NA61/SHINE tracking system upgrade: status and plans

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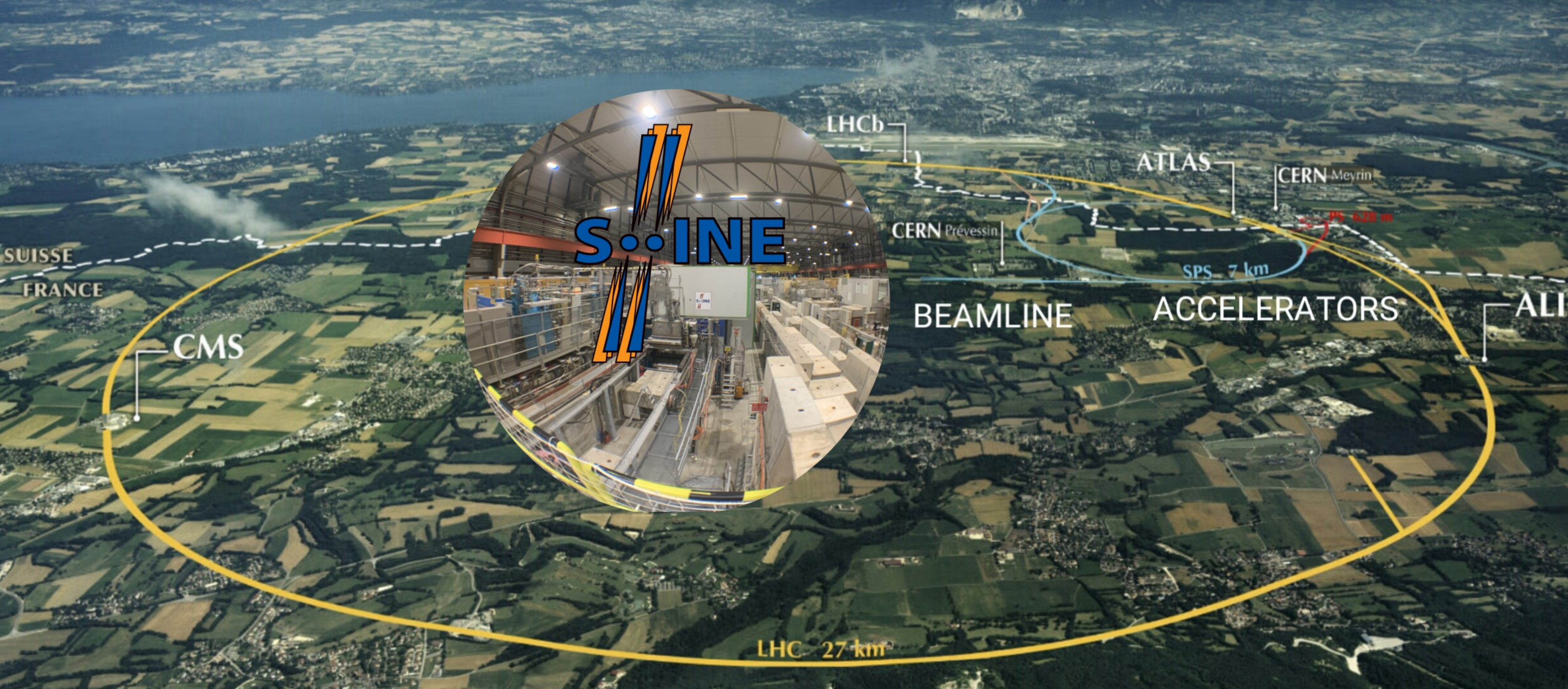
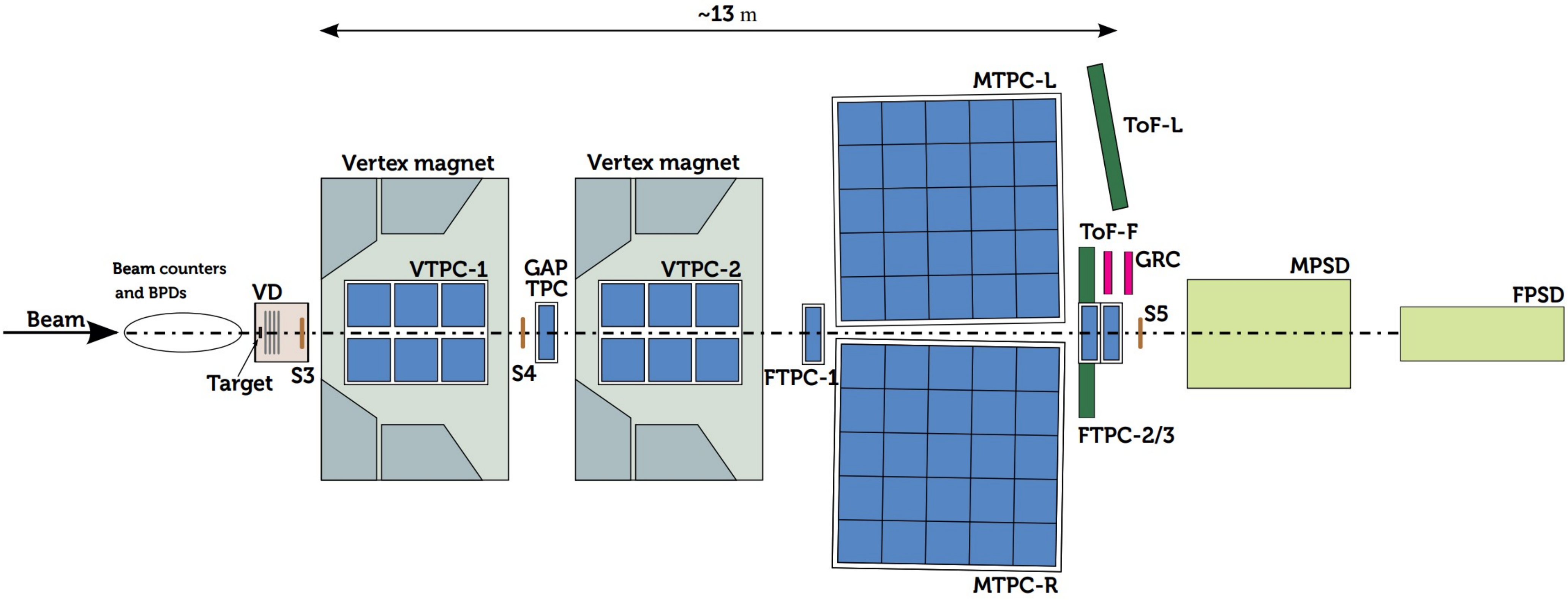
NA61/SHINE - UNIQUE MULTIPURPOSE FACILITY:
Hadron production in hadron-nucleus and nucleus-nucleus collisions at high energies

