A TPC for the Near Detector of the T2K Experiment

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for the T2K collaboration

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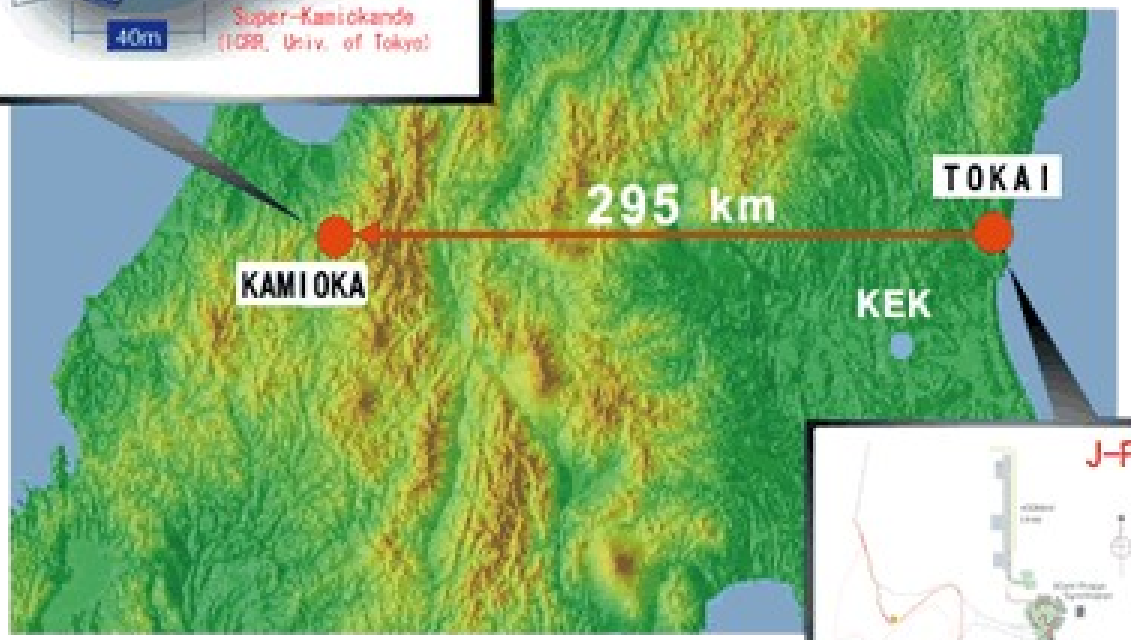
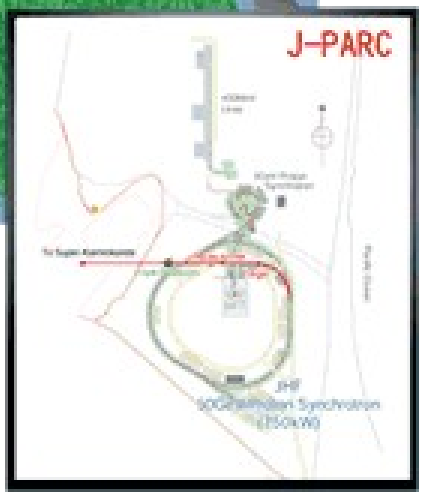
- The T2K Experiment
- The Near Detector
- The Time Projection Chamber
- Conclusion

T2K: Tokai-to-Kamiokande

- ν_μ beam created with 50 GeV *p* beam, 0.75MW
- ν_μ beam off-axis $\Rightarrow$ narrow energy band
- Far detector: Super K, 295km baseline





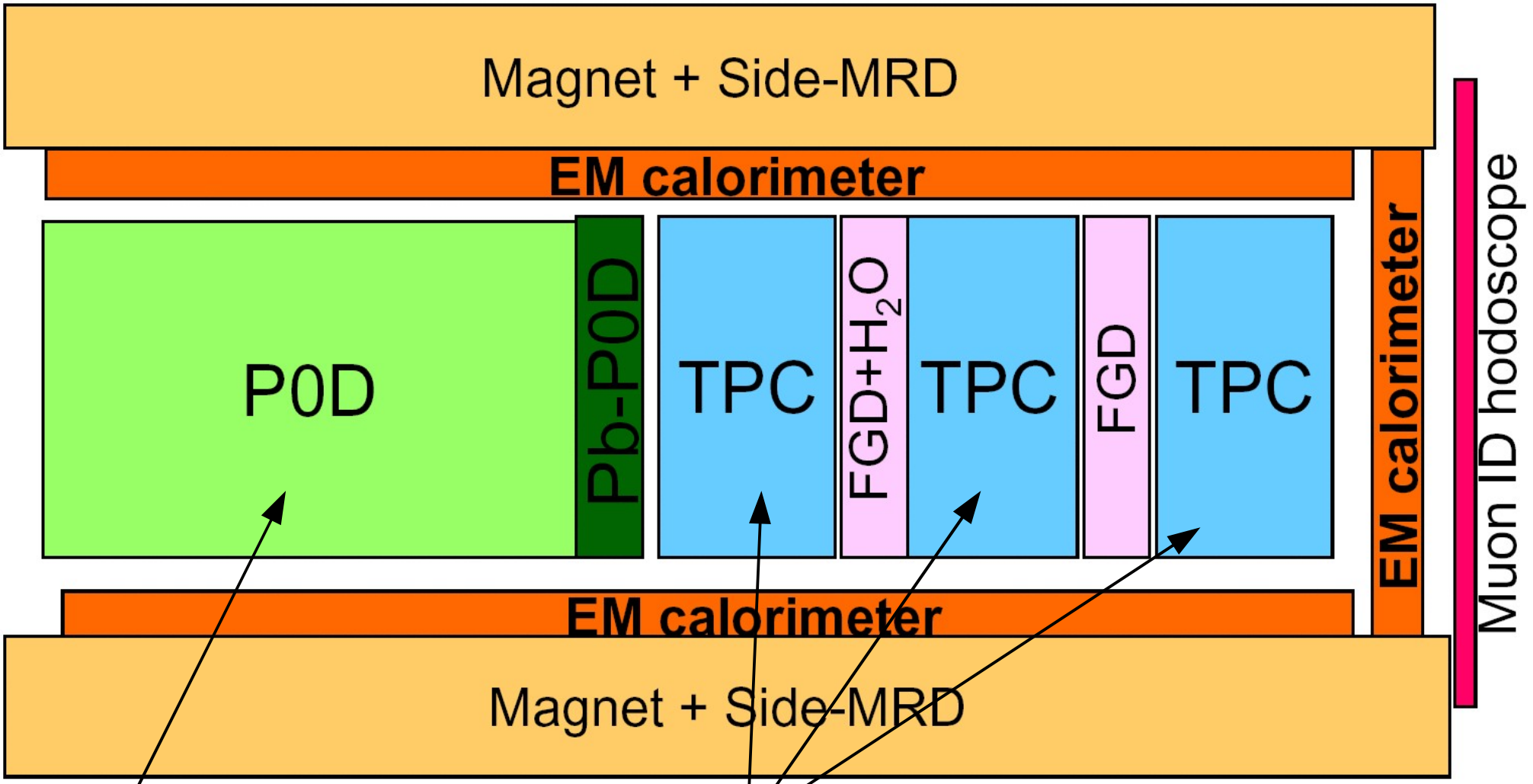
Physics Goals:

- ν_μ disappearance
- ν_e appearance: $\nu_\mu \rightarrow \nu_e$
- $\nu_\mu \rightarrow \nu_s$

The Near Detector

- Purpose:
  - provide predictions of neutrino flux and composition at SK
  - identify event types: CCQE, inelastic events, NC events
  - measure the neutrino energy spectrum
  - fully reconstruct CCQE by tagging the recoil proton
- Thus:
  - need massive and active target
  - interactions that are similar to those at SK
- Location:
  - off-axis
  - 280m from production target

Near Detector Concept

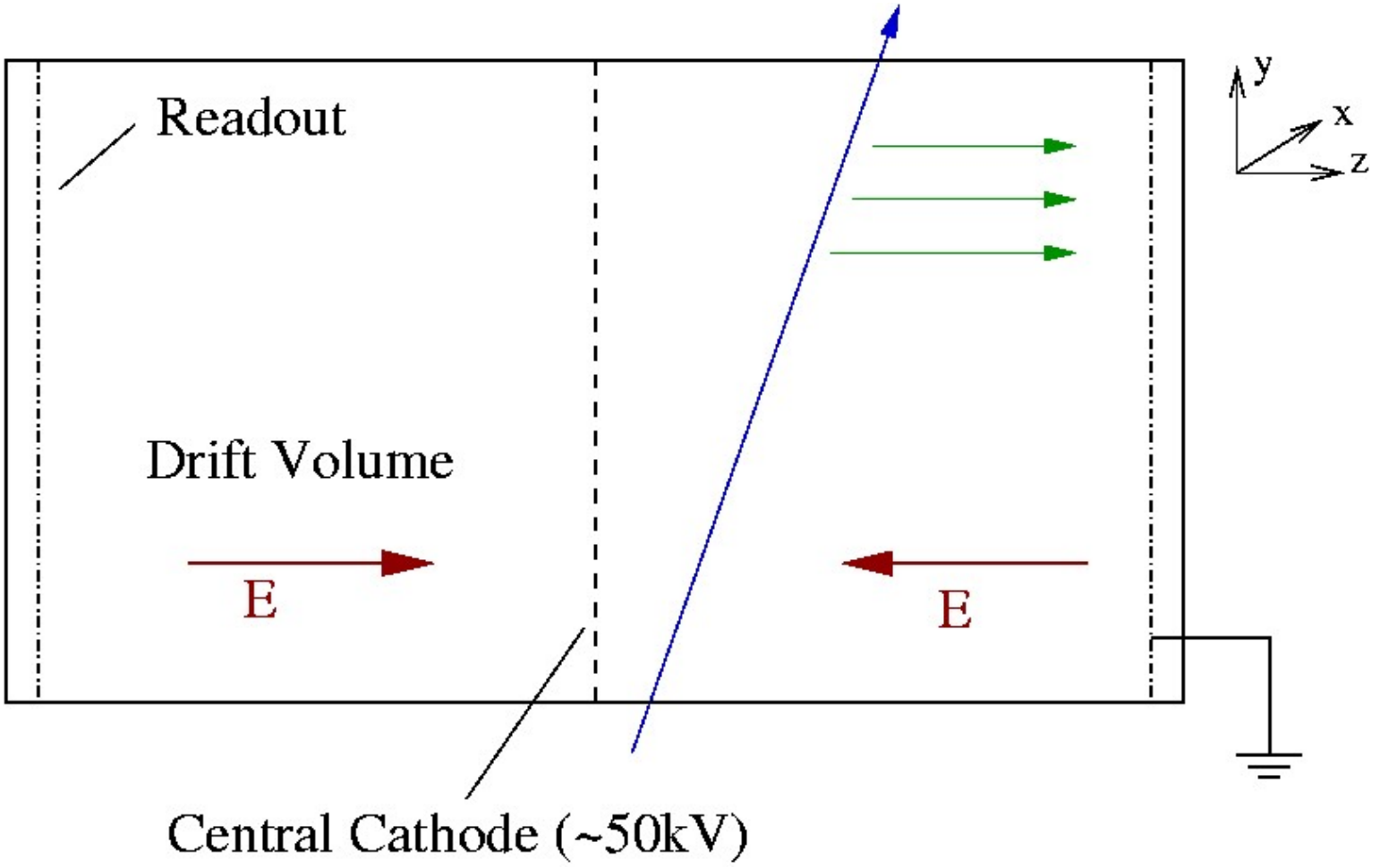


massive fine-grained detector

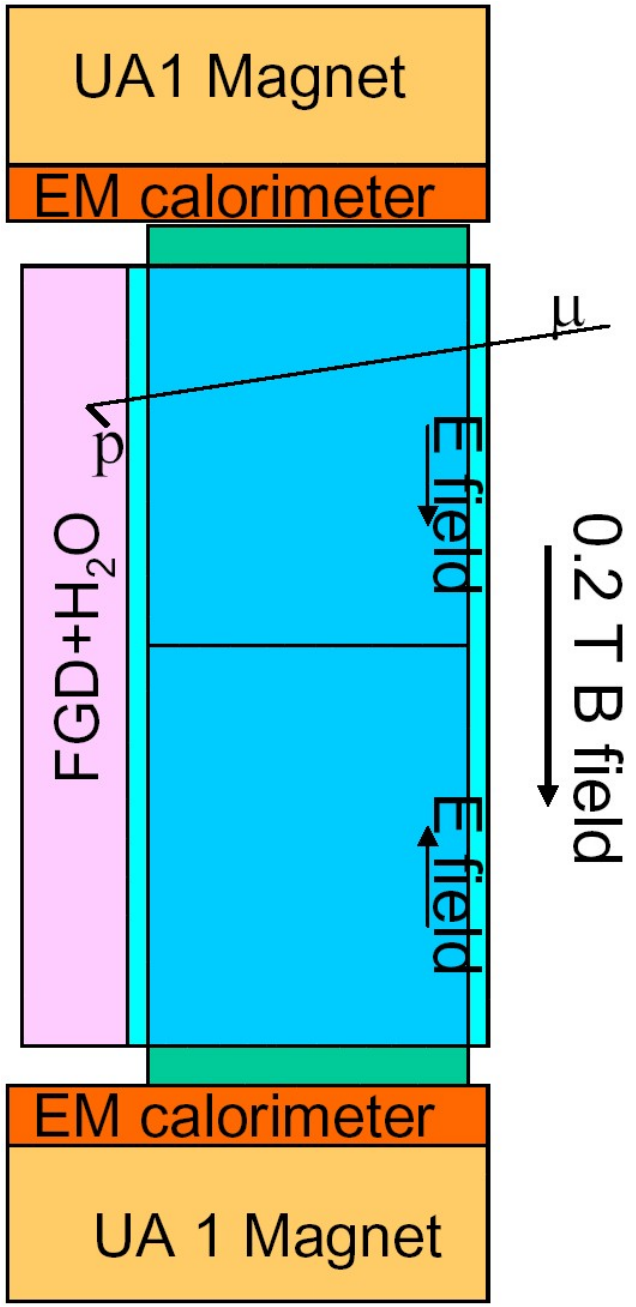
TPC modules: track interaction products from FGD and provide target mass

