Open charm measurement with a new vertex detector at the NA61/SHINE experiment at the CERN SPS

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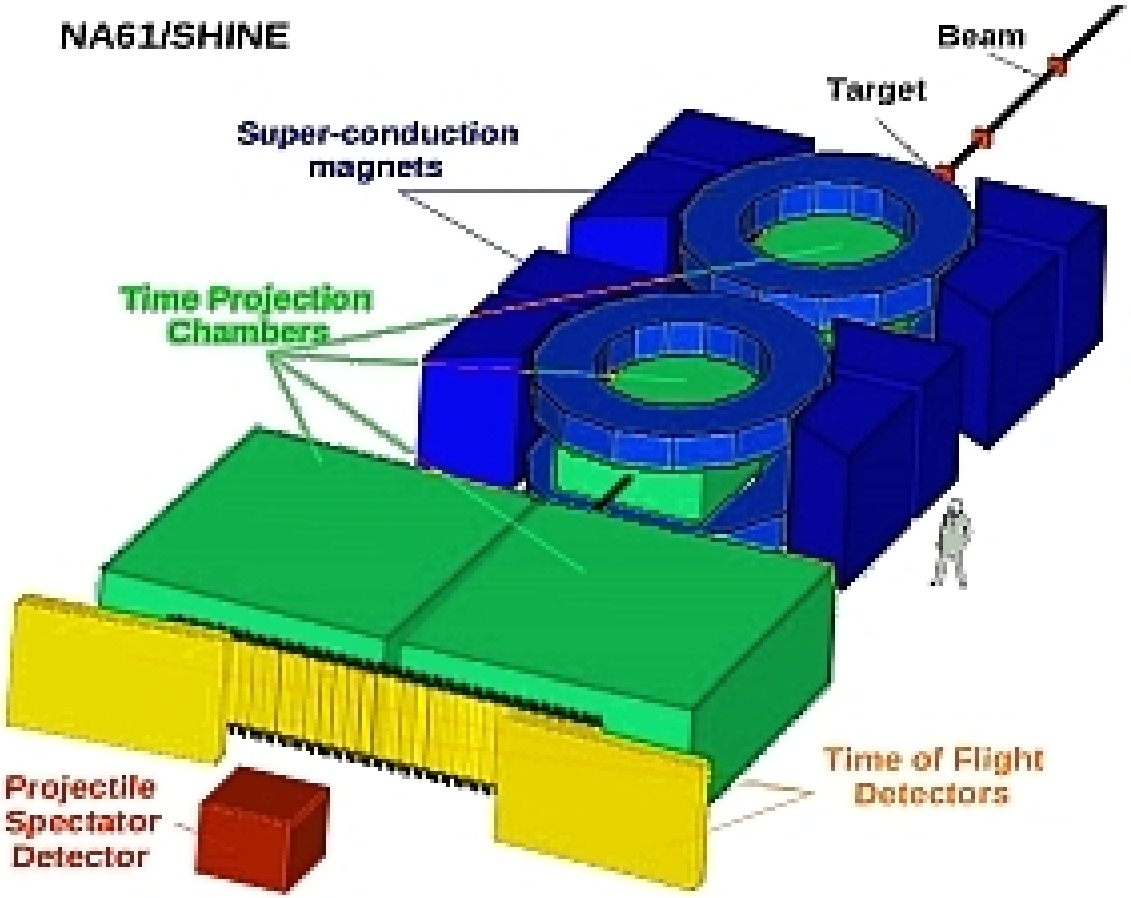
NA61/SHINE experiment set-up

