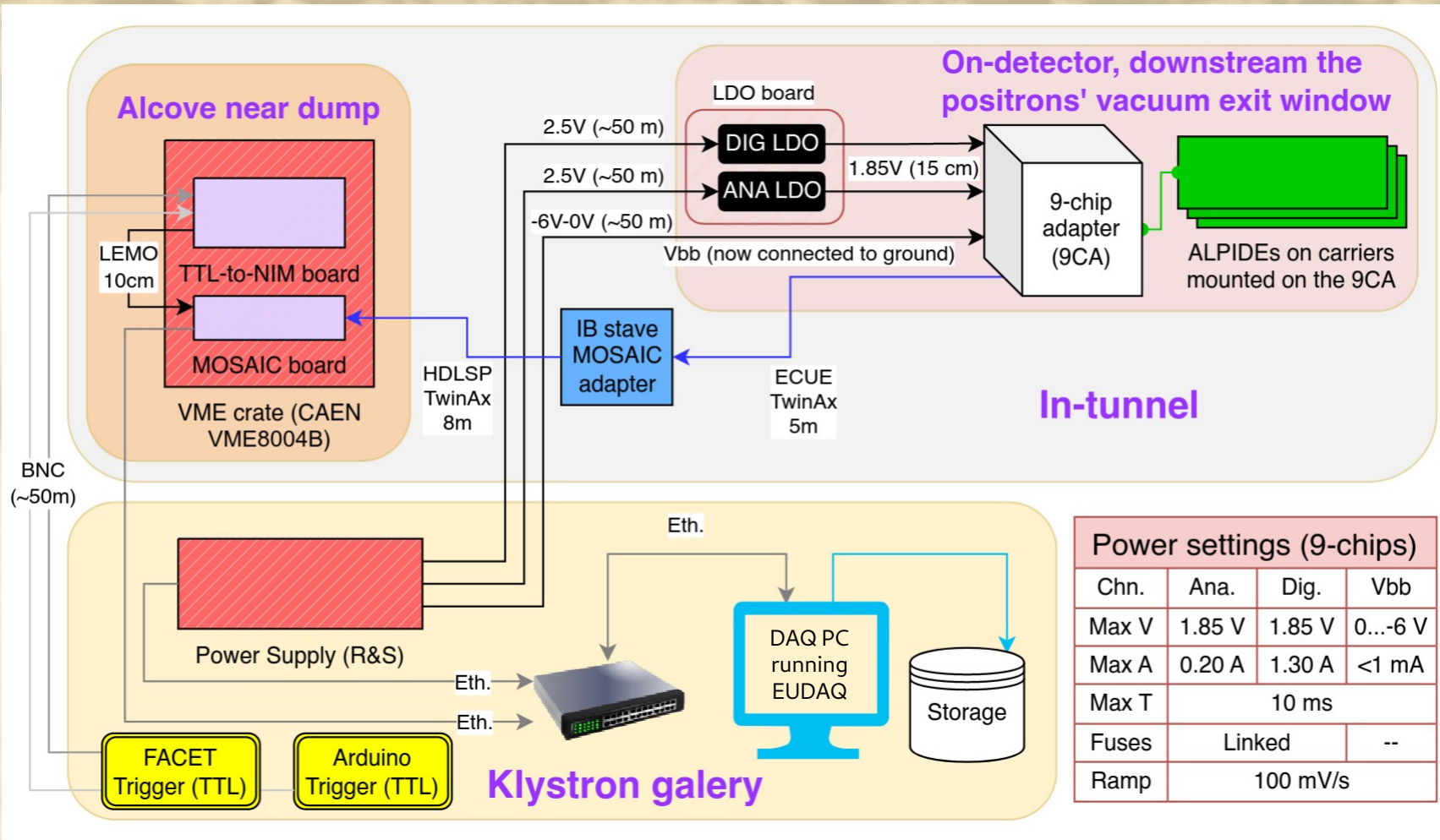
Rotational stage around X direction



Installation in FACET-II Lab before moving to the tunnel



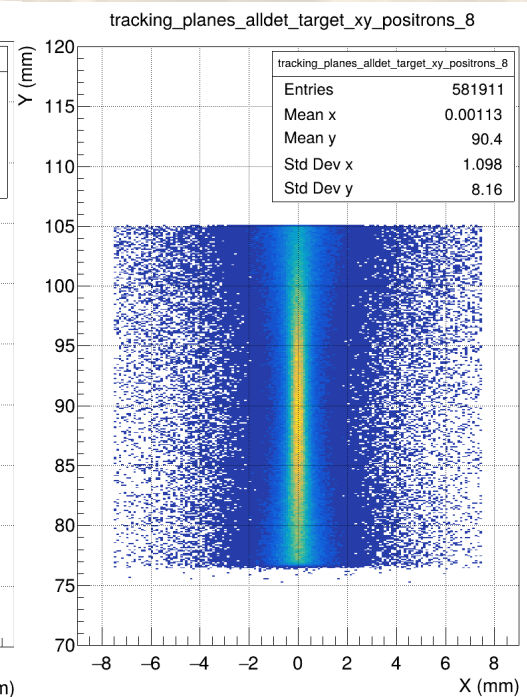
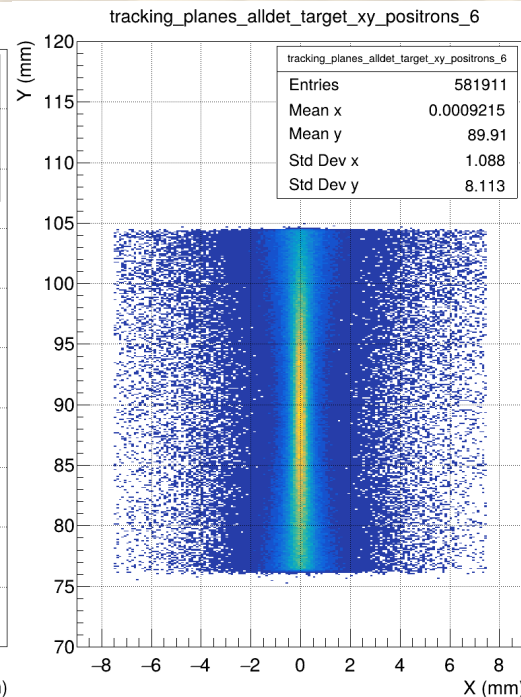