Time Projection Chamber 101

- Provides a complete, 3D picture of the ionization deposited
- Sensitive volume free of wires
- Readout pads segmented in *x* and *y*
- Resolution in *z* achieved by measuring time of the arriving electrons



The T2K Time Projection Chamber

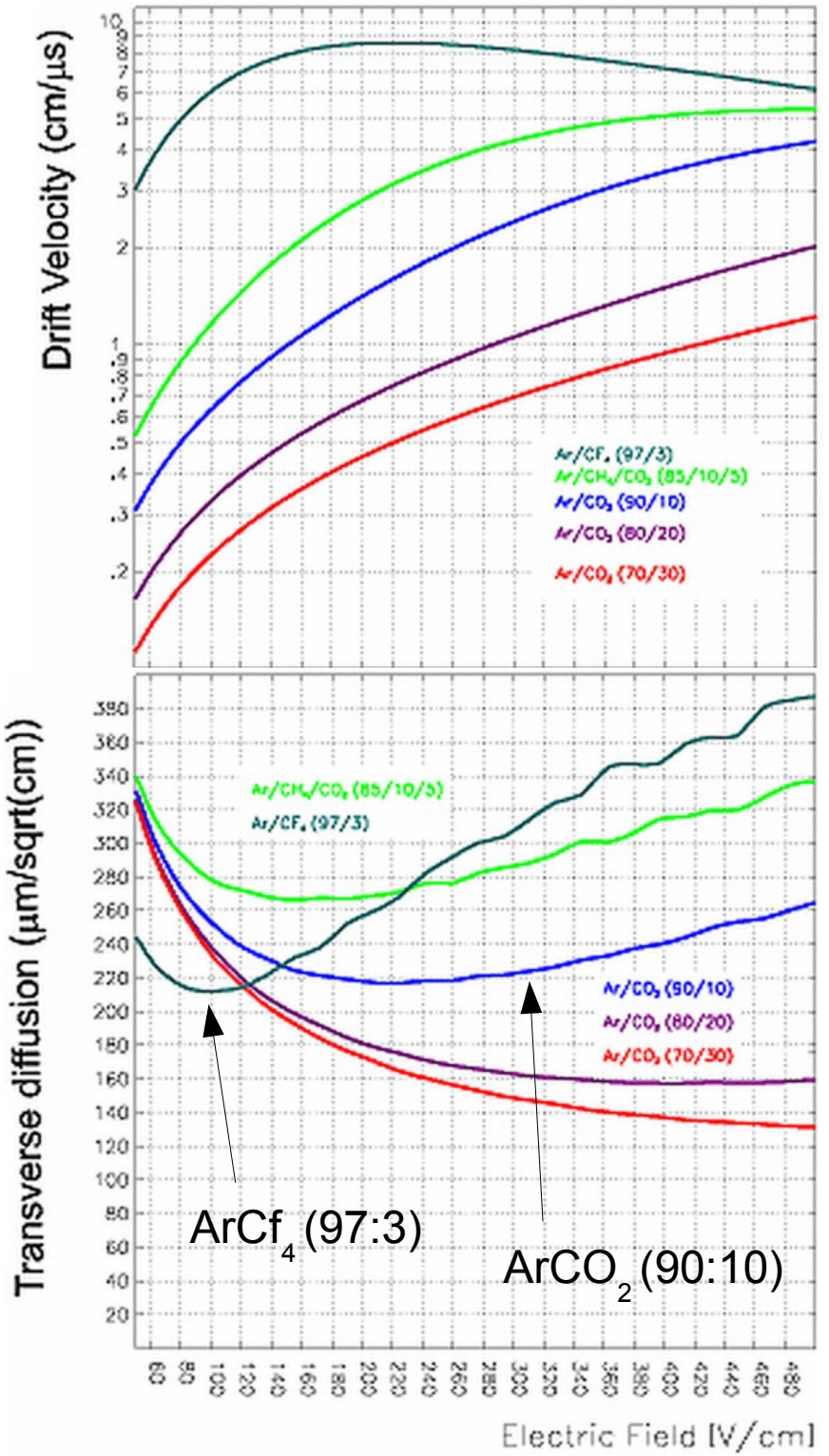


- $2.5\text{m} \times 2.5\text{m} \times 0.9\text{m}$
- *E*,*B* fields parallel, perpendicular to beam
- Outer skin at ground
- Purpose:
  - Measure $\vec{p}$ of μ's produced in CCQE
  - Measure neutrino spectrum
  - Determine charges of reaction products
  - Distinguish *e*'s and *p*'s from μ's and π's
  - Provide additional target nuclei
- Requirements:
  - Momentum resolution <10%
  - Minimize amount of inactive space