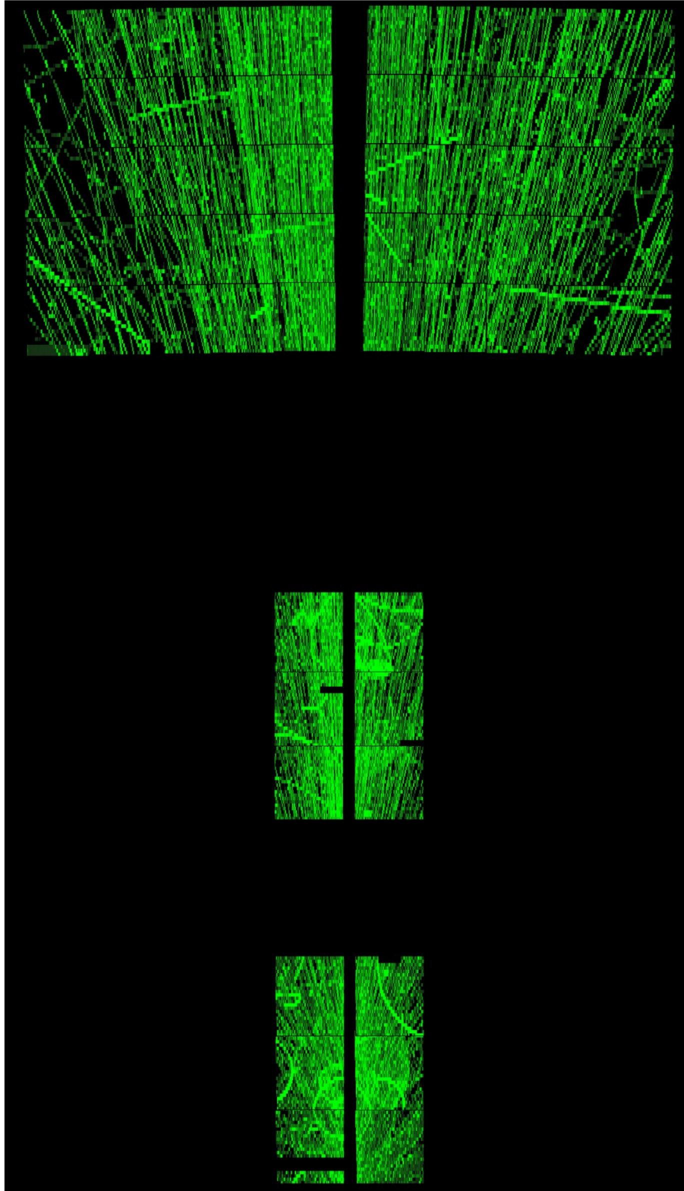


Current setup



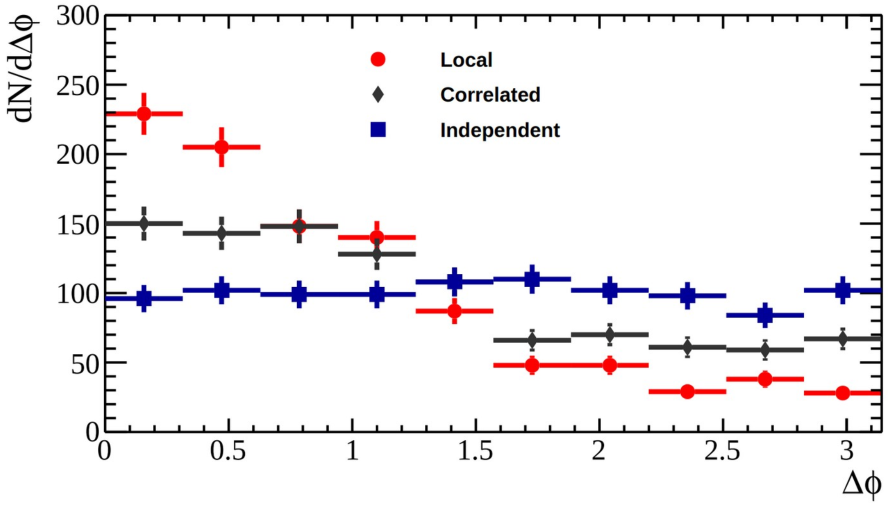
Current setup - tracking

- Silicon pixel detector based on ALPIDE sensors for precise vertexing
- 9 Time Projection Chambers
- 3 in magnetic field
- Using legacy ALICE TPC readout electronics (PASA+ALTRO)
- ~200k readout channels
- Max event rate ~1.2 kHz (Pb+Pb)



