S7 - Gas detectors

A compact TPC for the Crystal Ball

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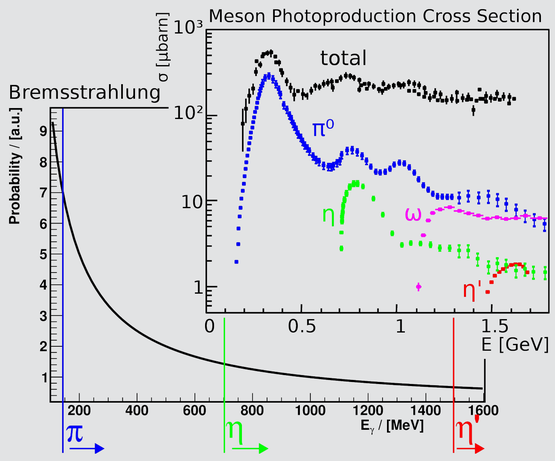
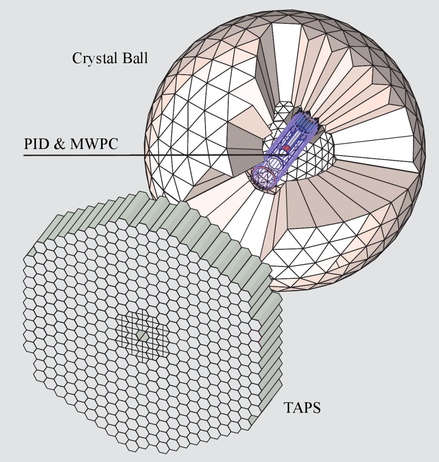
Crystal Ball @MAMI: Experiments with real photons

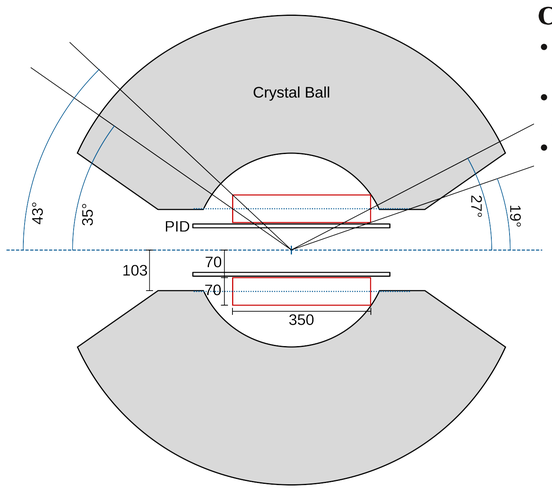


The A2 collaboration at MAMI

- Photoproduction of mesons and nucleon resonances
- Real photons from MAMI electron beam (bremsstrahlung)
- Crystal Ball and TAPS detectors optimized for neutral final states
- Goal: High rate production of η and η'
  - Direction information of charged particles required for:
  - **$\eta' \to \pi^+\pi^-\gamma$, $\eta' \to \pi^+\pi^-\gamma\gamma$**
  - **$\eta/\eta' \to 3\pi$, $\eta' \to \eta\,\pi^+\pi^-$**
  - Large background of other reactions due to bremsstrahlung spectrum and low production cross section.
  - Tracking detector: two-layer MWPC
  - Currently used MWPCs have problems at high rates of charged particles.