Gas Choice

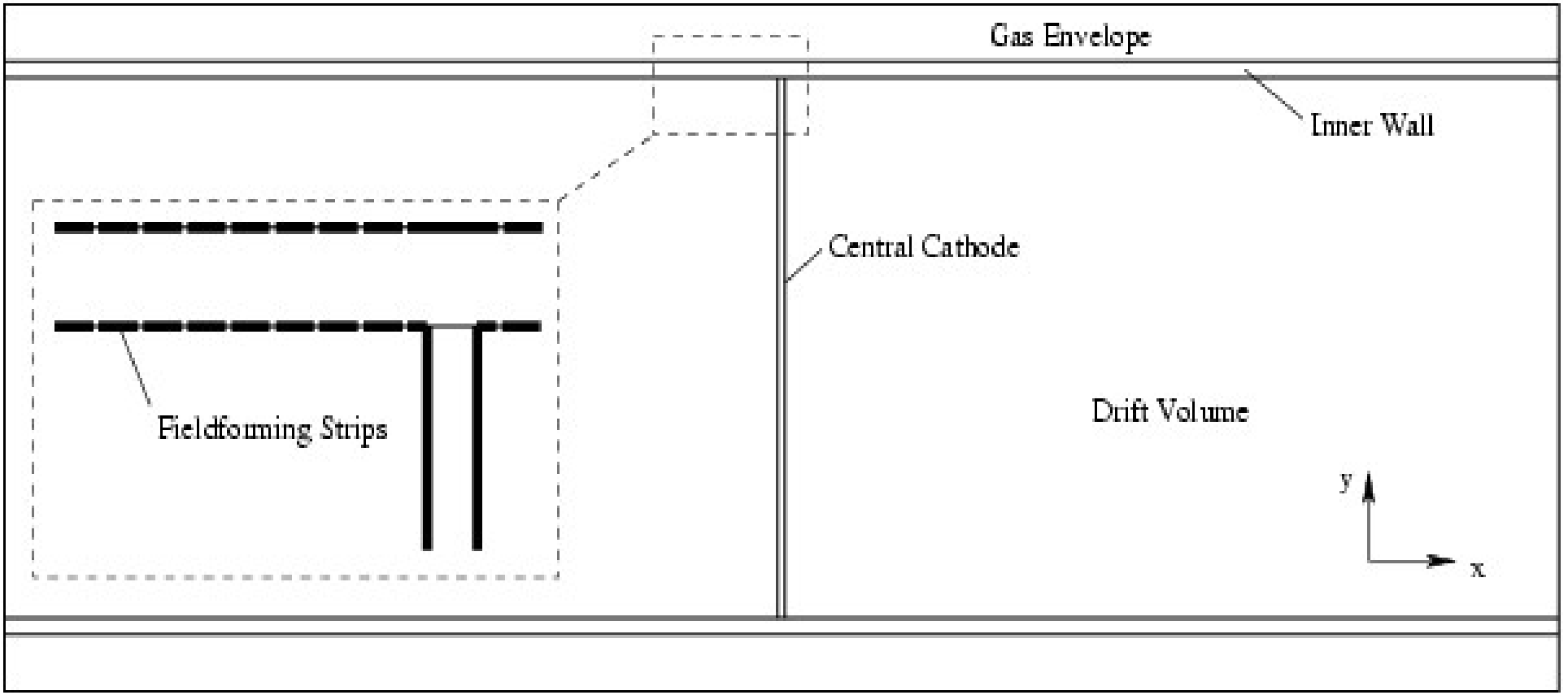
Many accurate space points along the length of the track

- Slow gas acceptable b/c 3.5s btw spills
  - has low diffusion
  - weak sensitivity to E×B distortions
  - weak sensitivity to spill width (5μs)
  - electron attachment on O_2
- Gas candidates:
  - **$ArCO_2$ (90:10)**
  - $ArCf_4$ (97:3)
  - Ne
- Electric Field:
  - 200V/cm (up to 400V/cm)



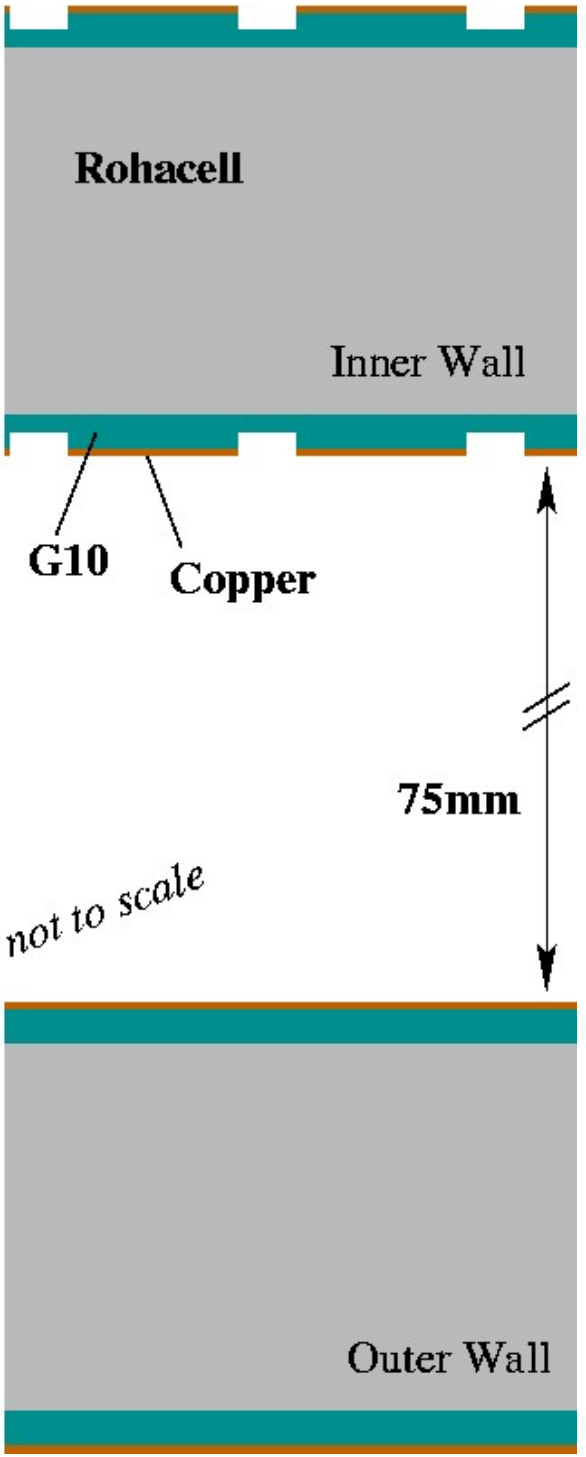
Field Cage

- Central Cathode <50kV
- Design resembles STAR field cage
- Potential degrader realized by copper strips on composite walls
- Gas envelope reduces gas contamination, drops high voltage