Motivation for new detector topology

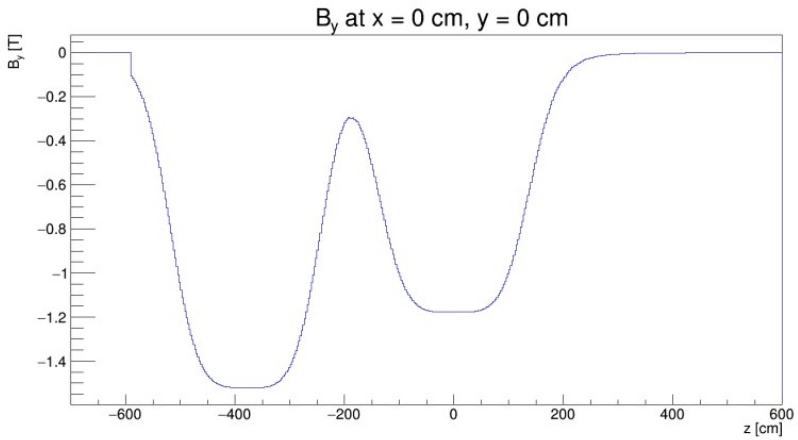
- Azimuthal angle correlation of charm hadrons produced in heavy ion collision at SPS energy (on average less than c-cbar pair produced) is expected to be sensitive to space correlation (locality) at their origin
- Directly accessible in NA61/SHINE++ via neutral D mesons.
- High event rate – **beyond 10 kHz** – is necessary, up to 1000 charged tracks per event

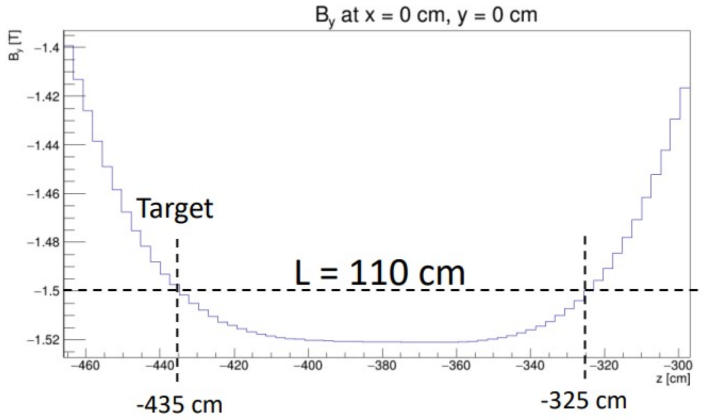


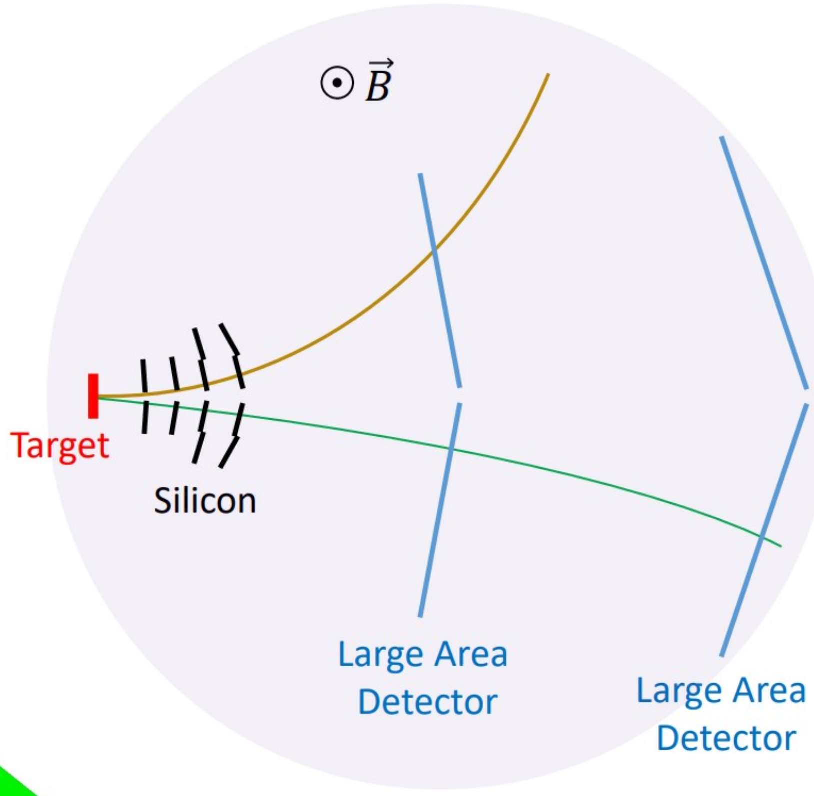
Plans and needs

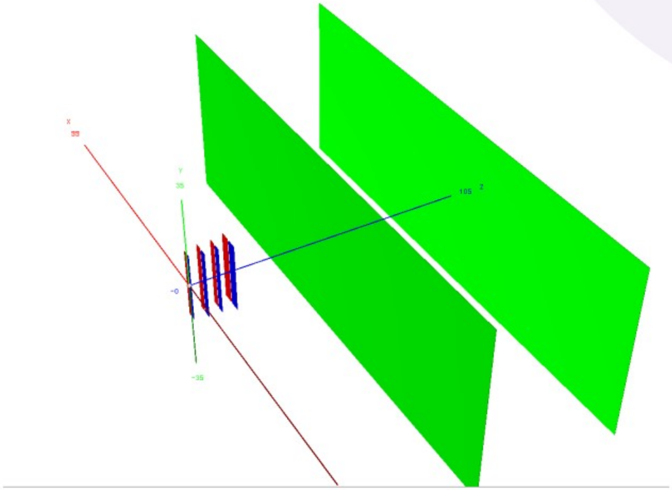
- Magnetic spectrometer with fast Silicon tracking detector for precise primary and decay vertex reconstruction
- Silicon supplemented with large area gas detectors – further tracking to improve momentum resolution

