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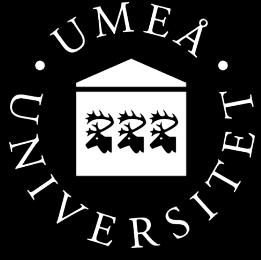
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NA62 straw tracker simulations

18th RD51 Collaboration Meeting, Aveiro

Richard Skogeby (jan.richard.skogeby@cern.ch)
Umeå University, SE

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Supervisors: Hans Danielsson
Giuseppe Ruggiero

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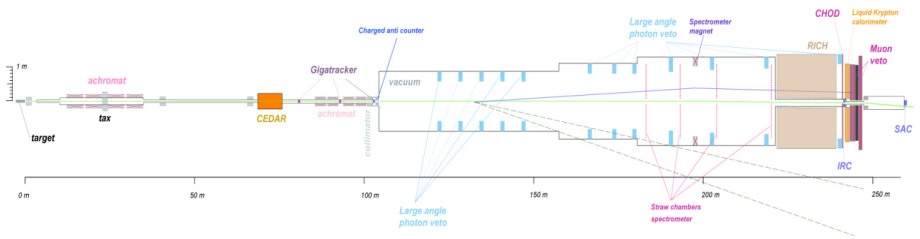
Introduction

The NA62 Experiment at CERN



- NA62 Objective: Measure branching ratio of $K^+ \to \pi^+ \nu\bar{\nu}$
- 750 MHz hadron beam, 6% kaons.
- 11 detector systems

- Ar/CO_2-filled spectrometer for momentum and coordinate measurements: Straw tracker
- 7168 straws over 4 chambers

Introduction

Simulation of the NA62 Straw tracker

Objectives of simulations utilizing Monte Carlo methods include:

- Determining trailing edge timings.
- Determining the R-T dependence (track distance from anode versus drift time) for use in the reconstruction.
- Estimating the spatial resolution using R.M.S. of residuals.

Setup

The programs used for simulations of the straw tracker include

- HEED - Calculates the ionization distribution utilizing the Photoabsorption Ionization (PAI) model[1]. Specifically it calculates the cluster density, cluster distribution and the thermalization of δ-electrons [1].
- MAGBOLTZ - Solves the Boltzmann transport equations for the electrons [2].
- GARFIELD - Detailed simulation of two- and tree-dimensional drift chambers [3].

[1] Could also have used DEGRAD, which calculates it through thermalization of equivalent electrons.

Physics of the simulations

- The Penning effect
- Mobility
- Clustering of primary ionizations

The Penning Effect

Plenty of gas molecules go into excitation rather than ionization. Because of the Penning effect this creates a, sometimes large, discrepancy between the measured signal and the signal created from primary ionizations. Two modes

- Tunneling of an electron, similar to an Auger electron (Hotop 1969, [4]) [2]

$$A^* + B \rightarrow A^{*-} + B^+ \tag{1}$$

$$A^{*-} \rightarrow A + e_A^- \tag{2}$$

- Optical excitation (Smirnov 1965, [7])

$$A^* \rightarrow A \tag{3}$$

$$B \rightarrow B^+ + e_B^- \tag{4}$$

[2] There has been claims that Lise Meitner is the actual discoverer of the Auger electron (Sietmann 1988, [5]). On the contrary, O. H. Dupac says Sietmann neglected Auger's 1923 publication and that the discovery is rightly attributed to Auger (Dupac 2009, [6]).

The Penning Effect

Based on research from Şahin et. al. the Penning transfer rate is set to 60% (Şahin 2010 & 2014 [8]) for the mixture 70% Ar & 30% CO_2, 1.02-1.04 bar, 300K in the Straw tracker.

- The Penning transfer rate is used by GARFIELD along with MAGBOLTZ' computed rates of excited molecule production [9].

Mobility

- All the simulations for the straw tracker at NA62 using Garfield have so far incorporated wrong physics, however mostly correct results have been obtained.
- Since last year we know that the signal ions are cluster ions.
  - Upon ionization Ar+ rapidly ionizes CO_2. The CO_2^+ in turn attracts other CO_2 molecules through induced dipoles (Kalkan 2015, [10]).

