Status of studies from HPAr TPC

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Moving forward

• The document circulated by the ND study group conveners has asked us to consider the capabilities of the HP gas TPC in two configurations
  • Within an iron-dominated dipole
    – Magnet similar in design to that in the ND CDR, but re-optimized for the HP gas TPC
      • Magnetic volume must be no larger than that in the CDR (162 m$^3$)
  • Inside the KLOE magnet
• Address how well the gas TPC does as a stand-alone detector for a number of channels and with respect to a number of performance criteria
• Address how well the gas TPC does in conjunction with ArgonCube
Iron-dominated dipole

- Assume that the FGSD is not in the dipole
- Room for ECAL inside magnet must be included
  - 0.3m on radius
- Now consider a cylindrical TPC (as in ALICE)

- Staying within the 162 m$^3$ allows for
  - TPC active volume 5m in diameter and 5 m long (2.5 m drift)
    - Active mass – 1.8t
- Working outwards from TPC
  - 0.09m for the field cage
  - 0.05m for the gas insulator + outer TPC cylinder
  - 0.03m for the pressure vessel
  - 0.30m for ECAL
- Diameter of TPC/ECAL assembly is then 5.94m which allows for a total L (including chambers and readout electronics) of 5.8m
With KLOE magnet

- The KLOE magnet imposes much more stringent constraints on the size of the HP gas TPC
- Magnet bore
  - 4.8m ID by 4.6m long
- Again, assume ECAL is within magnet
- Assuming we rebuild the iron yoke and use the same assumptions regarding space needed outside TPC active volume
  - Max. TPC active diameter is 3.6m with L = 3.8m
    - Active volume: 0.7t
- If we work with existing KLOE iron
  - Active length limited to ~ 2.8m
    - ~0.5t
KLOE magnet
Event rates

• Assumptions
  – neutrino flux: 2016 DUNE Flux: CP_run15_12388 (80 GeV)
  – POT/yr. = 1.47 X 10^{21}
  – x-sections: GENIE v2.12.0 default splines courtesy of Steve Dytman
  – On Ar40
    • 10 ATM Ar-CH_{4}
    • ~ 97% interactions on Ar
  – Numbers shown: #/t-yr.
    • Dipole magnet configuration yields 1t fiducial mass
• The following is for neutrino running
<table>
<thead>
<tr>
<th>Channel</th>
<th>Number of evts (per t-yr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC Total</td>
<td>1.64 X 10^6</td>
</tr>
<tr>
<td>NC Total</td>
<td>5.17 X 10^5</td>
</tr>
<tr>
<td>CC Coherent</td>
<td>8.35 X 10^3</td>
</tr>
<tr>
<td>NC Coherent</td>
<td>4.8 X 10^3</td>
</tr>
<tr>
<td>$\nu_\mu$ – electron elastic</td>
<td>292</td>
</tr>
<tr>
<td>CC $\pi^0$ inclusive</td>
<td>4.47 X 10^5</td>
</tr>
<tr>
<td>NC $\pi^0$ inclusive</td>
<td>1.96 X 10^5</td>
</tr>
<tr>
<td>Low $\nu$ (250 MeV)</td>
<td>2.16 X 10^5</td>
</tr>
<tr>
<td>Low $\nu$ (100 MeV)</td>
<td>7.93 X 10^4</td>
</tr>
<tr>
<td>$\nu_\mu$-bar CC Coherent (anti-$\nu$ mode)</td>
<td>6.90 X 10^3</td>
</tr>
<tr>
<td>Channel</td>
<td>Number of evts (per t-yr.)</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>CC Tot</td>
<td>$1.89 \times 10^4$</td>
</tr>
<tr>
<td>NC Tot</td>
<td>$5.98 \times 10^3$</td>
</tr>
<tr>
<td>CC Coherent</td>
<td>93</td>
</tr>
<tr>
<td>NC Coherent</td>
<td>52</td>
</tr>
</tbody>
</table>
Detailed geometry and simulation work

- Justo will give details in the next presentation
- A few comments
  - Developing within the DUNE code framework, but a great deal is still to be done
  - In parallel, we have setup the ALICE software framework with the capability of “inserting” GENIE events (track root tree) into their framework and do full (charge generation, drift, amplification, cluster/hit definition, pattern recognition, reconstruction, etc.
    - Close to having this working
    - Many thanks to Jens Wiechula, Institut für Kernphysik, Frankfurt
Performance specifications of HP TPC

