Low Pressure Focal Plane Detectors for the K600:A design study

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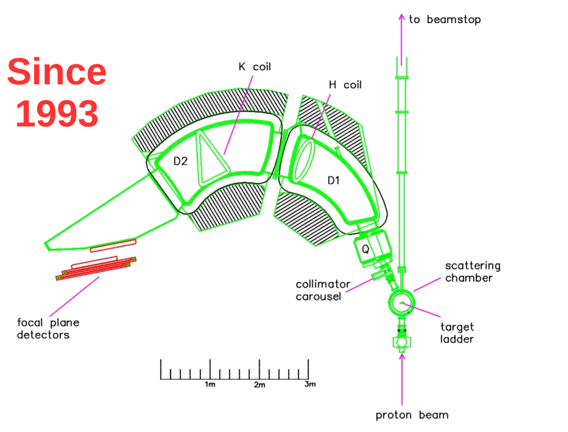
THE K600 AT iTHEMBA LABS

A kinematically corrected QDD magnetic spectrometer for light ions

Nominal bending radius = 2.1 m
Maximum magnetic rigidity = 3.60 Tm
Resolving power p/Δp = 28000

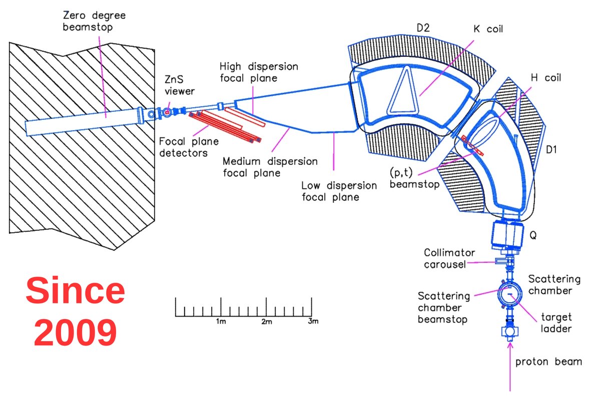
Max solid angle: 4.4 msr
Angular acceptance = ±37mrad
B (max)=1.84 Tesla
3 focal planes : low (LDFP), medium (MDFP) and high (HDFP)

Since 1993



Finite angle measurements (θ_{scat}>5°)
Medium dispersion focal plane B(D1)=B(D2)
Large momentum range: p_{max}/p_{min}=1.097
Horizontal magnification M_x =-0.52
Vertical magnification M_y =-5.5
Dispersion: 8.4 cm/%

Since 2009



Zero degree measurements (θ_{scat}<2°)
High dispersion focal plane B(D1)/B(D2)=1.49
Momentum range: p_{max}/p_{min}=1.05
Horizontal magnification M_x =-0.74
Vertical magnification M_y =-7.05
Dispersion: 10.9 cm/%

CURRENT PHYSICS PROGRAM

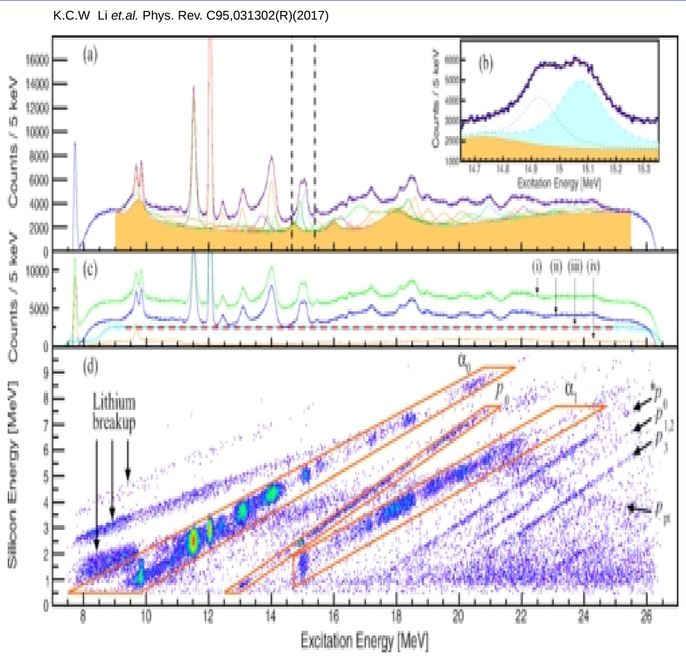
High resolution giant resonance studies e.g.
- IVGDR: (p,p') with Ep = 200 MeV at 0°, ΔE ~ 45 keV (FWHM)
- ISGQR: (p,p') with Ep = 200 MeV at finite angles, ΔE ~ 30-45 keV (FWHM)
- ISGMR: (α,α') with Eα = 200 MeV at 0°,4°, ΔE ~ 66 keV (FWHM)