Mobility

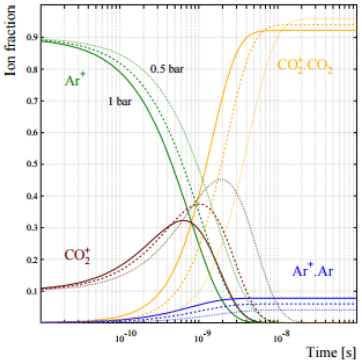


Figure: Ion fraction over time with a gas mixture of 90% Ar & 10% CO_2. Gas pressures: 1 bar (solid), 0.75 (dashed), 0.5 (dashed). (Image source: Kalkan 2015, [10])

Mobility

- The mobilities used in the simulations are based on outdated knowledge of how the ions are transported.
- For future simulations, mobilities of $CO_2^+ \cdot (CO_2)_n$ in a gas mixture with a CO_2 fraction of 0.3 will be used

Primary ionizations

Importance of the spacing of primary ionizations

The primary ionizations from HEED are not evenly distributed along the particle track. For the Straw tracker an exponential distribution for the spacing is used.

- Not so important for trailing edge timings.
- Very important for leading edge timings (used in computing resolution and R-T relation).

Primary ionizations

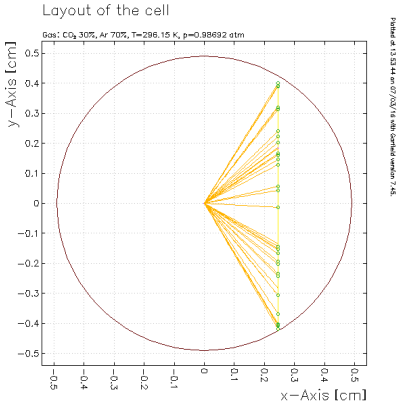
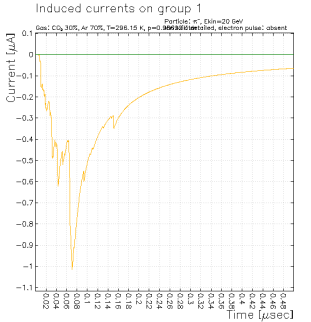
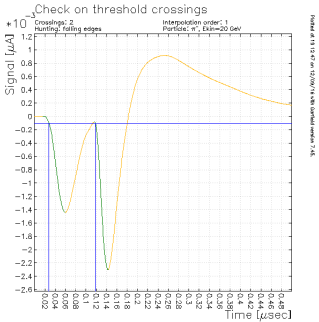


Figure: Primary ionizations for track at half maximum radius.

Signal examples



(a) Signal at anode.



(b) Signal after CARIOCA.

Figure: Signals before and after CARIOCA chip (same as for LHCb muon chambers, shaping time constant of $\approx$ 15 ns) for a 20 GeV π^- using 70/30 Ar/CO_2 mixture and HV 1750V.

Trailing edge timings

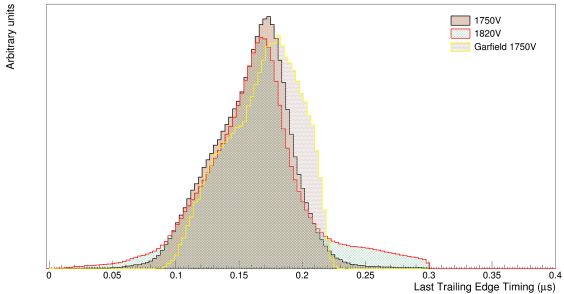


Figure: Trailing edge timings from the experiment (1750V and 1820V) and from Garfield with HV 1750V. Uniform distribution.

R-T determination

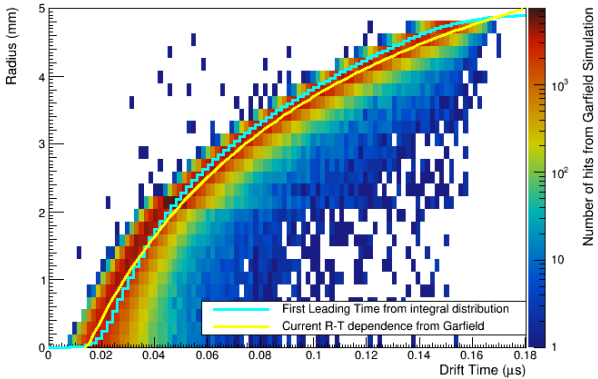


Figure: R-T data from simulations (colourmap), values used in NA62 (originating from Garfield data), attempt at defining an R-T from experimental data for each individual straw.

