Electrical properties of various gas mixtures for active target detector application

Daniel Yates
Adviser: Dr. Rogachev
Texas Active Target (TexAT)

- New active target detector under development by Rogachev Group
- Time projection chamber (TPC) setup
- Gases will be used with TexAT
  - Target of beam
  - Active medium for tracking
- Will be used for detailed, precise 3-D track reconstructions from reactions of gases and rare isotope beams
Motivation

● TexAT will rely on simulations for gas properties:
  ○ Drift Velocity
  ○ Gas Gain
● Verification of simulators needed to provide uncertainties in track reconstruction
● Quantifying accuracy of Garfield++ drift simulation package
Approach

● Testing four potential target gases for TexAT
  ○ He+4%CO₂
  ○ He+10%CO₂
  ○ Methane
  ○ Isobutane

● TPC with applied electric field and proportional counters

● 5.4MeV alpha particles ionize gas, electrons drift and undergo Townsend avalanche near wires

● Alphas hit Si detector causing timing trigger on wires

● Use timing values to determine drift velocity
Setup

- Voltage applied to field cage surrounding TPC
- Mesh 3mm above wires
  - $e^-$ undergo avalanche in region
- Si detector with 6-slit mask across from alpha source
  - Defines alpha tracks
Data Interpretation

- Apply cut around alpha energy deposits
- Ensures only timing signals from alphas, not from outside noise

1 Channel = .6mV
Data Interpretation

- Fit gaussians to wire timing, use means to determine drift time
- Drift velocity can be calculated from drift time
- Averaged drift velocity of all 5 wires

1 Channel = .25ns
Simulations

● Using Garfield++\(^1\) drift simulation package
● Drifting e\(^-\) in same gas, pressure, and E-field
● Drifting every .5cm up to 10cm above floor
● Outputs drift velocity, timing and position resolutions

Results: Helium+CO₂

- 5% systematic uncertainty shown in error bars
  - mainly from uncertainty in E-Field and pressure/temperature
- Exp/Sims:
  - He+4%CO₂: 1.12
  - He+10%CO₂: 1.07
- Sims slightly underestimate drift velocity
Results: Methane

- Best fit of all gases
- Exp/Sims: 1.02
- Deviations start to occur at higher E/P values
Results: Isobutane

- Systematic deviation apparent in Isobutane
- Experimental data is 18% higher on average
Conclusion

● Garfield underestimates drift velocities of He+CO$_2$ mixtures by 7-12%
● Methane had only 2% deviation between experimental and simulation values
● Isobutane exhibited a systematic deviation from simulation data
  ○ Requires further testing with higher pressures and different geometry
Moving Forward

- Further testing of Isobutane gas
- Energy gains
  - Analyze data and run simulations
- Track reconstruction of alphas and electrons

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Results

- Both He/CO$_2$ mixtures exhibited similar drift velocities and deviations from simulations
- 5% systematic deviation in error bars
- Exp/Sims:
  - He4%CO$_2$: 1.15
  - He10%CO$_2$: 1.10
Results

- Methane matched best of all gases
- Exp/Sims: 1.03
- Some deviations at lower pressure
Evidence for Field Distortion

- Wires are consistent with external alpha source
- Deviations increase closer to source
Evidence for Field Distortion

- Individual wires are compact
- Wires spread when alpha source is moved inside

[Graphs showing drift velocity vs. electric field for different wires and conditions]
Surrounding pressures

With 1.5% air in mixture