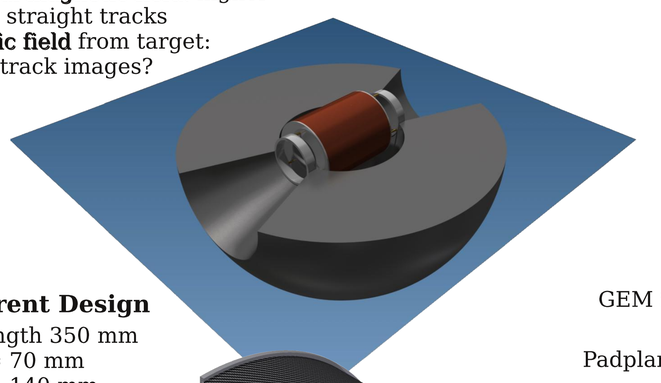
➡ Construct a new compact TPC





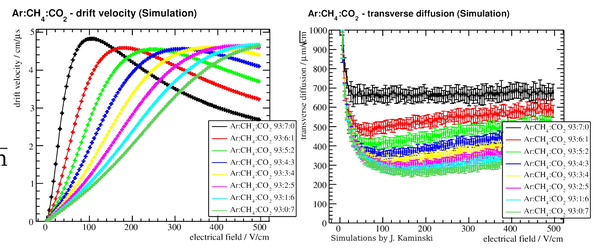
Challenges:

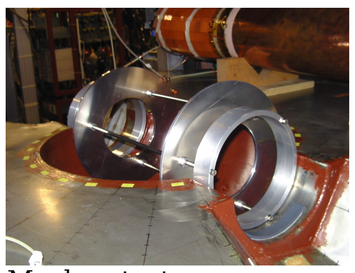
- **Limited space:** Leave enough space for PID and target
- **No longitudinal magnetic field:** higher diffusion, only straight tracks
- **Stray magnetic field** from target: Distortions of track images?



Gas: 93% Ar, 5% CH_4, 2% CO_2

- E = 246 V/cm
- v_d = 4.5 cm/μs
- U = 11.25 kV
- Transverse diffusion D_t = 446 μm/$\sqrt{cm}$
- Longitudinal diffusion D_l = 269 μm/$\sqrt{cm}$
- t_{max} = 7.7 μs