Fixed-target experiment at the CERN SPS

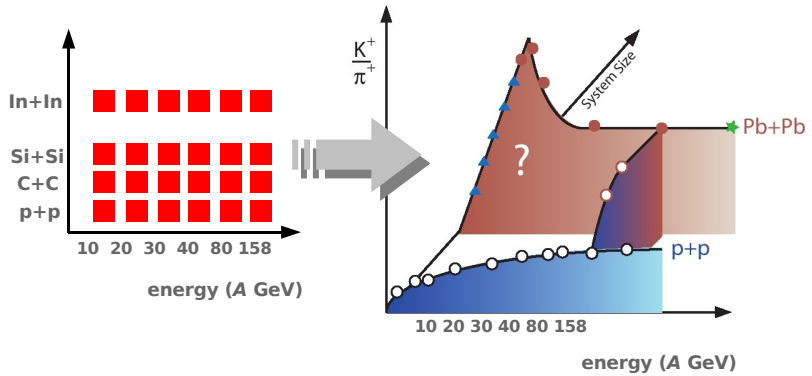


NA61/SHINE physics goals

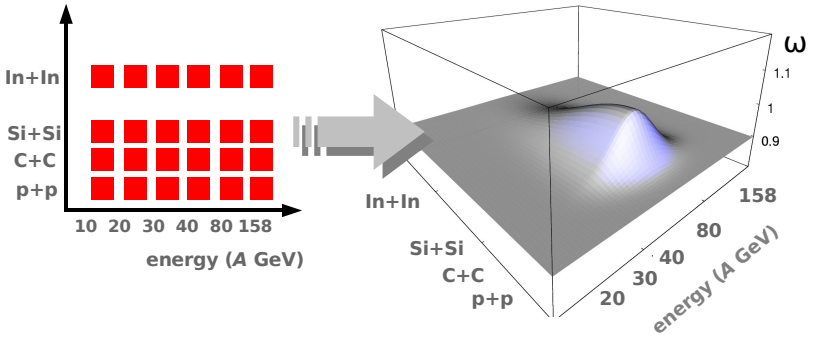
- Strong interactions programme
  - Search for the critical point of strongly interacting matter
  - Study of the properties of the onset of deconfinement
- Hadron-production measurements for neutrino experiments
  - Precise data on p+C and p+(long target) interactions
    for the T2K experiment at J-PARC and Fermilab neutrino experiments
    for computing initial neutrino fluxes
- Hadron-production measurements for cosmic ray experiments
  - Reference measurements of p+C, p+p, p+C, and K+C interactions
    for cosmic-ray physics (Pierre-Auger and KASCADE experiments)
    for improving air shower simulations

NA61/SHINE strong interactions programme

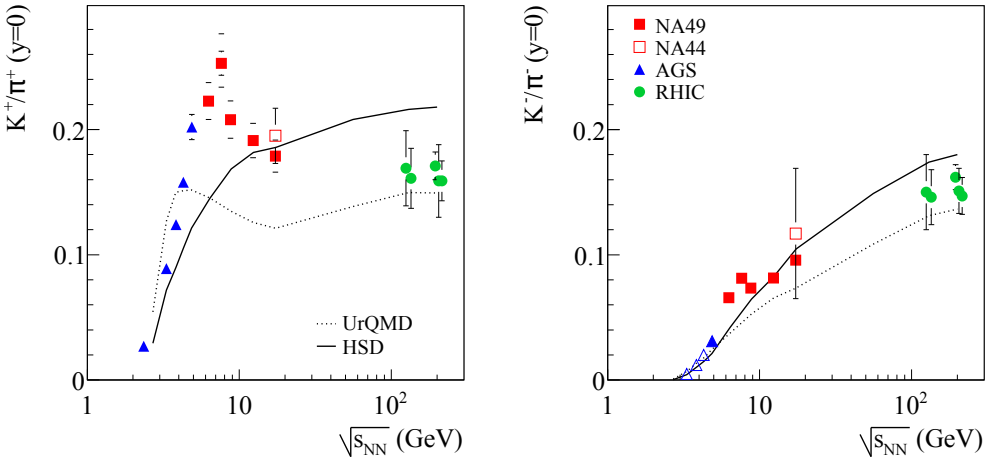
Energy scan of the phase diagram



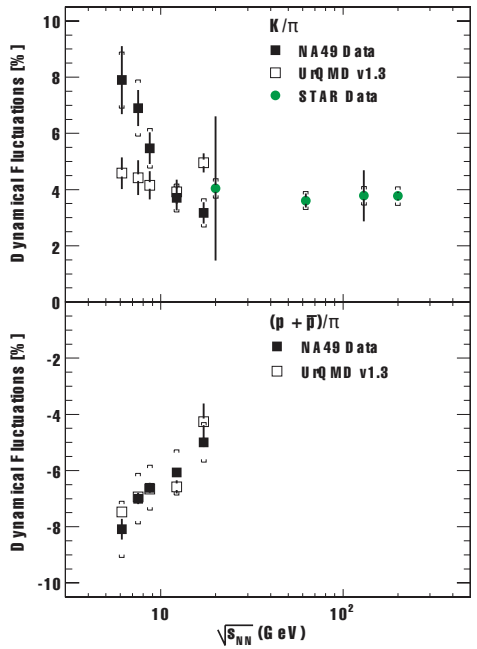
Uncovering properties of transition hadron gas $\rightarrow$ QGP



Search for critical point of strongly interacting matter



K^+/π^+ and K^-/π^- ratios in central collisions
Phys. Rev. C **77** 024903 (2007)



Event-by-event non-statistical fluctuations, K/π and $(p+\bar{p})/\pi$
Phys. Rev. C **79** 044910 (2009)

An addition of a vertex detector (close to the primary vertex) to the current set-up will allow for measurements of open charm