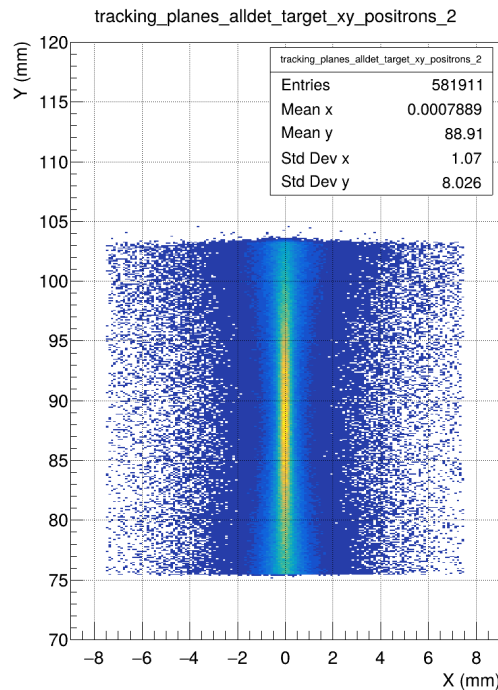
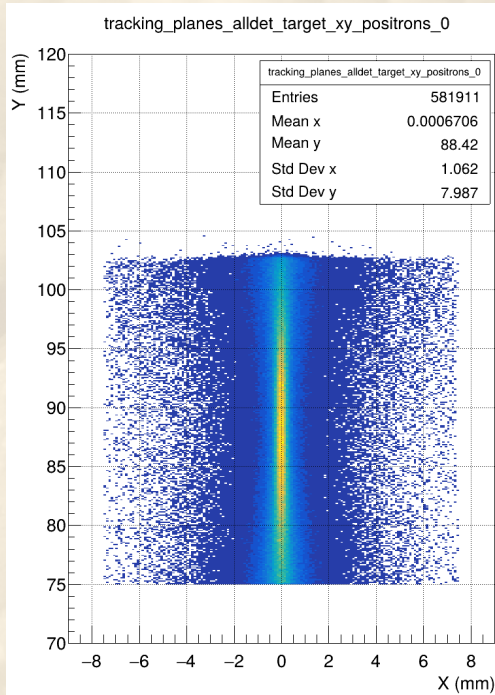
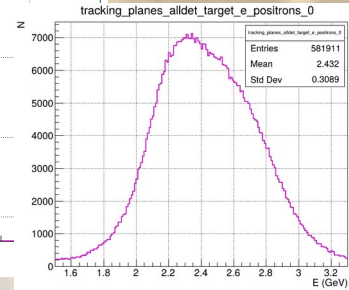
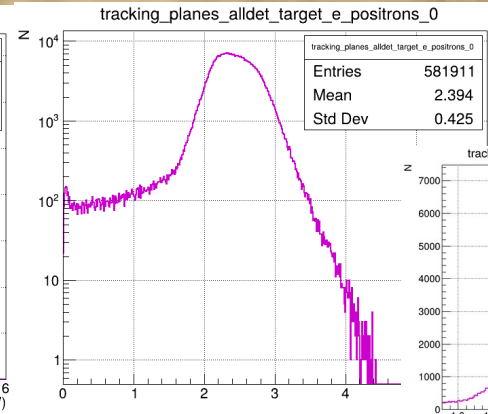
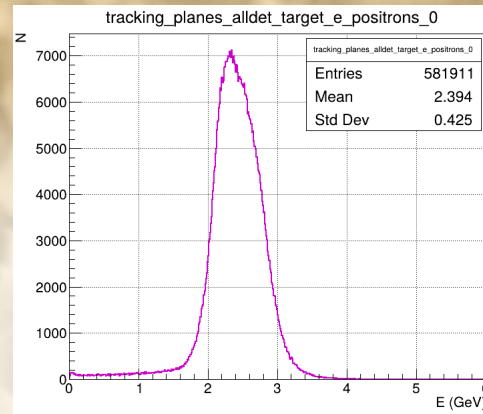
Readout and power