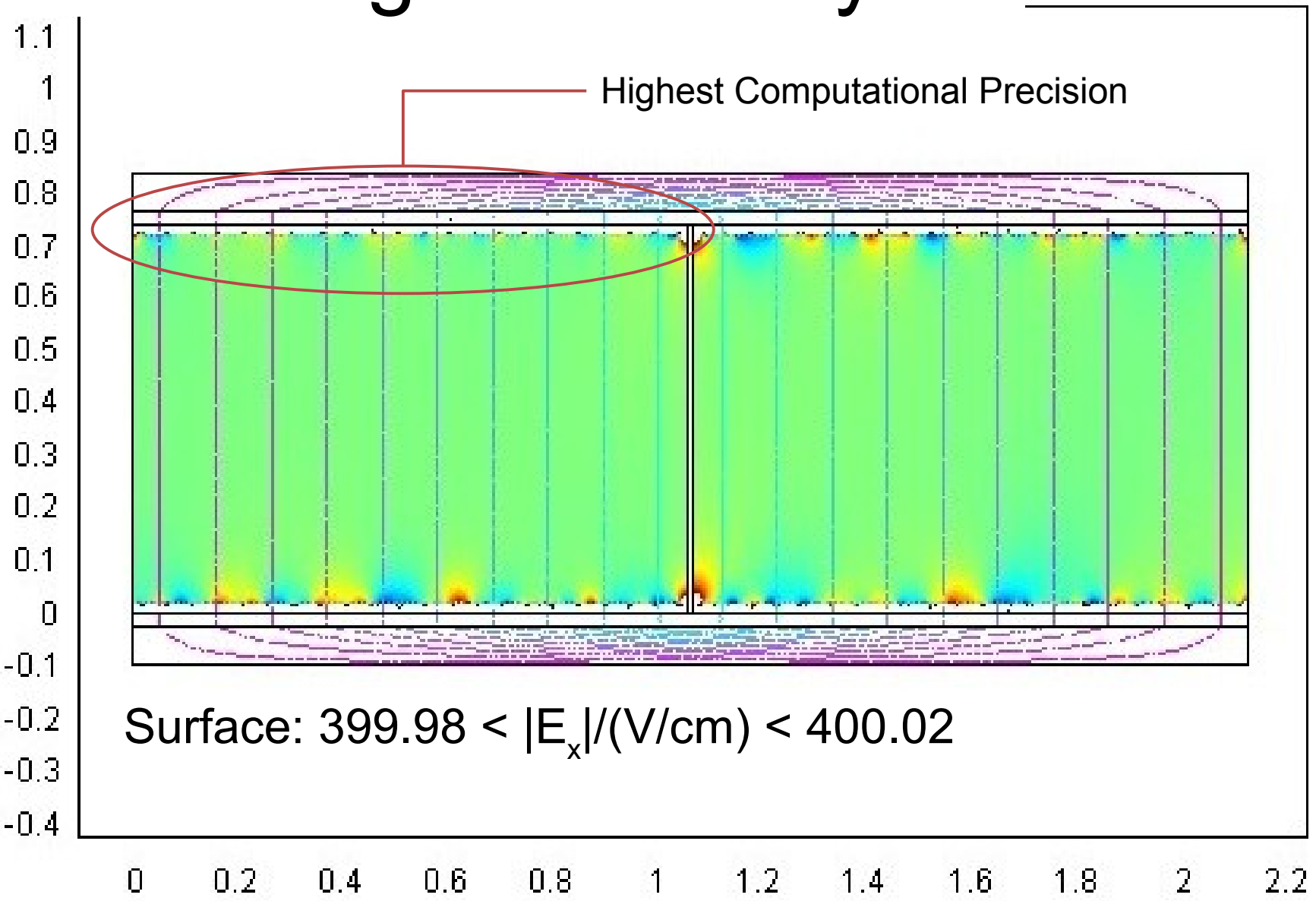


Wall Properties

- 20μm Copper, 1mm G10, 10mm Rohacell
- 2.84% radiation length per wall
- Grooves to be cut with a router (Δd~50μm)



Field Cage: FE Analysis

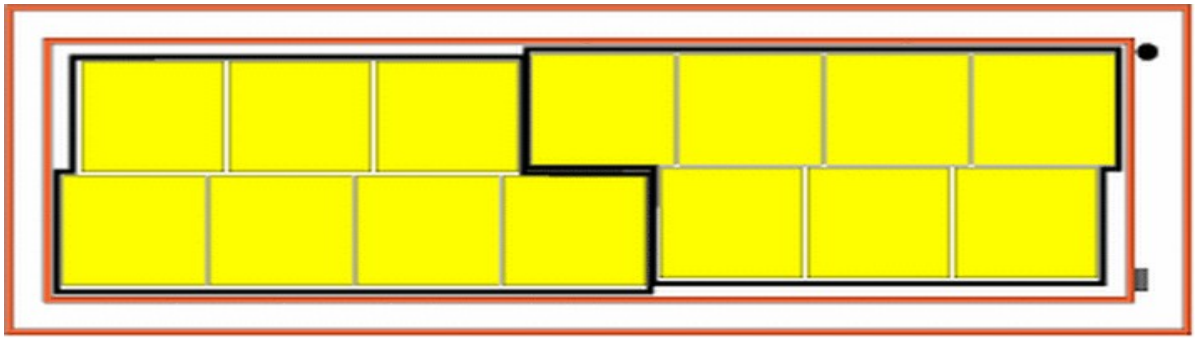


Excellent field uniformity for distances >2cm from inner wall.

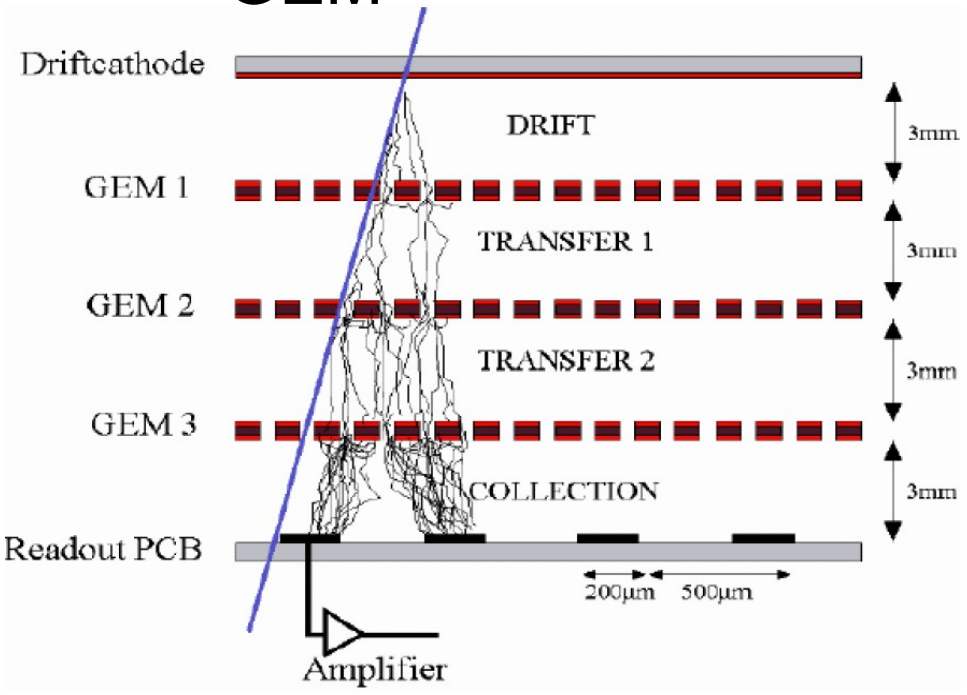
Finite element analysis done using FEMLAB (comsol.com)