General concepts of charm tracker



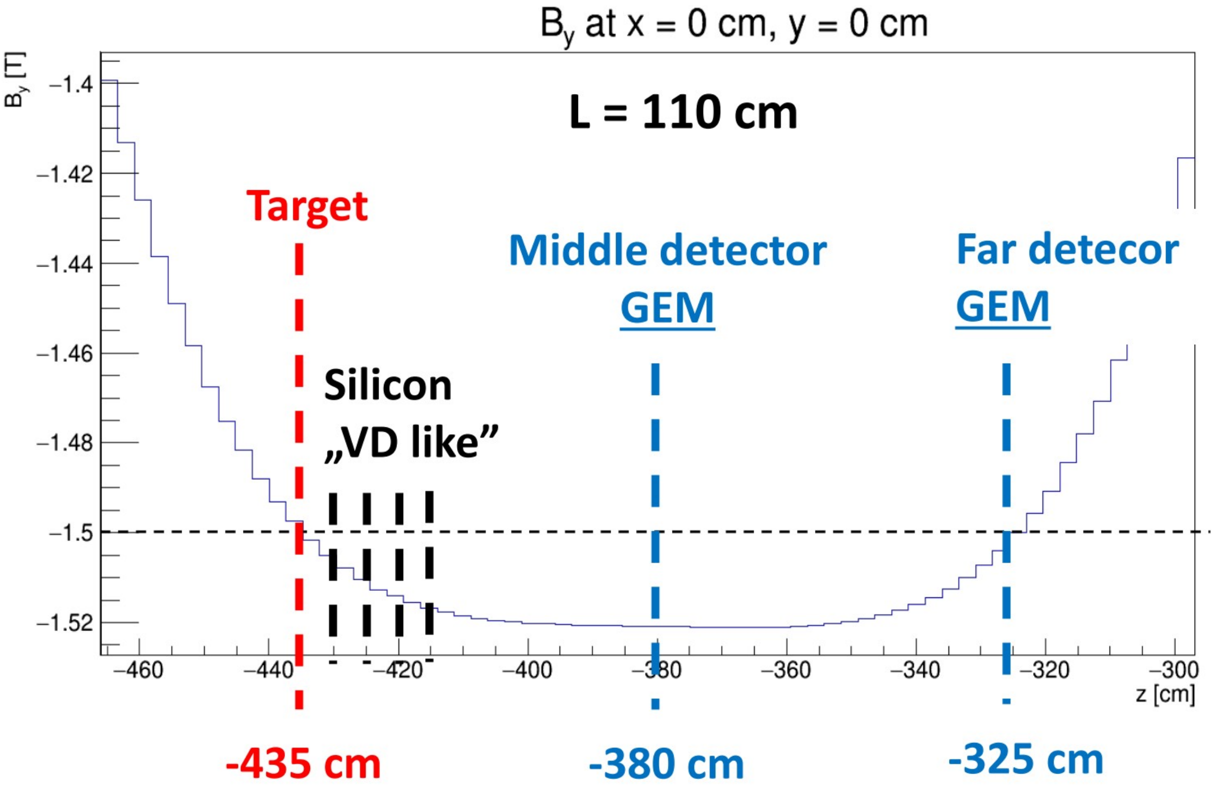






Large area detectors

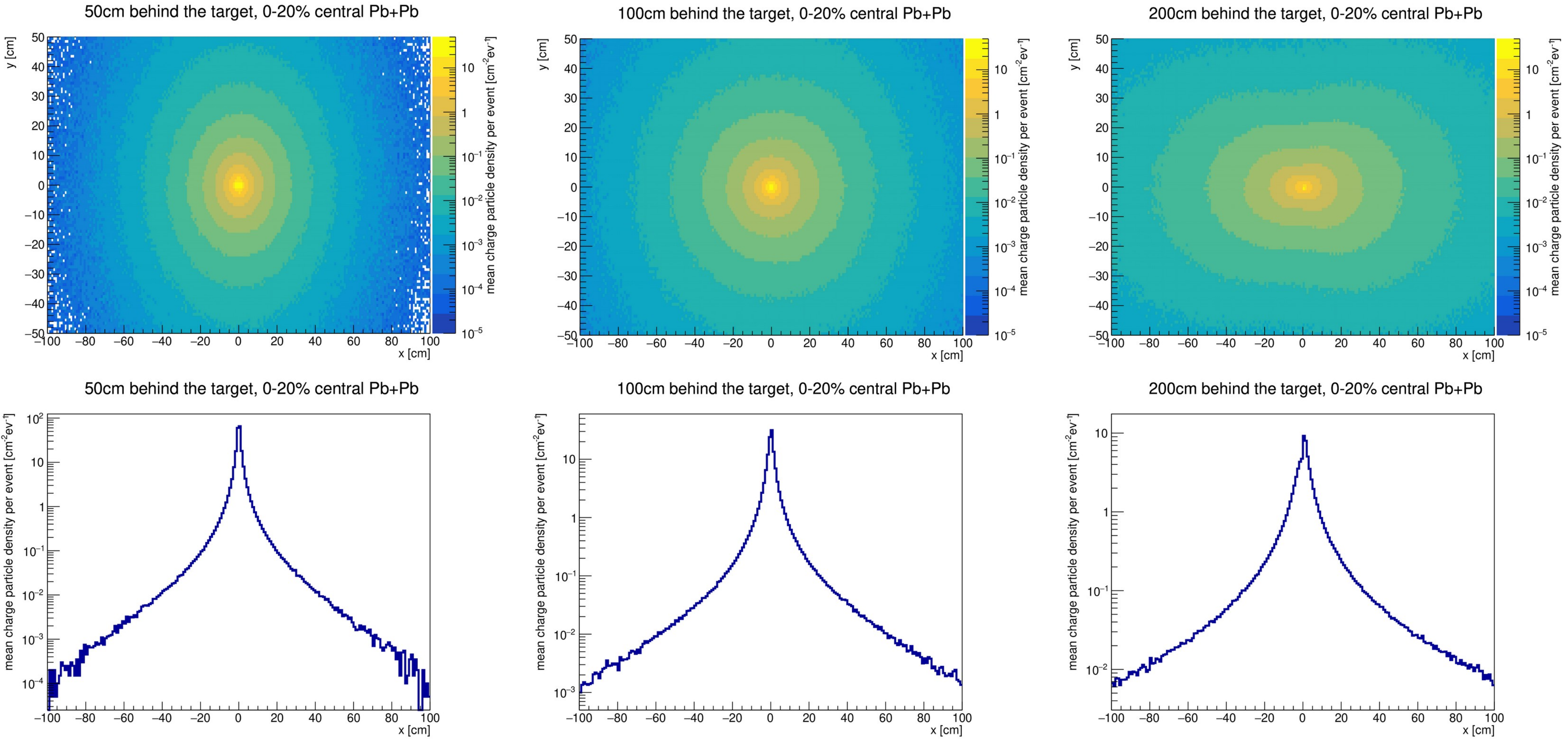
- First idea:
  - Two layers
  - Up to 70cm x 200 cm in size
  - Readout and detector topology optimized for track density, number of channels and beam exposure
  - Material budget: as low as possible