Open charm direct measurement motivation

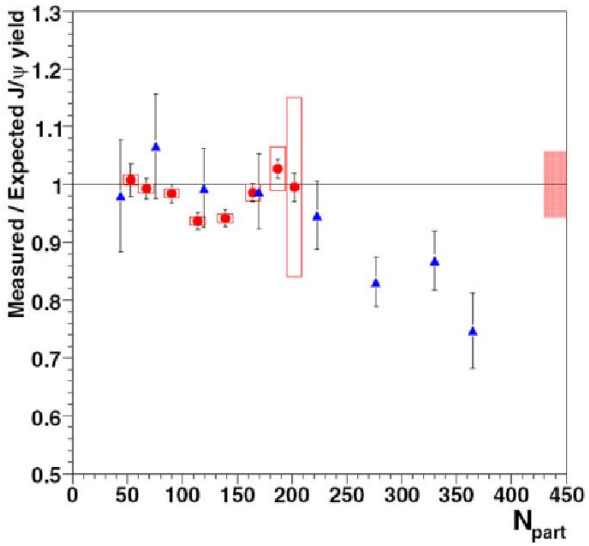
- Measurements of heavy flavour mesons important for understanding A+A reactions at relativistic energies

- Open charm (charm and light quark): two models
  - pQCD-based model
    - Perturbatively created c quark forms bound state with d, u or s quark
  - Statistical model
    - In 1997, Gorenstein and Gazdzicki observed that J/ψ ($c\overline{c}$) yield from A+A proportional to pion multiplicity

- For Pb+Pb @ 158AGeV yields from pQCD and statistical approaches differ by factor 30
- Also predicted system sizes very different

Open charm direct measurement motivation (cont.)

- J/ψ measurements at top SPS energies by NA38/NA50 and NA60 are consistent with pQCD for $N_{part} < 200$, but not above
  - Anomalous J/ψ suppression
  - Onset of QGP, or other scenario?
  - Enhancement of open charm in A+A may be correlated with suppression of J/ψ

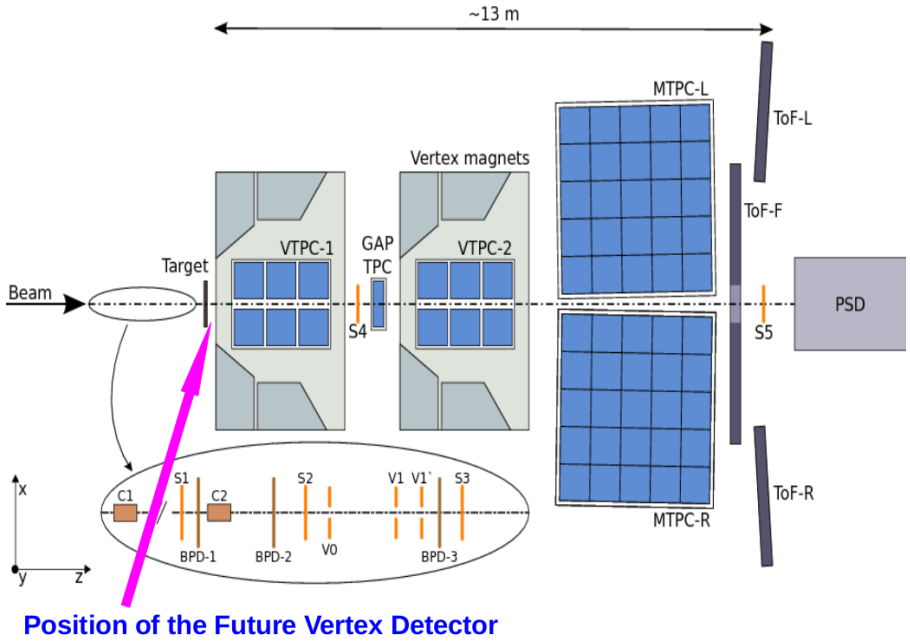


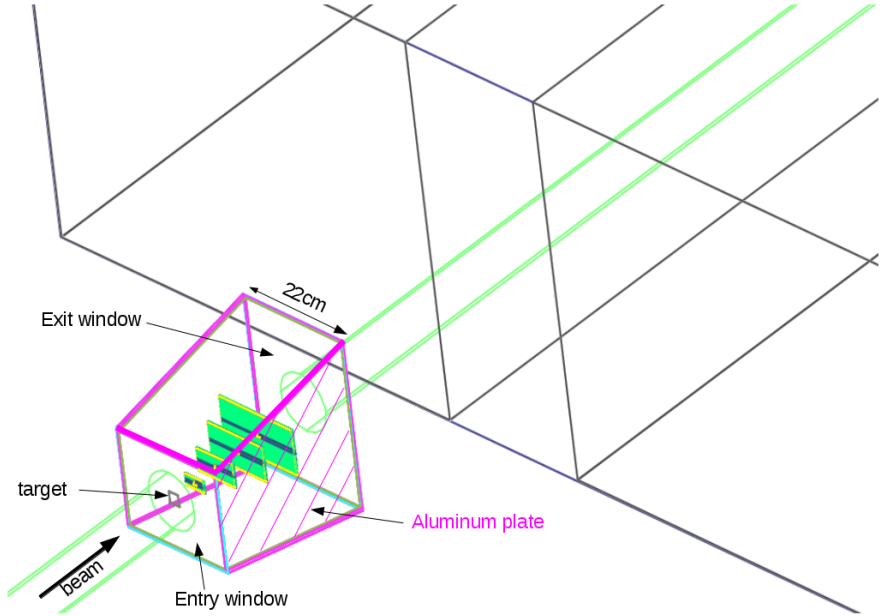
J/ψ suppression as function of N_{part}
Nucl. Phys A **830** 239c (2006)