Geant4 simulations with prototype

Positrons:

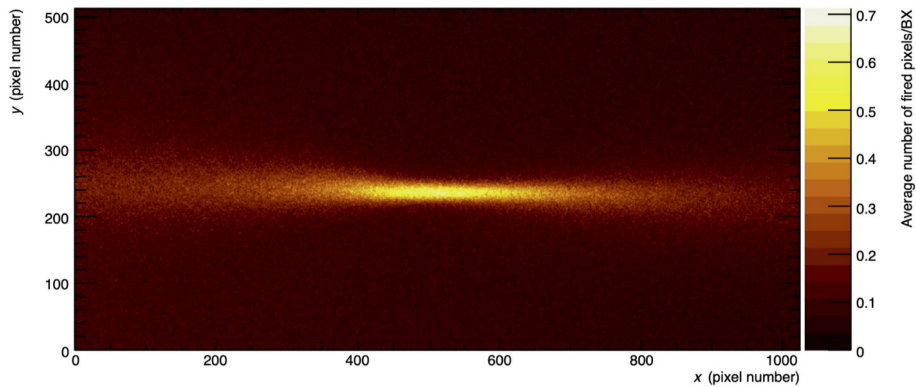
- produced in Be target
- crossed all 5 planes of the tracker;
- Occupancy of first and last two are shown