MC simulations to estimate track densities

- Pb+Pb @ 150 A GeV, 0-20% central in AMPT model
- Target at Z=-435 cm (inside vertex magnet 1, at the most upstream location where B>1.5T)
- Charged track number histogrammed in 3D with 1x1x1 cm3 bins for 20k events
- Mean charged track density in each bin calculated by dividing the number of charged tracks in the bin by the total number of events,
- Track density maps drawn at XY planes at various Z distances from the target
- Plots presented at Z = +50, +100 and +200 cm downstream from the target

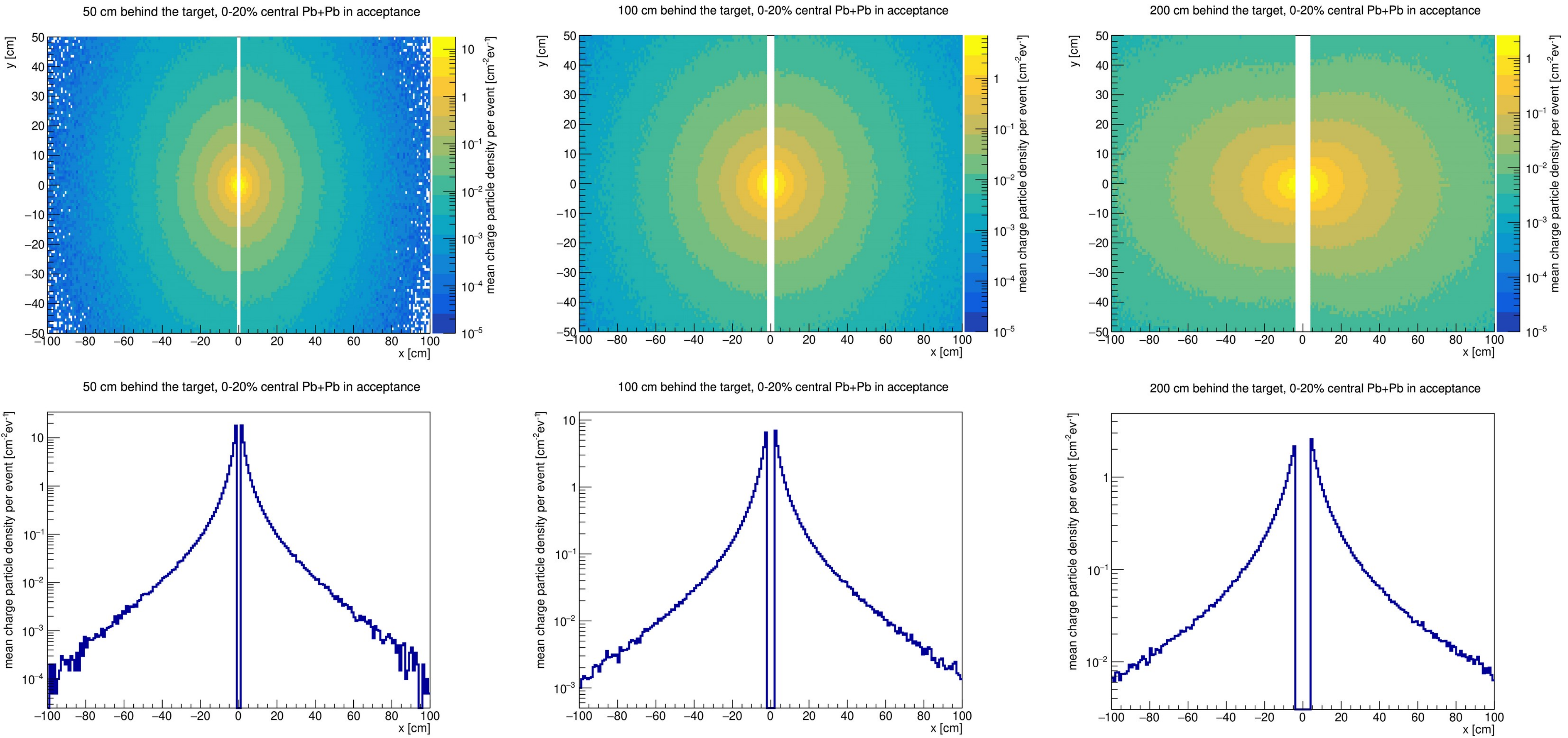
Per-event particle densities



Per-event particle densities

- High intensity Pb beam will pass through x=y=0
- Magnetic field orientation and Si tracker topology:
  - Detectors can have gap around x=0
  - Lower particle density and detector occupancy (by factor ~5)
  - Very conservative gap presented in the following slides – can be increased without big harm to the acceptance