- Direct open charm measurement needed to understand validity of pQCD and statistical models
  - NA61/SHINE will be able to do this measurement with the vertex detector upgrade at SPS energies
  - ALICE is upgrading vertex detector to measure open charm at LHC energies
  - NA61/SHINE and ALICE measurements complement each other

Vertex detector for NA61/SHINE

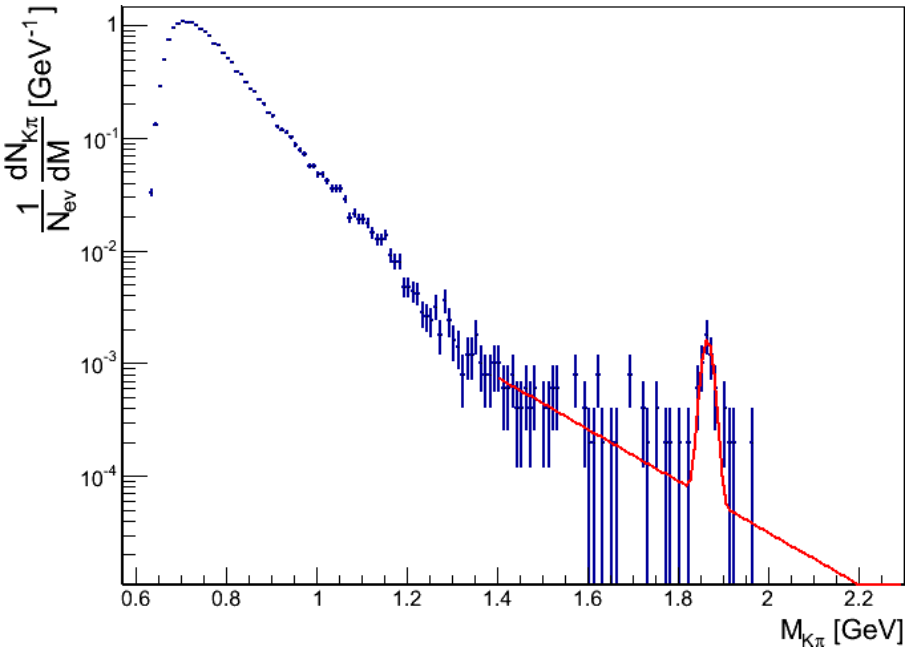
- New vertex detector will enable NA61/SHINE to do direct open charm measurements
- Placed just behind target
- Based on Mimosa-26 sensor chip
- Challenging to keep material budget low, but can take advantage of carbon-fibre mechanical support





Vertex detector simulations

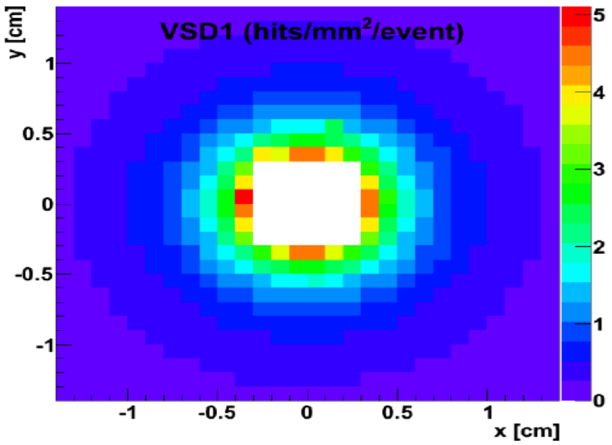
- Simulations show that direct open charm measurements for NA61/SHINE will be possible with the vertex detector
- Prototype optimised for D^0
- Optimal sensor locations found from simulations
- AMPT event generator