• Will require full event gen and simulation, but:
• We have extrapolated from ALICE as-built performance the following (1 ATM vs. 10 ATM operation, yes. But effects compensated by higher S/N at 10 ATM).
  – Tracking efficiency: >99% over $4\pi$
  – Track detection energy threshold: 5 MeV
  – $\delta p/p$: 0.7% at 1 GeV/c, ~ 5% at 5 GeV/c
  – $\Delta \lambda$: ~ 0.3 mrad ± 0.01
  – Energy scale uncertainty < 1% for both muons and electrons
  – $\text{NC}\pi^0/\nu_e\text{CC}$ rejection >$10^4$ (MARS simulation)
  – $\pi^0$ energy resolution $8%/\sqrt{E(\text{GeV})}$
    • Based on ECAL design work by Frank Simon’s group
      – Pb-scintillator
Some slides on hardware development
System Development

- ALICE TPC test stand: Guillermo Fernandez, Jen Raaf, Kirsty Duffy (Fermilab) and Gavin Davies (Indiana U)
- TPC Gas testing: Philip Hamacher-Baumann (Aachen)
- TPC pressure vessel: Bob Flight (Rochester)
- ECAL: Frank Simon
ALICE TPC Test Stand: Guillermo Fernandez, Jen Raaf, Kirsty Duffy (Fermilab) and Gavin Davies (Indiana U)

- Using one of ALICE’s readout chambers (spare) for testing
- Goals for test stand:
  - Run from 1 to ~10 atm pressure and Different gas mixtures
  - Detector performance:
    - Gain
    - Uniformity
    - Stability
    - Energy resolution
    - Ion feedback
  - Gas properties: (with Aachen University)
    - Transversal and longitudinal diffusion
    - Drift velocity
    - Test stand for electronics
    - Possibility for light detectors

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DUNE ND general meeting
ALICE Readout chamber (IROC)

IROC @ FNAL

~5500 channels

47 cm

Pad size
IROC: 4x7.5 mm²
OROC: 4x10, 4x15 mm²
HP Test stand: Ready to start testing

Will use the muon tag system to trigger pad signal going to the Ortec 109A preamp and CAEN digitizer (Lariat electronics & DAQ)
Gas Detector Lab: Philip Hamacher-Baumann

In-house gas mixing

Universal Gas Mixing Apparatus (UGMA)

Mixing of up to 3 gases with high precision (<0.1 vol-%) with output pressure of up to 3 barg. Operation in open & (semi) closed loop.

High Pressure Extension?

Applied for funding of compressor stage capable of providing output pressures up to ca. 12 barg.

Fully autonomous operation, months long or until supply empty.
Gas Detector Lab II

Working principle of a Gas Monitoring Chamber (GMC)

Idea: Like a TPC, but reversed

Low pixel TPC with known track positions for reconstruction of gas properties:
- drift velocity \( v_d \)
- (relative) gas gain
- gas mixture, diffusion

Measurement of \( v_d \)

1. traversed \( \beta \) starts timing
2. electron cloud drifts to readout
3. gas amplification
4. induced signal stops timing
The High Pressure Gas Monitoring Chamber

Goal

- variable pressures
- any kind of gas mixture
- measure gas properties

HPGMC

Features

- Safe high pressure system up to 10 bar
- Cathode voltages up to 20 kV at atmospheric pressure
  - at 10 bar $\frac{E_T}{p}|_{\text{max}} \approx 84 \ \text{V/cm}^K/\text{mbar}$
- High purity experimental conditions
Realistic pressure vessel – Bob Flight

- Starting with standard design
  - SS construction, conventional heads
- In communication with vendors
  - So far found 3 vendors capable of doing the fabrication
    - On-site construction
• Using CALICE work as foundation
• Pb-scintillator (maybe some Cu-scintillator layers)
• ½ ECAL inside pressure vessel, ½ outside
• Studies needed to optimize energy resolution and pointing accuracy
  – Note: geometry is non-projective
• Preliminary results
  – Sigma(E) ~ 8%/√E(GeV)
  – First pass at angular resolution study to the right ->