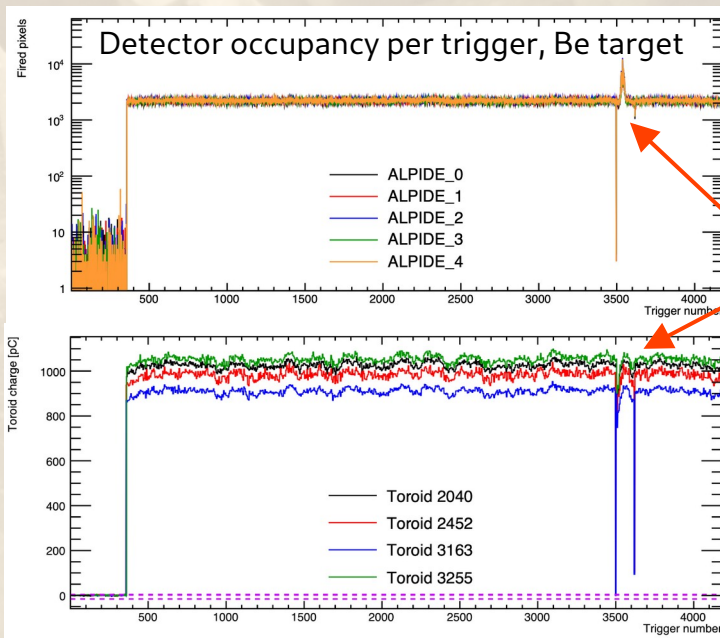
Data Taking Campaigns with Tracker Prototype

- Data-taking campaigns:
 - Nov. 2024 (initial test)
 - Feb. 2025 (e+ from Be, Al targets)
 - May 2025 (NBW positrons, ongoing analysis)
- Experience in alignment, subsystem synchronization, magnet operation, etc.
- Close communication with accelerator control team for beam orbit tuning to minimize the background.

ALPIDE_0: average pixel occupancy over 250 BXs

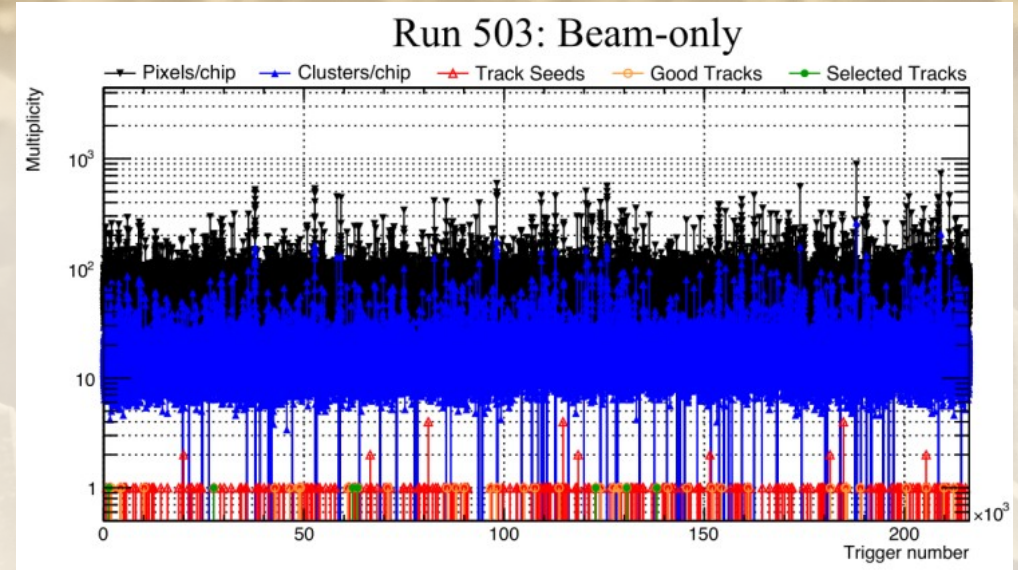
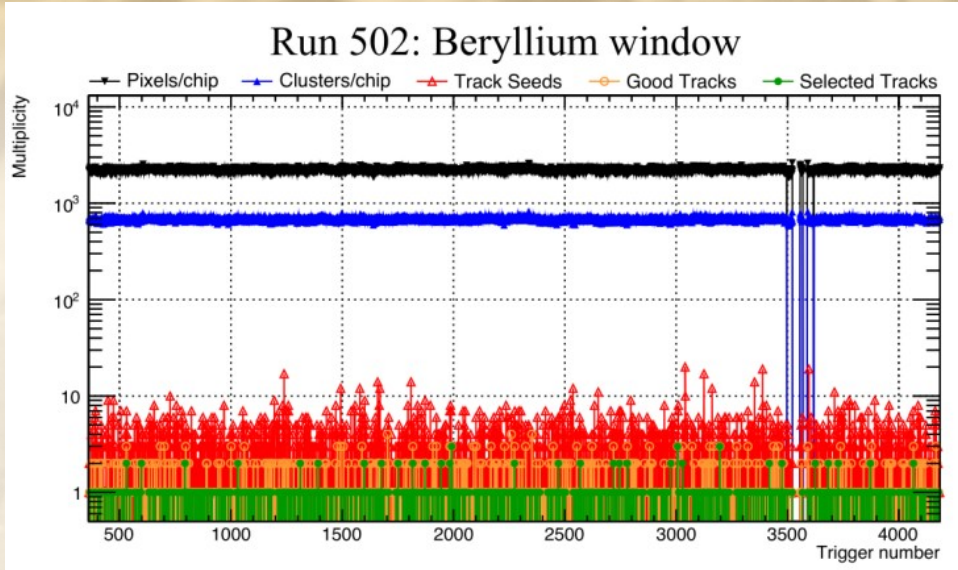