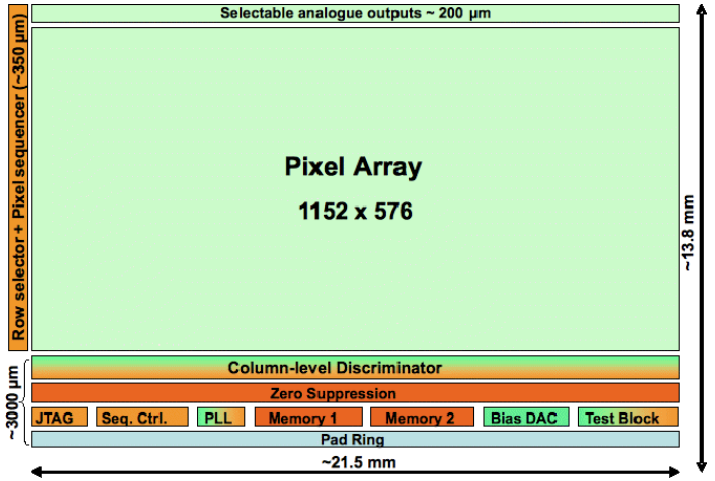
Combinatorial invariant mass spectrum for 0-10% central Ar+Ca @ 158 AGeV after background reduction. Red curve is fit to sum of exponential (background) and Gaussian function (D0 signal). No PID information used in analysis.
J.Phys.Conf.Ser. **509** 012083 (2014)

Mimosa-26 sensor chip

Pitch size: 18.4μm. Resolution: 1152$\times$576. Readout time: 115.2μs.



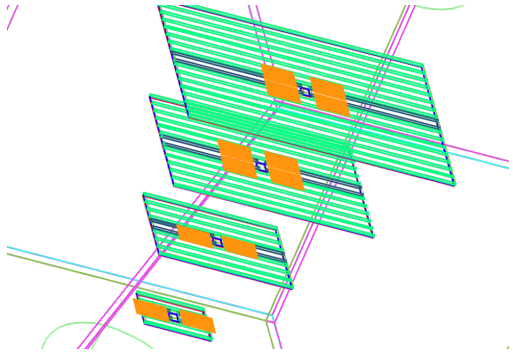
Hit occupancy for inner part of first detector station for 0-10% central Pb+Pb



Schematic view of architecture of Mimosa-26 chip

	NA-61	Hybrid	CCD	MIMOSA-26
Resolution	< 5 µm	30 µm	<5 µm	3.5 µm
Material Budget	few 0.1 X_0	~ 1% X_0	~0.1% X_0	0.05% X_0
Rad. Tol. (1)	3x10^{10}neq/cm^2	>10^{14} neq/cm^2	<10^{9} neq/cm^2	>10^{13} neq/cm^2
Rad. Tol. (2)	~1 krad	>10 Mrad	~1 Mrad	> 300krad
Time res.	~100 µs	20 ns	~ 100 µs	115.2 µs