Gas Amplification

- Micro-pattern devices: GEM or μMEGAS
- Both come in ~30×30cm² size ⇒ 14 modules per face

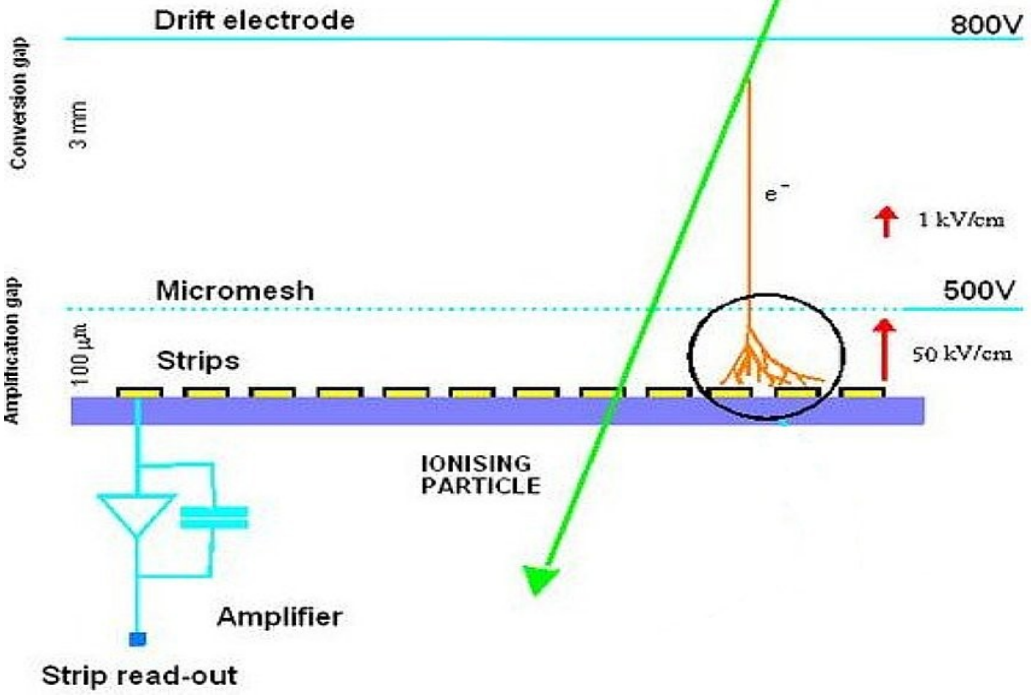


GEM



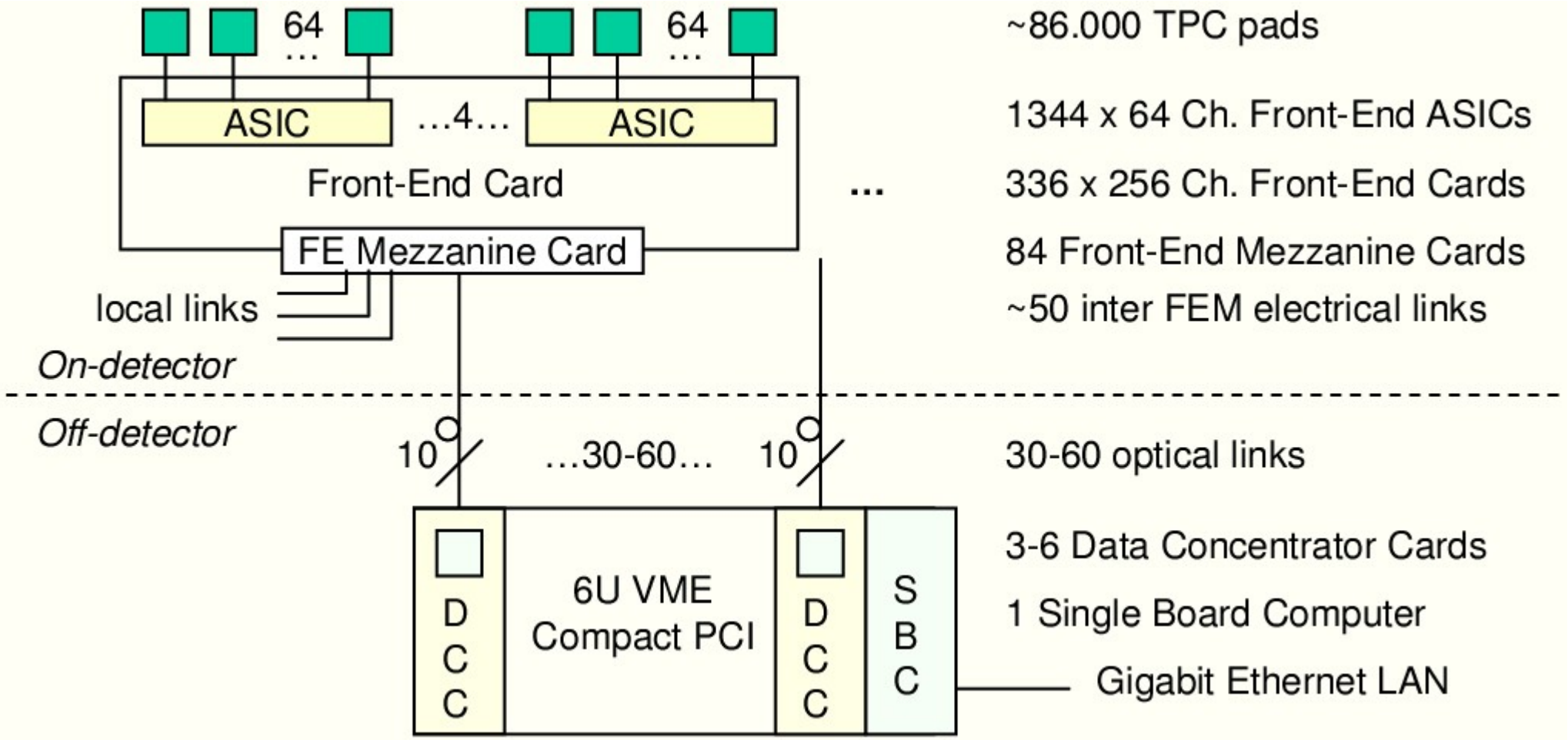
MICROMEGAS

Micro Mesh Gaseous Structure



Electronics and DAQ

- Very large number of channels (86k – 130k for three modules)
- Modest event rate (beam spills ~3.5s + cosmics and calibration)