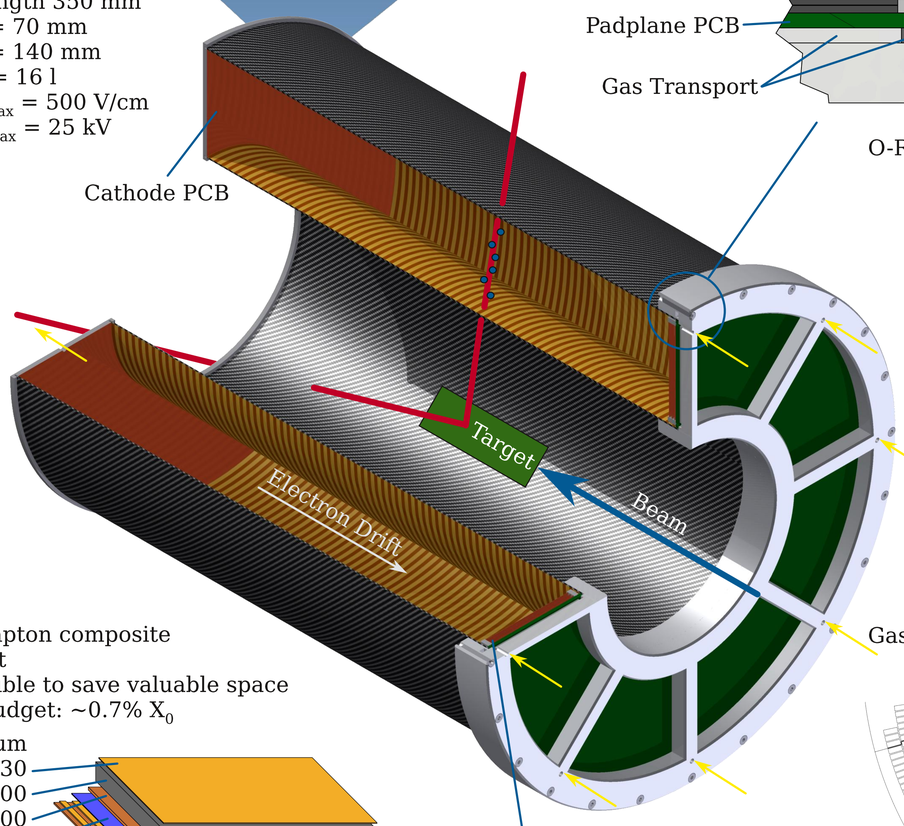


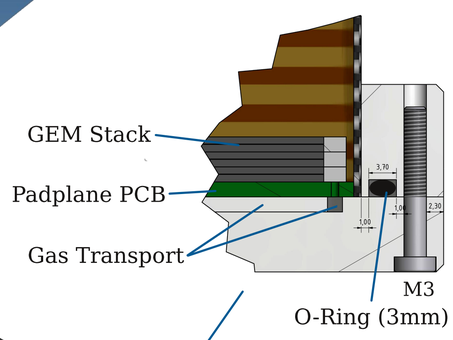


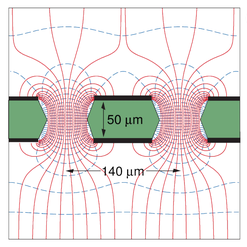
Mockup test

Current Design

- Length 350 mm
- r_1 = 70 mm
- r_2 = 140 mm
- V = 16 l
- E_{max} = 500 V/cm
- U_{max} = 25 kV







GEMs:

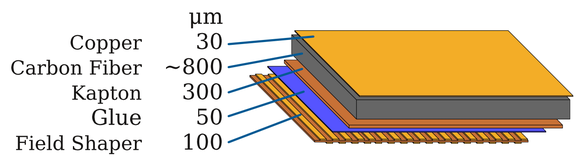
- Standard GEMs from CERN
- 3 GEMs in stask
  - 2mm transfer gaps

Field Shaper

- Copper strips on Kapton foil, double sided
- 85 strips
- 2 mm / 2 mm spacing
- 10 MΩ resistors, SMD, inside the wall
- Per wall:
  - 2 Chains
  - 480 MΩ
  - I = 47 uA
  - P = 1 W

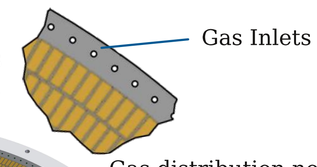
Walls

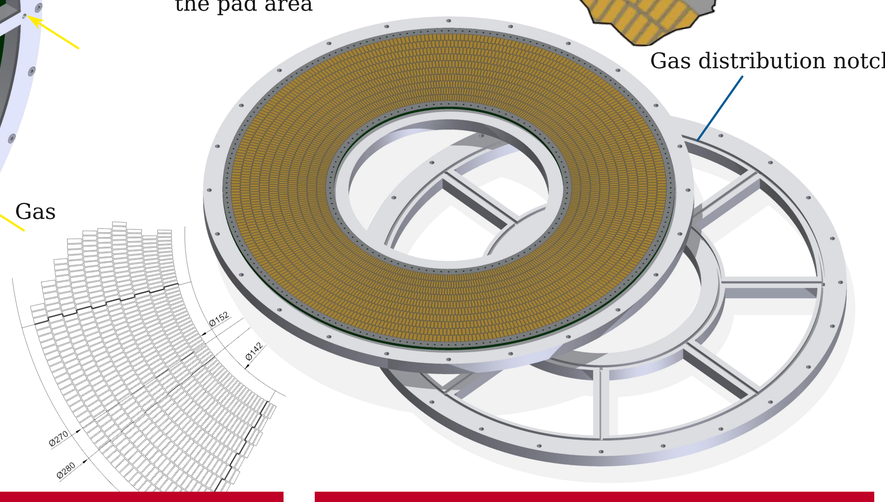
- Carbon fiber/Kapton composite
- Strong and light
- Thin walls possible to save valuable space
- Low material budget: ~0.7% X_0