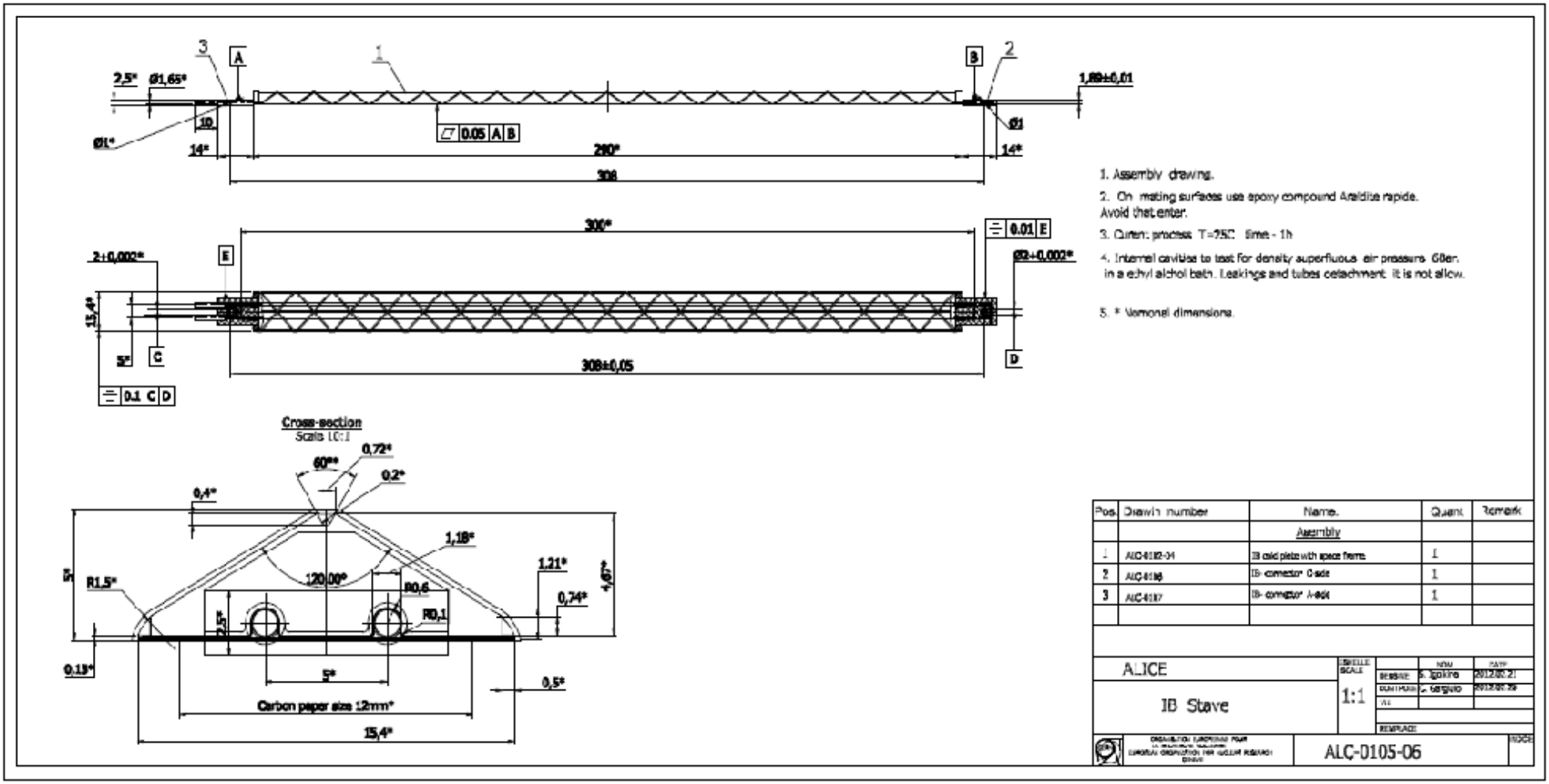
Requirements of NA61/SHINE vertex detector compared to Mimosa-26 and other options considered



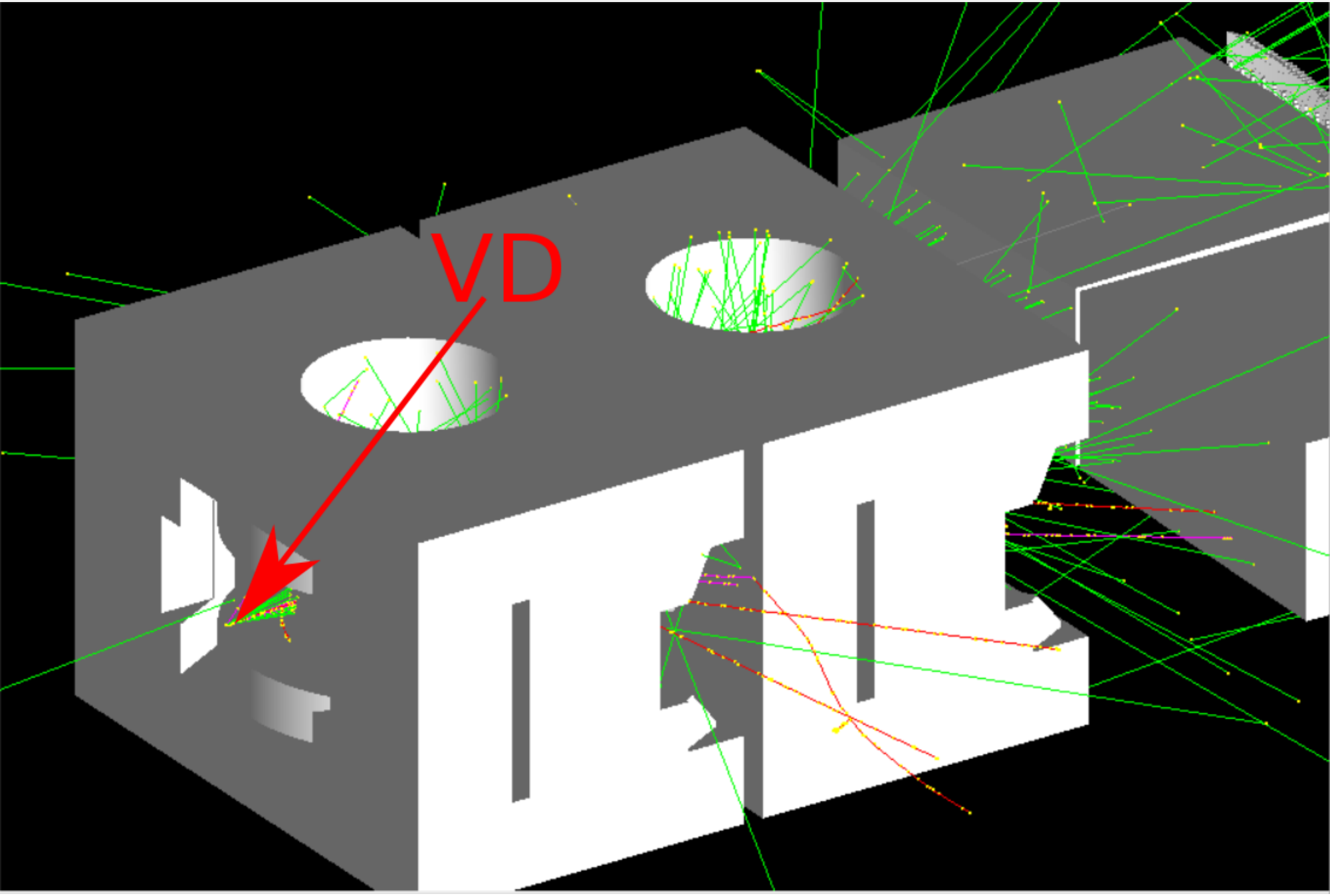
Layout of prototype vertex detector with sensor locations shown as orange boxes