Resolution

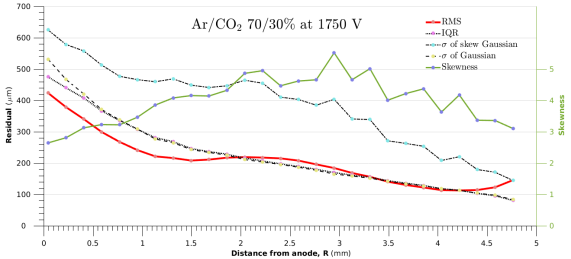
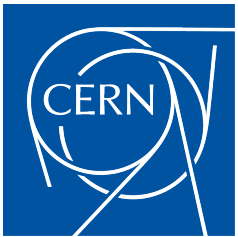


Figure: Resolution (red solid line) compared to σ of gaussian and skew gaussian fit to residuals as well as the IQR of pure data.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Appendix

Blanc Plot

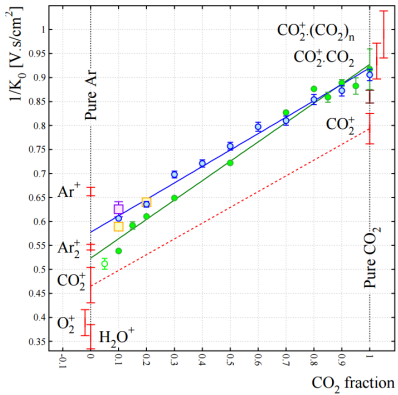

Figure: Blanc plot for Ar-CO_2 mixture.

Appendix

NA62 layout

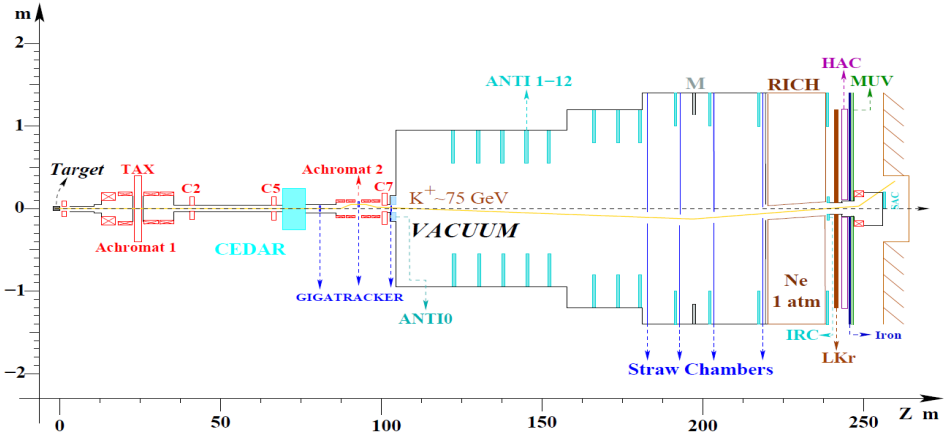

Figure: Layout of the NA62 experiment.

Bibliography I

1. Igor Smirnov. Heed. http://heed.web.cern.ch/heed/.
2. Stephen Biagi. Magboltz. http://magboltz.web.cern.ch/magboltz/.
3. Rob Veenhof. Garfield. http://garfield.web.cern.ch/garfield/, .
4. H. Hotop and A. Niehaus. Reactions of excited atoms and molecules with atoms and molecules. *Zeitschrift für Physik A Hadrons and nuclei*, 228(1):68–88, feb 1969. doi: 10.1007/bf01392435. URL http://dx.doi.org/10.1007/bf01392435.
5. Richard Sietmann. False attribution. *Physics Bulletin*, 39(8):316–317, aug 1988. doi: 10.1088/0031-9112/39/8/017. URL http://dx.doi.org/10.1088/0031-9112/39/8/017.

Bibliography II

6. Olivier Hardouin Duparc. Pierre Auger – Lise Meitner: Comparative contributions to the Auger effect. *International Journal of Materials Research*, 100(9): 1162–1166, sep 2009. doi: 10.3139/146.110163. URL http://dx.doi.org/10.3139/146.110163.
7. B. M. Smirnov and O. B. Firsov. Ionization of atoms by collision with excited atoms. *Vacuum*, 15(9):472, sep 1965. doi: 10.1016/0042-207x(65)92197-4. URL http://dx.doi.org/10.1016/0042-207x(65)92197-4.
8. Ö Şahin, İ Tapan, E N Özmutlu, and R Veenhof. Penning transfer in argon-based gas mixtures. *J. Inst.*, 5(05):P05002–P05002, may 2010. doi: 10.1088/1748-0221/5/05/p05002. URL http://dx.doi.org/10.1088/1748-0221/5/05/p05002.

Bibliography III

9. Rob Veenhof. Garfield:&optimise - penning-transfer documentation. http://garfield.web.cern.ch/garfield/help/garfield_57.html#Ref0573, .

10. Y. Kalkan, M. Arslandok, A.F.V. Cortez, Y. Kaya, İ. Tapan, and R. Veenhof. Cluster ions in gas-based detectors. *J. Inst.*, 10(07):P07004–P07004, jul 2015. doi: 10.1088/1748-0221/10/07/p07004. URL http://dx.doi.org/10.1088/1748-0221/10/07/p07004.