Per-event particle densities



Two-hit resolution

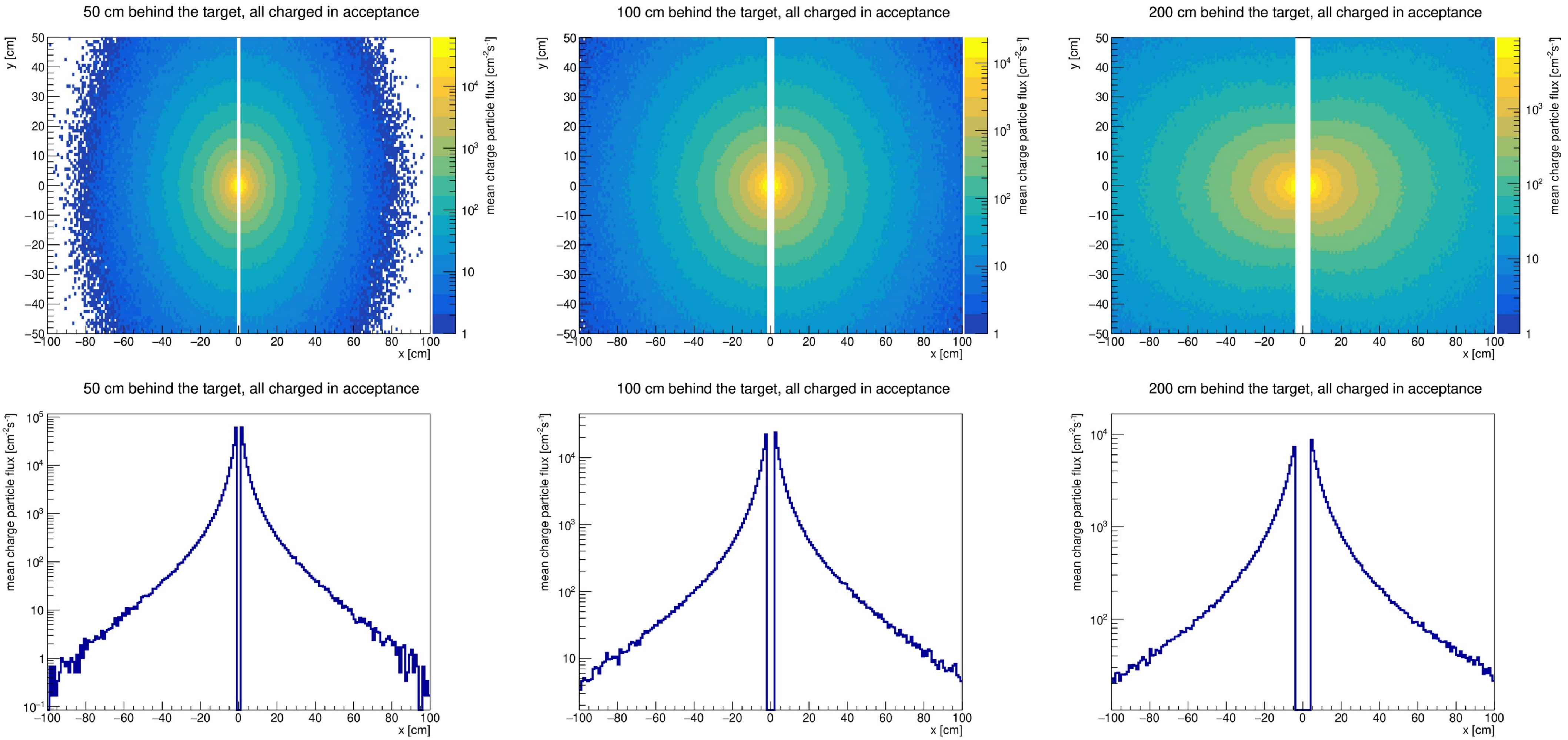
- We want to resolve two hits in the detector planes for central Pb+Pb interactions
- Values shown on histograms are ideal for this purpose
- For example: in the closest location we would need ~1mm pixels close to the beam (~10 tracks per cm2 by average)
- Other topologies to be considered for outer regions to optimize electronics fan-out and cost

Scaling to get total flux

- Plots presented on previous slides show charged particle flux per cm^2 per central Pb+Pb event
- To convert to total flux of particles per cm^2 per second:
  - Take into account all Pb+Pb interactions, not only central ones
  - Assume 5% of interactions in the target and 200 kHz Pb beam

$$\frac{\mathrm{d}^2 N_{all}}{\mathrm{d}t\mathrm{d}A} = \frac{\langle W \rangle_{0-100\%}}{\langle W \rangle_{0-20\%}} \cdot f_{beam} \cdot P_{int} \cdot \frac{\mathrm{d}N_{central}}{\mathrm{d}A} = \frac{94}{274} \cdot 200\,\mathrm{kHz} \cdot 5\% \cdot \frac{\mathrm{d}N_{central}}{\mathrm{d}A} \approx 3.4 \cdot 10^3 \cdot \frac{\mathrm{d}N_{central}}{\mathrm{d}A}$$

Total charged particle flux

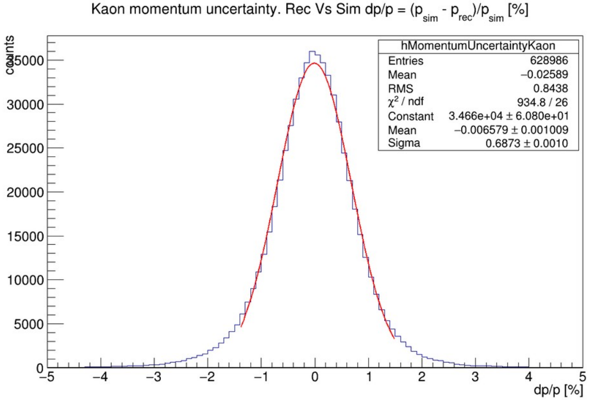


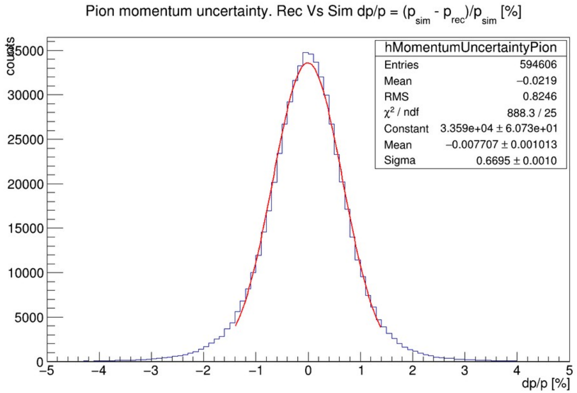
Total charged particle flux

- Up to $5*10^4$ MIP/cm^2/s in the inner regions of the detectors
- On top of that, presence of some high-Z fragments is also possible – MC studies are planned