- Hit map of positrons produced in Al foil;
- ~50k hits per BX, no tracking.



Beam instability observed in toroids and tracker

Results with positrons from Be target



- Studied two runs:
 - 502, 7 minute, with positrons from Be target;
 - 503, 6 hours, with electron the beam only.
- Be window run rate: 0.17 tracks/BX;
- Beam-only run rate: 3.4×10^{-5} tracks/BX.

5000 times less

- Reconstruction is based on:
 - Hough transform for track seeding;
 - Track fitting using maximum likelihood estimation accounting for multiple scattering;
 - Geometrical and quality cuts.
- Ongoing analysis with ACTS and KF.

Summary

- Positron production in collisions of an electron beam with high-power laser pulses is an interesting process for SFQED studies. Its observation requires advanced detectors and analysis techniques due to the high background from NCS electrons and photons.
- We demonstrated that ALPIDE tracker built of ALICE IB staves provides unambiguous detection of single non-linear Breit-Wheeler positrons in the E320 experiment at FACET-II, in the presence of an overwhelming background.
- Tracker prototype with five layers of single ALPIDE chip was installed at E320.
- Fully participated in data collection in February and May run campaigns.
- Developed and tested algorithms for data cleaning, alignment and reconstruction, though there is definitely still room for improvement.
- Data analysis is very challenging because of high background which is partly related to electron beam orbit settings.
- This technique is considered for application at several other facilities searching for NBW positrons: ELI-NP (Romania), Apollon (France), and CoReLS (Korea) using PWFA electron beams.