Carbon fibre ladders

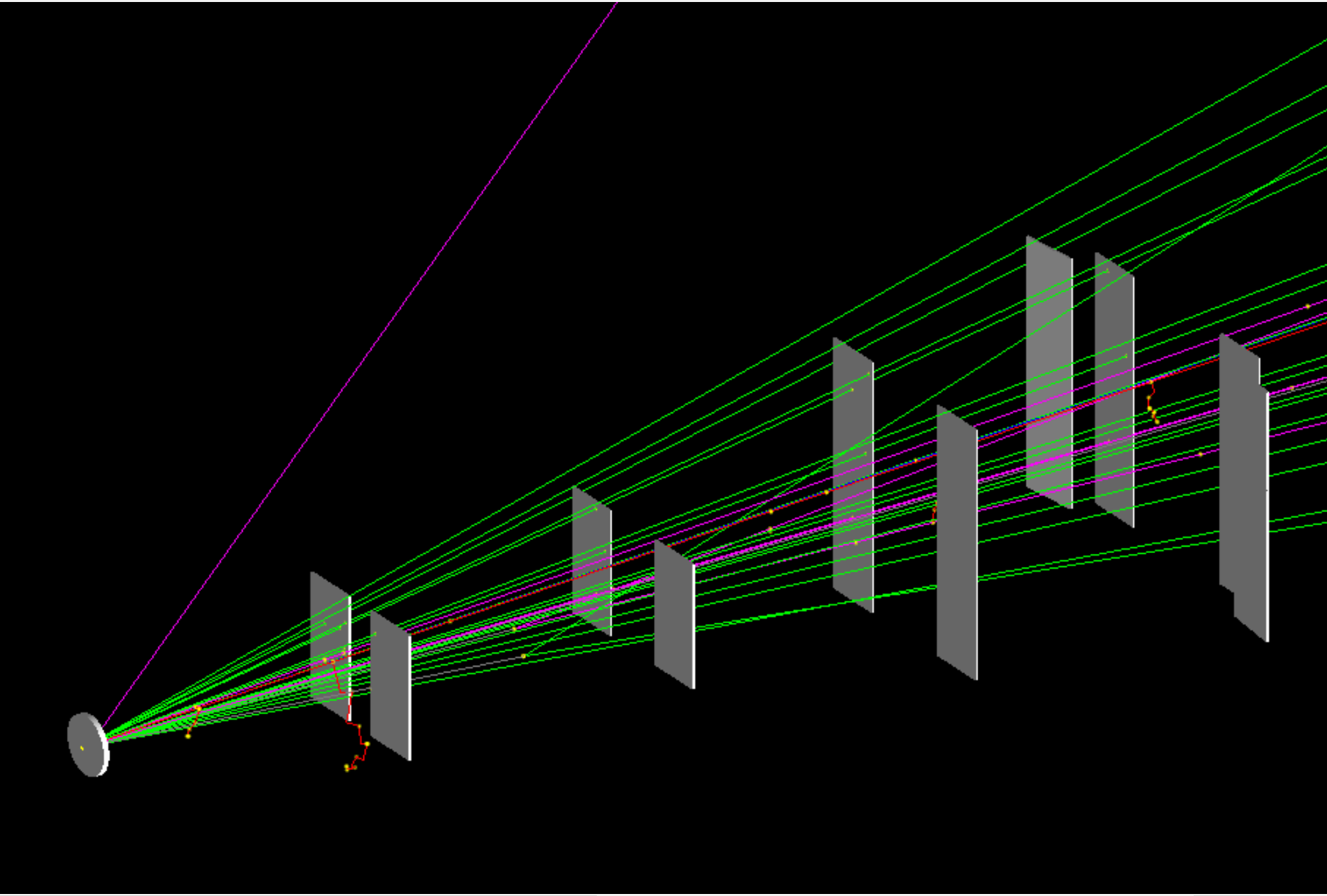
- Sensor mechanical support by very light carbon fibre ladder
- Originally developed by St. Petersburg for ALICE ITS