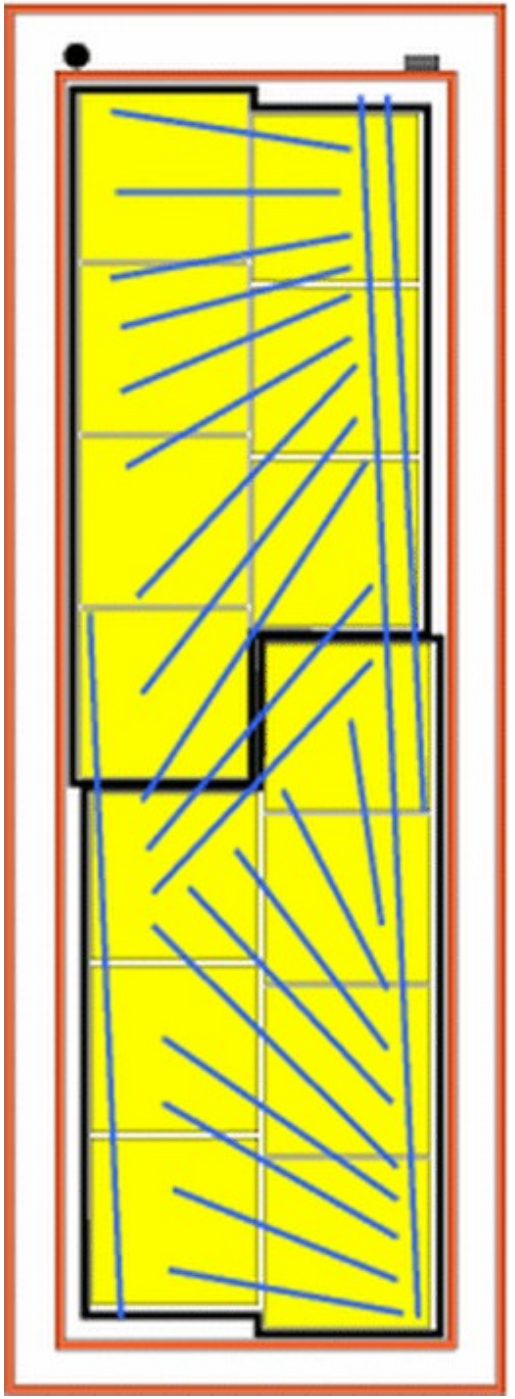


Calibration

Field distortions, module to module alignment

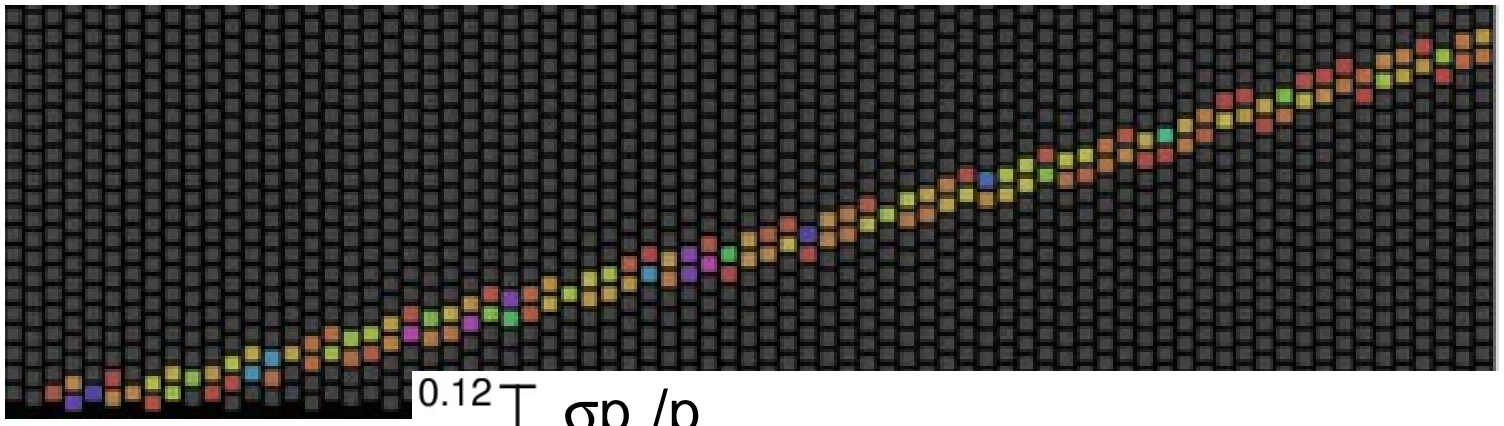
Investigate distortions with straight tracks:

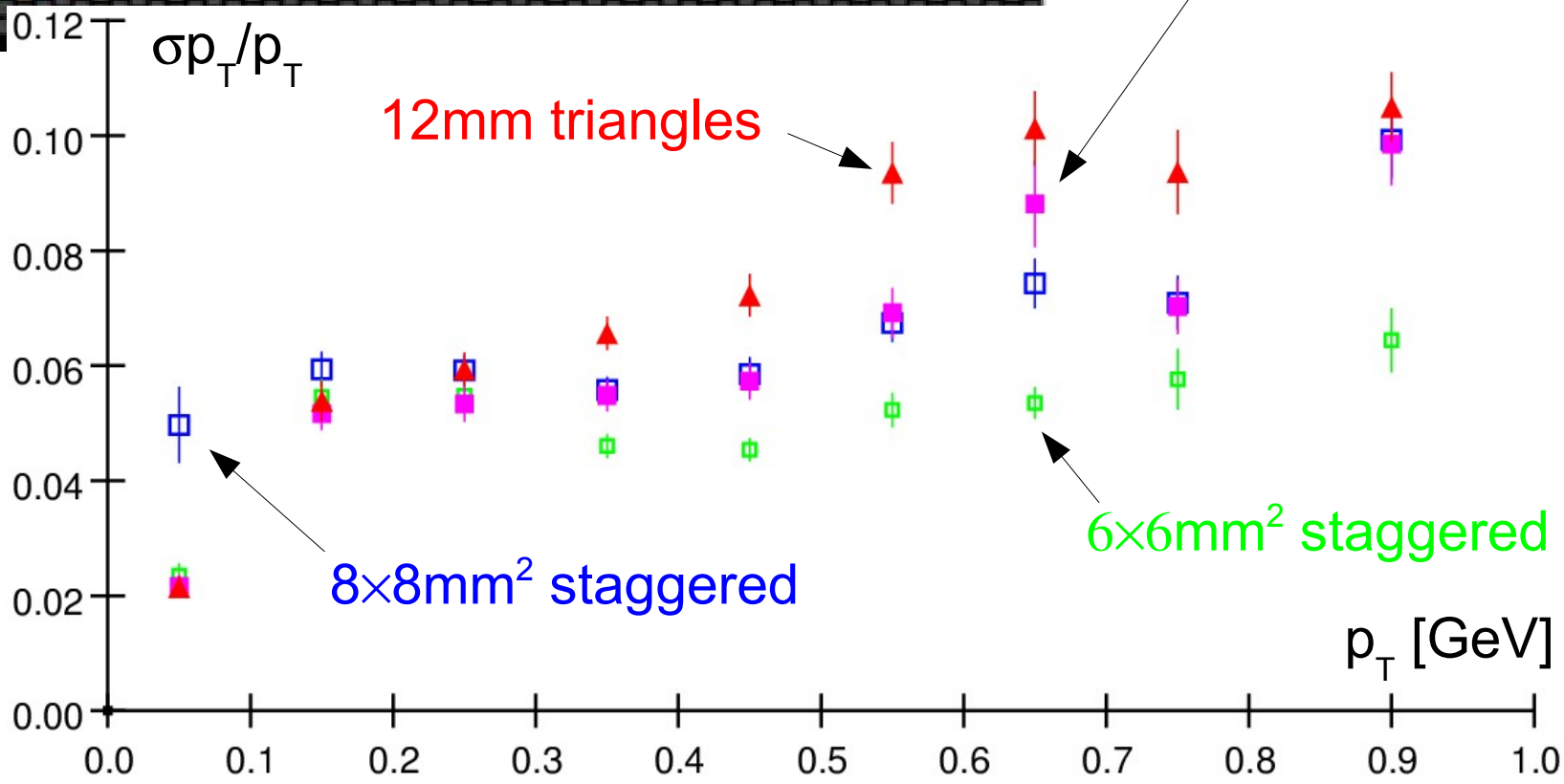
- few GeV muons
  - fairly parallel to beam direction
  - rate undetermined
- cosmic rays
  - top to bottom
  - several hundred Hz
- laser beam
  - photo-emission from aluminum strips on central cathode



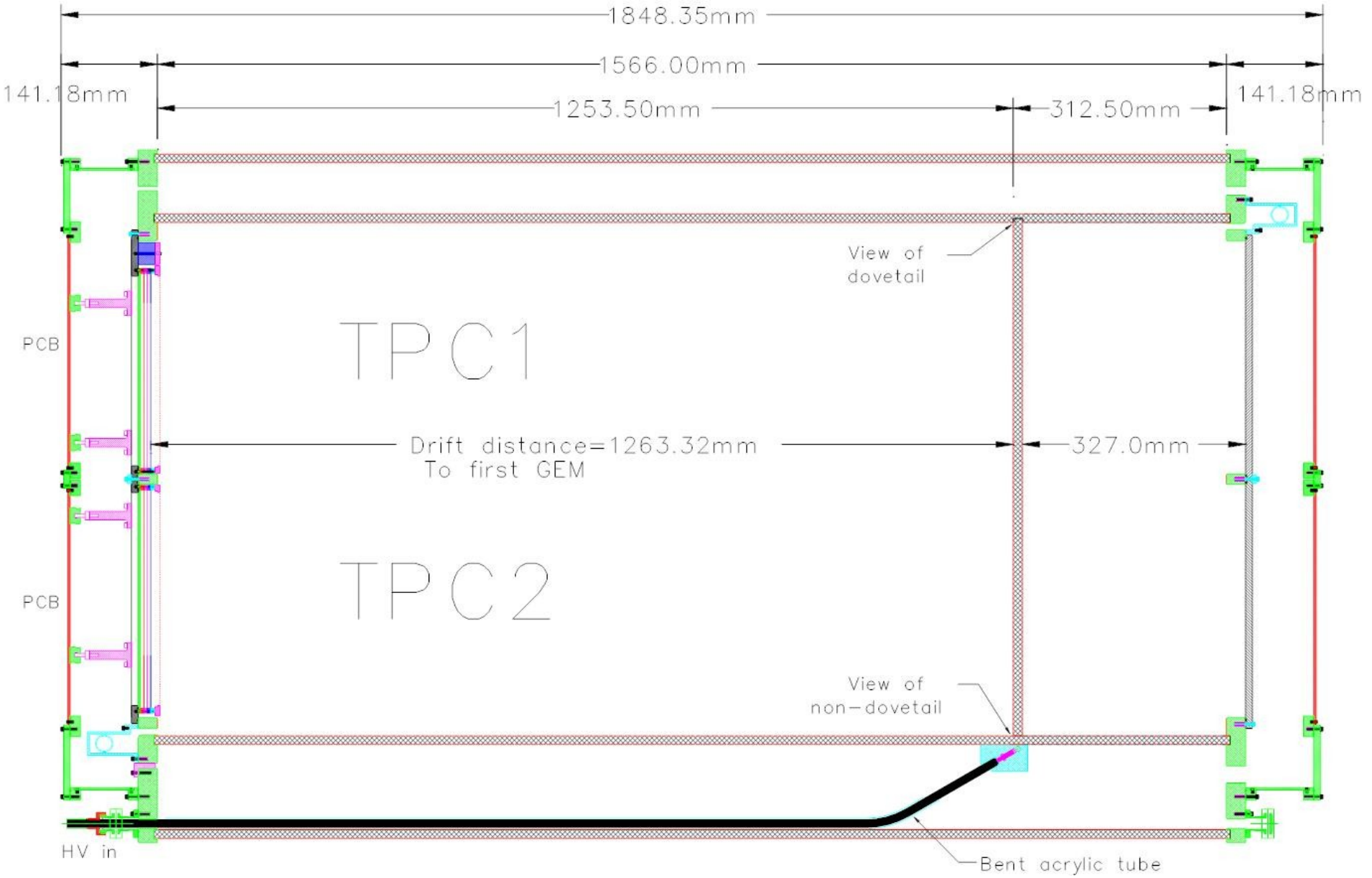
Performance

- Tracks traverse the TPC with a broad angular range
- Square readout pads envisaged ($8\times8mm^2$)





Prototyping



Summary

- T2K near detector concept includes 3 TPC modules
- TPC well suited for tracking neutrino interactions
- Gas choice: $ArCO_2$ (90:10)
- Field cage follows STAR design, excellent field uniformity
- Potential degrader realized with an industrial router
- Signal detection with GEM's or μMEGAS
- Calibration with cosmics, high energy muons and electrons from aluminum strips via the photoelectric effect
- Prototype construction to start this summer