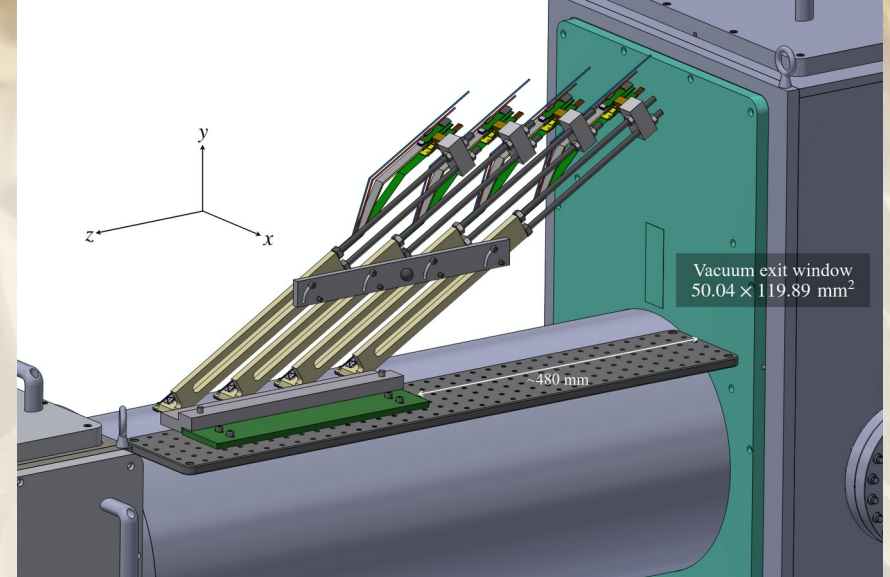
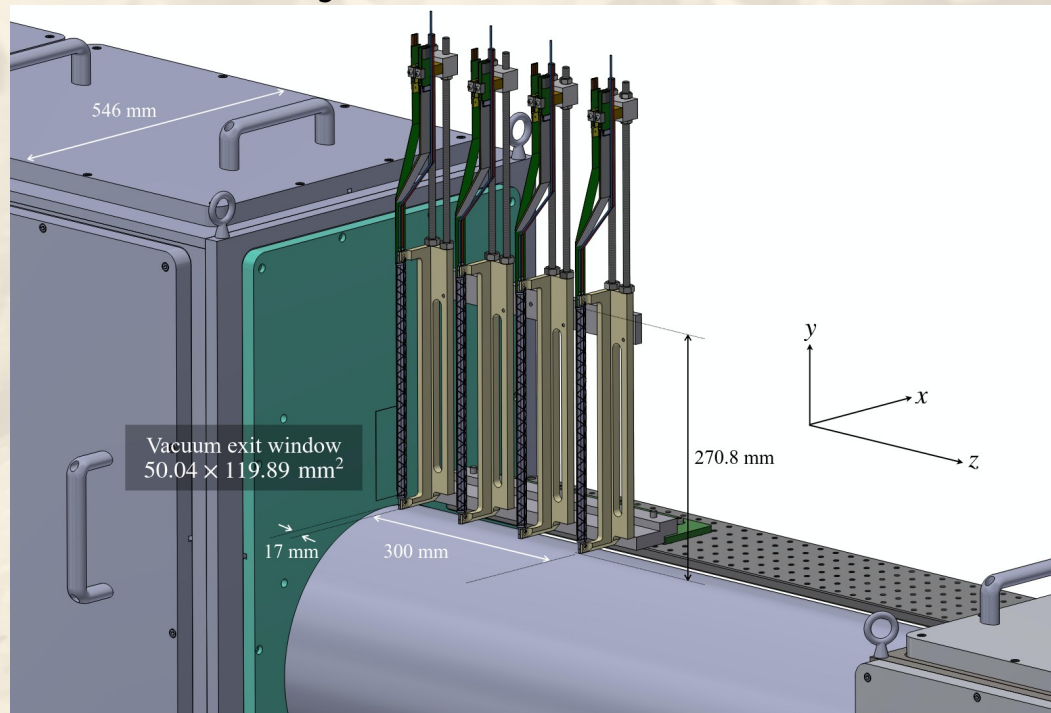
Thank you for your attention!