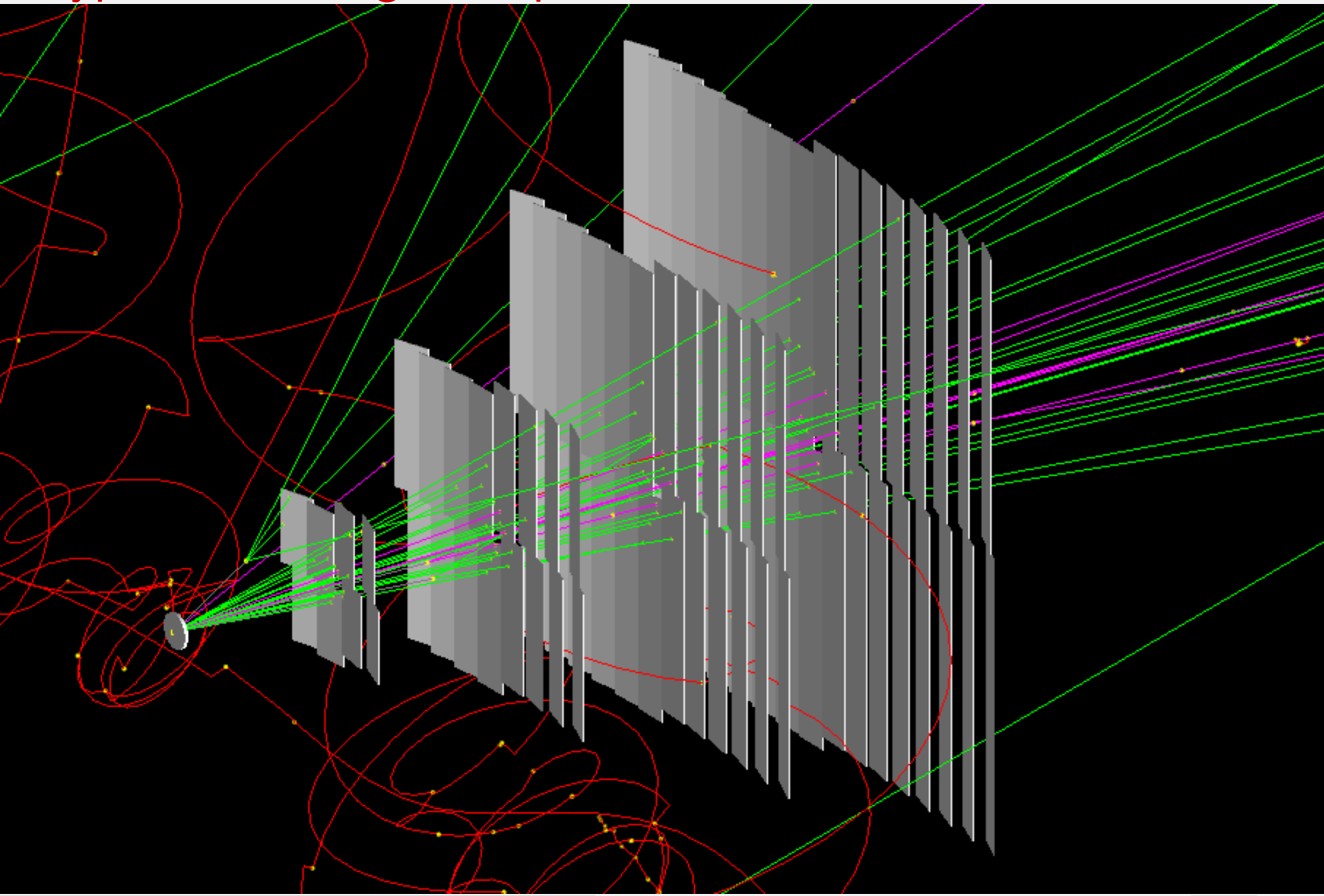
Location of vertex detector



Small-acceptance vertex detector under construction



Hypothetical large-acceptance vertex detector



Status and plans

- Detector construction
  - Ongoing
    — first data taking expected next year
- Simulations
  - Simulations for feasibility study completed
    — now detailed simulations taking into account all effects
- Reconstruction and analysis
  - Reconstruction/calibration and open charm signal extraction using simulated data ongoing