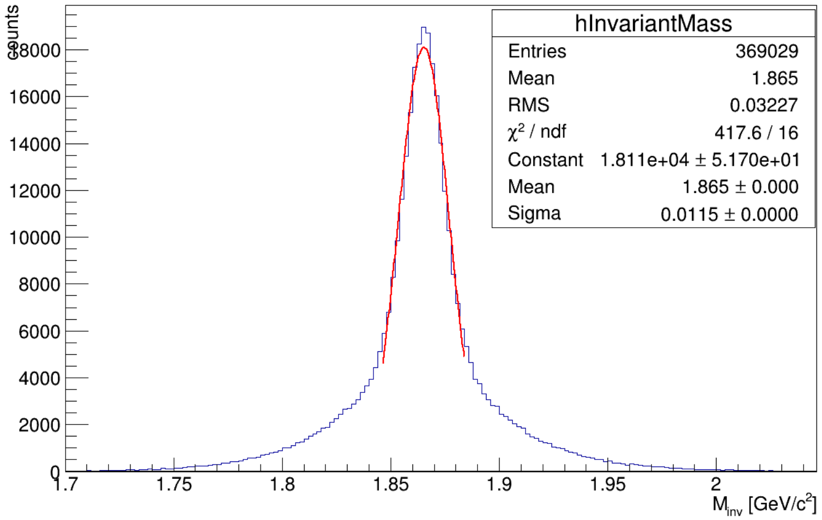
Material budget - baseline

Momenta reconstructed with Kalman Filter using hits in detectors as well as position of secondary vertex known from MC.





D^0 mass reconstructed using particle ID from MC



Sources of uncertainty:

- multiple scattering in the target, silicon and Helium atmosphere,
- intrinsic position resolutions.

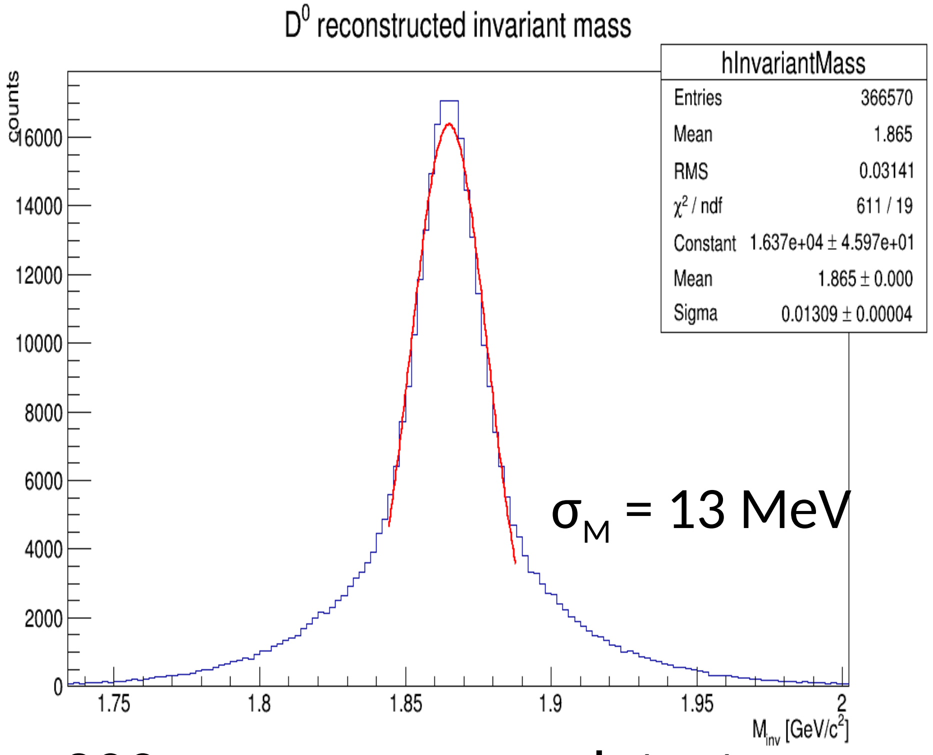
To account for finite detector resolutions, positions of MC hits were smeared by adding a normally distributed random number:

Secondary vertex: σ = 10 μm

Silicon: σ = 5 μm

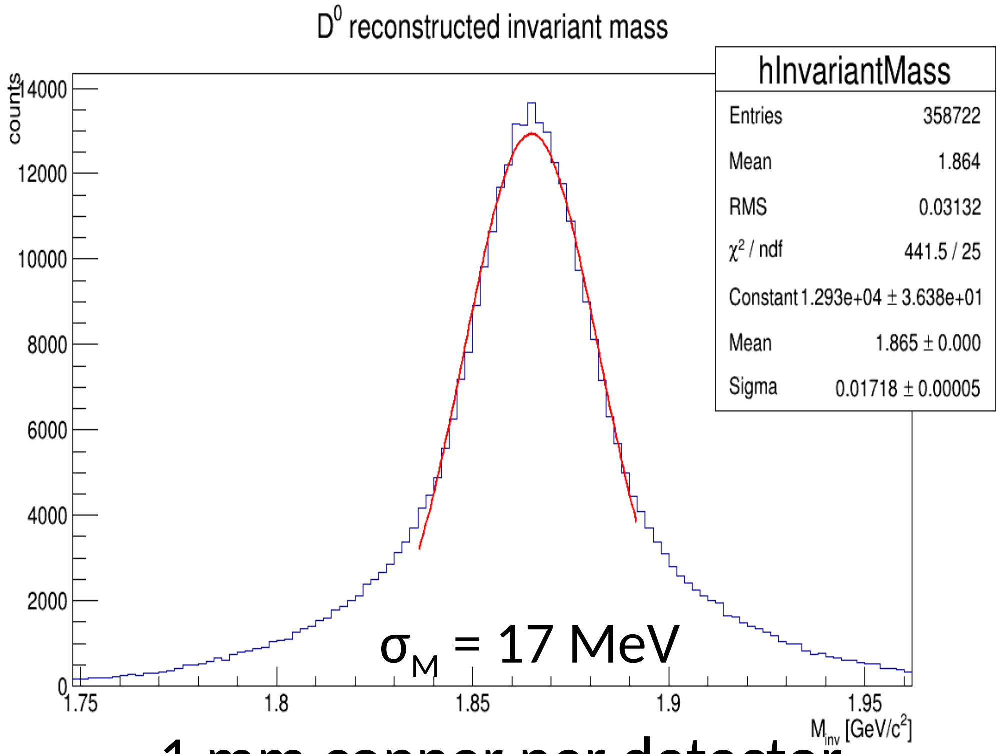
GEM: σ = 100 μm

Material budget and resolution



σ_M = 13 MeV

200 µm copper per detector



σ_M = 17 MeV

1 mm copper per detector

Baseline (detector made of helium): σ_M = 12 MeV

Summary and timeline

- Initial gathering of necessary information to prepare proposal for such detector has started
- We have first estimations of particle fluxes
- Two (VERY preliminary) scenarios in terms of timeline:
  - Installation during LS3, to be ready for run 4
  - Installation 2 years into run 4
- If you have suitable detector technology and want to implement it in NA61/SHINE++, please contact:
  - Bartosz.Maksiak@cern.ch
  - Przemyslaw.Adrich@cern.ch

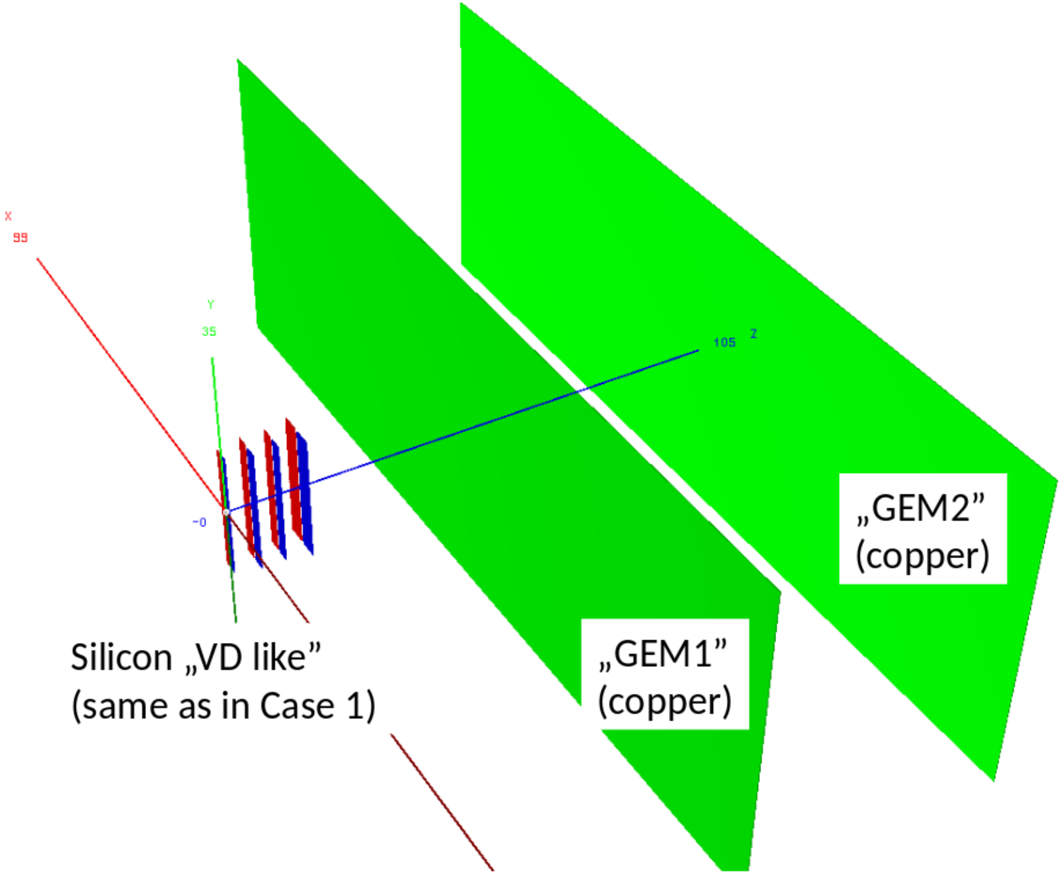
Thank you

Backup

Case 2: silicon „VD” + GEMs

Spectrometer geometry

- World Material = Helium
- Target at Z=-435 cm
- Silicon: 4 stations, 5 cm separation (see fig.), starts at Z = -430 cm (5cm downstream target)
  9 sensors per stave,
  1, 2, 2, 3 staves per station per arm
  7 mm central gap for the beam,
- „GEM1” at Z=-380 cm (middle od vertex magnet 1)
- „GEM2” at Z=-325 cm (1.1 m downstream target)
- GEM dimensions (xy) 2x0.7 m^2
- **In the Luminance, GEMs were tentatively implemented as position sensitive volumes of Copper of different thickness (50 um to 1 mm)**



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Tracker material and reconstruction resolution

„Detector" material	Thickness [mm]	Fraction of radiation length [%]	Momentum resolution [%]	D^0 invariant mass resolution (σ_M) [MeV]
Helium	1	2E-5	0.7	12
Copper	0.2	1.4	0.8	13
Copper	1	6.9	1.1	17