Backup

Design of positron tracker

The goal is to detect NBW positrons

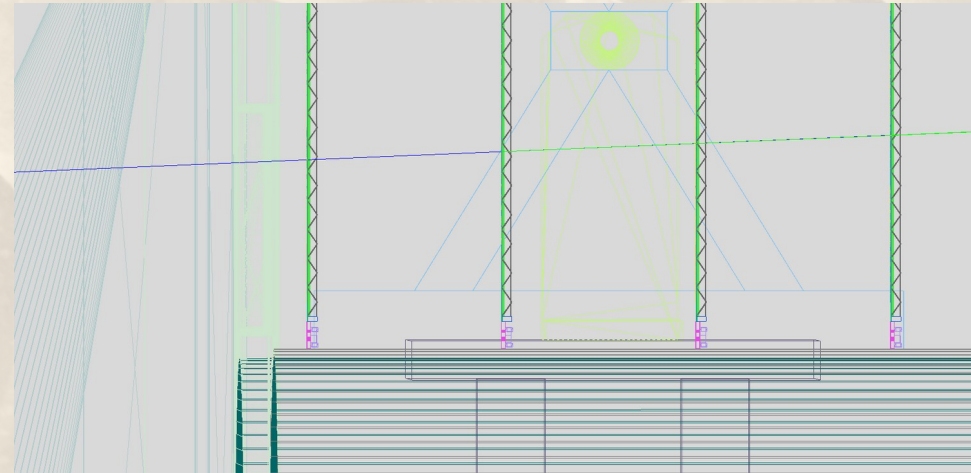
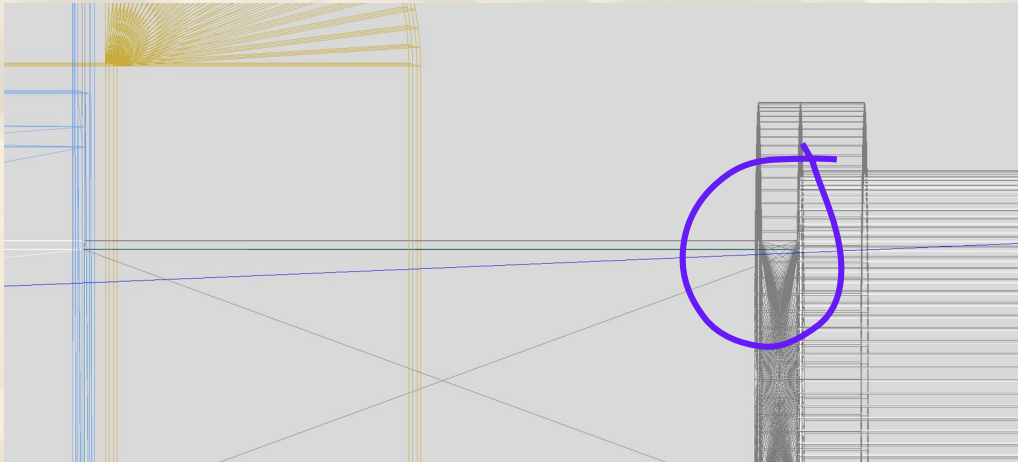
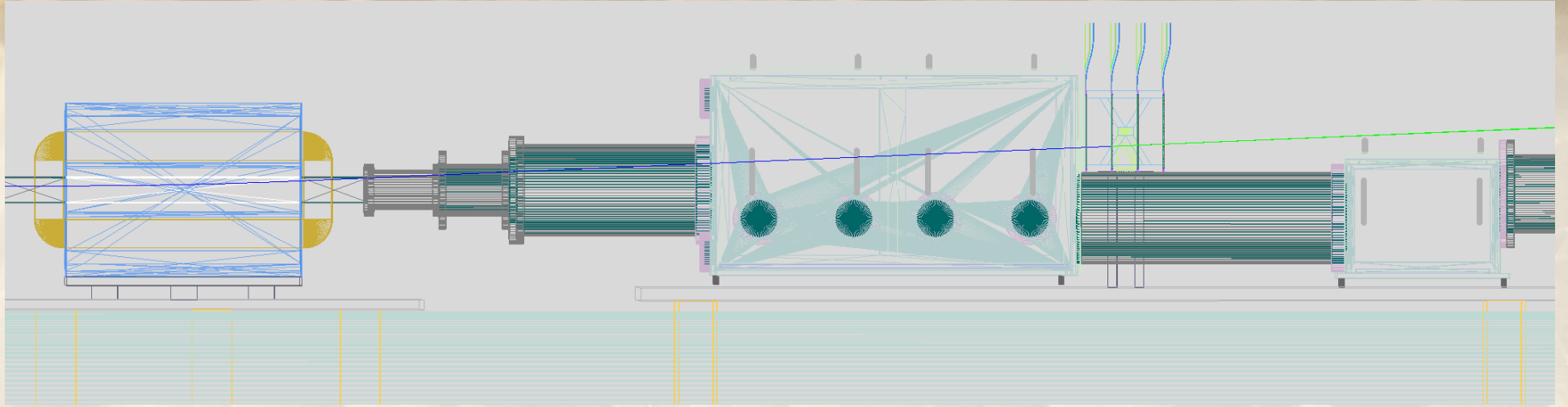
Baseline design