Gas Connection

- Limited space on pad plane PCB
- Gas inlets as small holes around the pad area

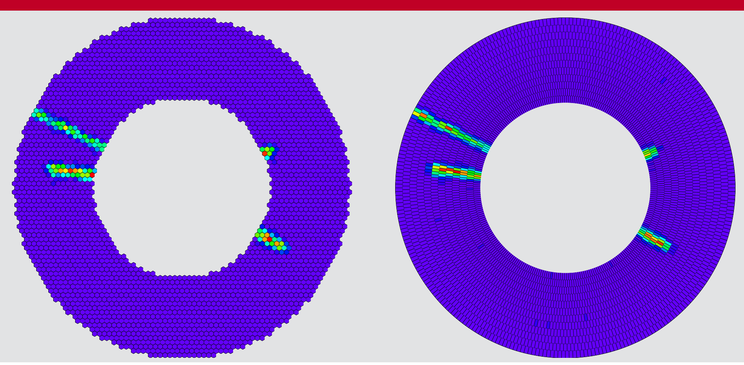




Simulations

Simulation Framework

- PLUTO Event Generator for realistic events
- Drift electron propagation based on diffusion law
- Multiplication, broadening in GEM stack
- Simulation of readout electronics
- Reconstruction with regular software



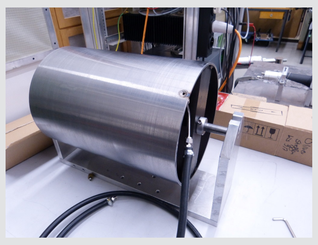
Readout Pads

- Trapezoidal pads
  - 3360 Pads
  - 10 or 12 Rows, staggered
  - Plane composed of 8 sectors
- Investigating hexagonal pads

Reconstruction Software

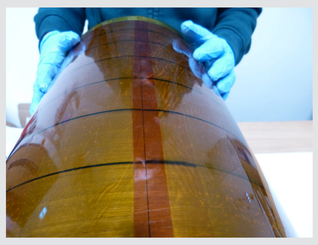
- Readout for STAR Electronics (old)
- Self-adapting pedestal subtraction
- Peak finding
- Clustering
- Different styles of pad planes
  - Tradezoid (Ring)
  - Hexagonal (Ring)
  - Rectangular (Rectangle)
  - Irregular pad shapes possible
- Cluster prefiltering by Huff transform and binning
- Simple Kalman filter for straight tracks

Out-of-Autoclave-Carbon-Fiber-Prepreg

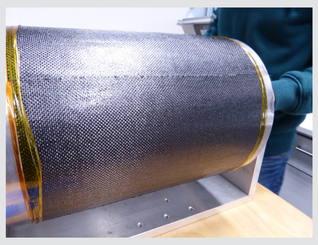


The mold with vacuum connection

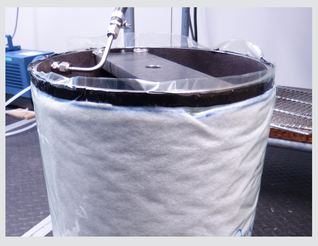
Cutting the material



Putting the Kapton layers on the mold



Prepreg sticks to the Kapton



Wrap in cloth and vacuum foil, evacuate

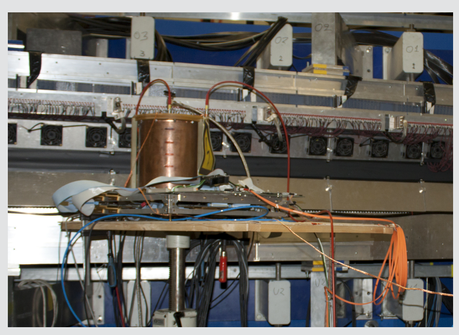
Bake at 100 °C, 4 hours

Removing the vacuum bag

The result

Tutorial at www.easycomposites.co.uk

Test Prototype



Chamber

- 320 channels
- old electronics

Test with electron beam

- Single hit resolution
  - x: ~0.4mm
  - z: ~0.6mm

Conclusion

Summary

- Development of a compact triple GEM TPC to replace MWPCs
- Field Cage design almost finished
- Working software framework
- Ongoing simulation studies
- Readout electronics needed

Next Steps

- Design HV-Feedthrough
- Build Chamber
- Find Readout Chip
- GEANT4 Simulation
- Optimize Pads
- Optimize Track Finder