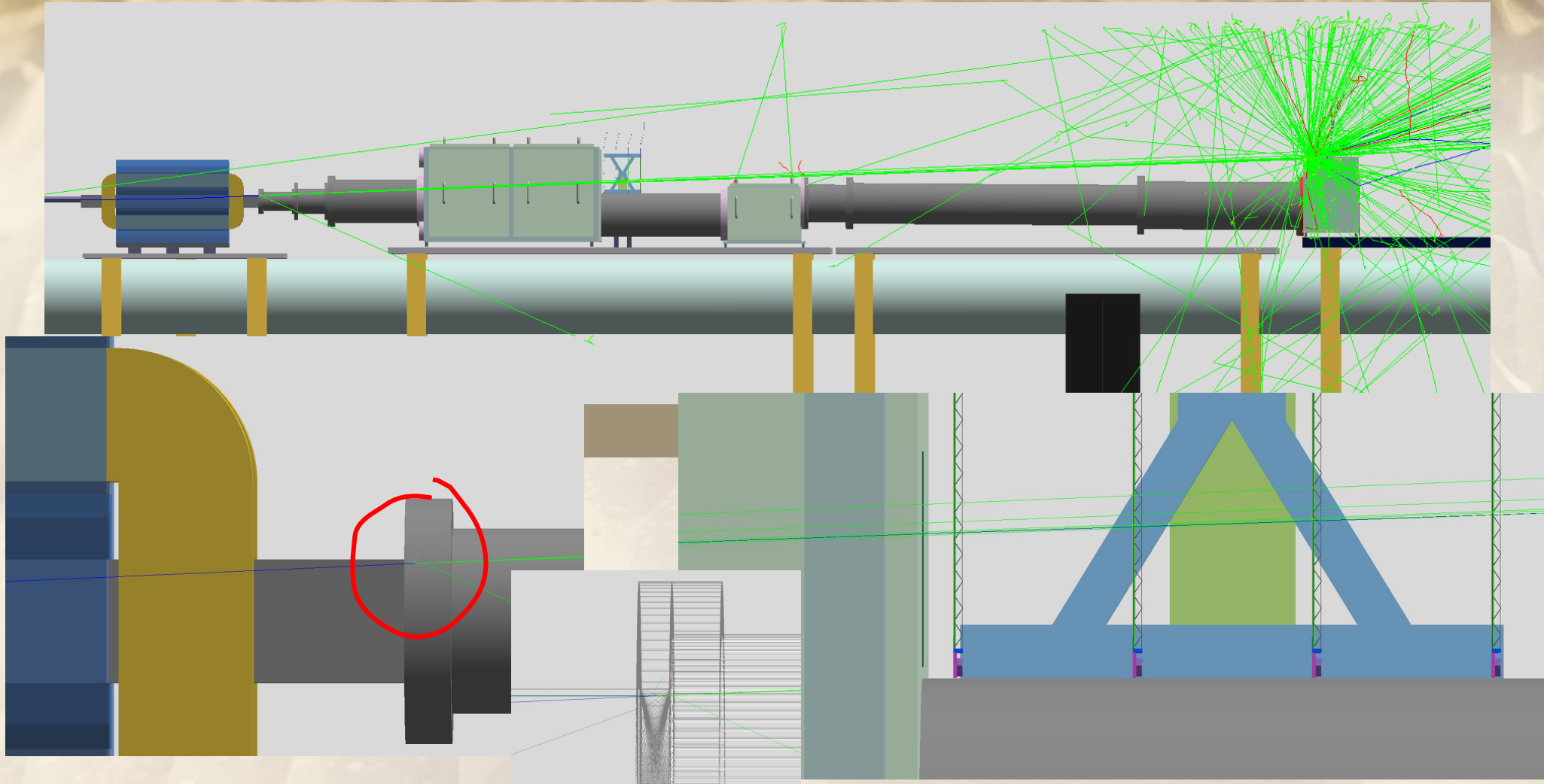
Alternative design

- Design, where staves are tilted to bring stave lower sensitive edge closer to the window bottom edge. So that window acceptance match the tracker acceptance; (illustration on the next page).
- It is conceptual design, have not been studied in simulation.

e+ 2.0 GeV



e^+ 1.9 GeV



Tracker stave