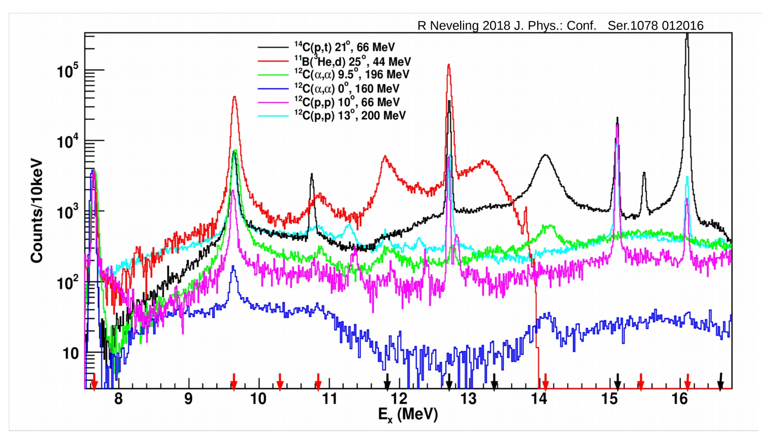
Nuclear reaction mechanism studies e.g. α knockout (p,pα) studies at Ep= 100 MeV, or proton knockout (p,2p) at 200 MeV

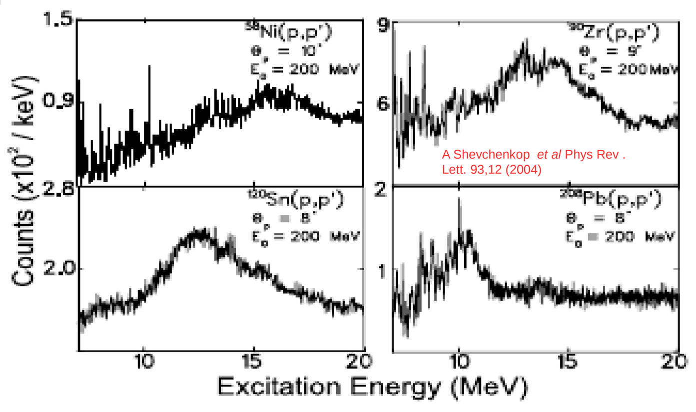
Searching for cluster states, their collective excitations and particle decay through CAKE coincidence runs, using e.g. (3He,d) at 44 MeV, (p,p') at 66 MeV, (α,α') = 200 MeV, (p,t) at 66 MeV

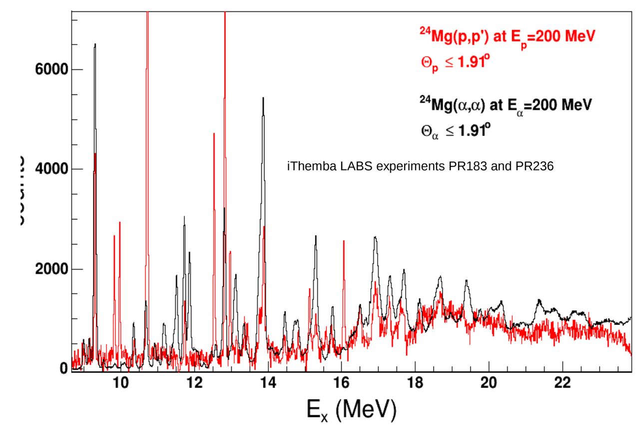
High resolution nuclear structure studies of nuclei for astrophysical interest: (p.t) at 100 MeV and 0°

PDR studies in coincidence with the BaGeL gamma detector array: (α,α') with Eα = 100 MeV at 0°

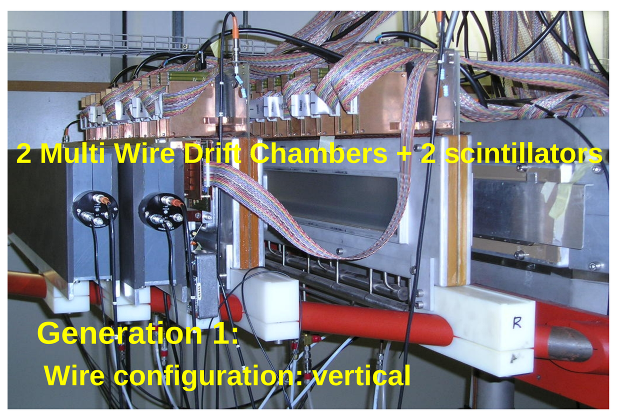








EXISTING FOCAL PLANE DETECTION SYSTEM

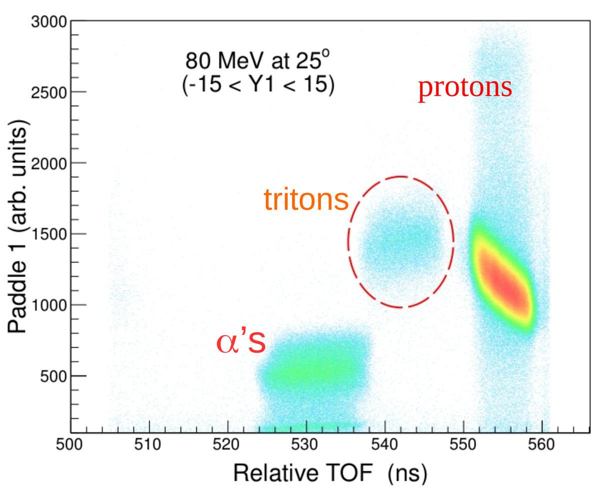


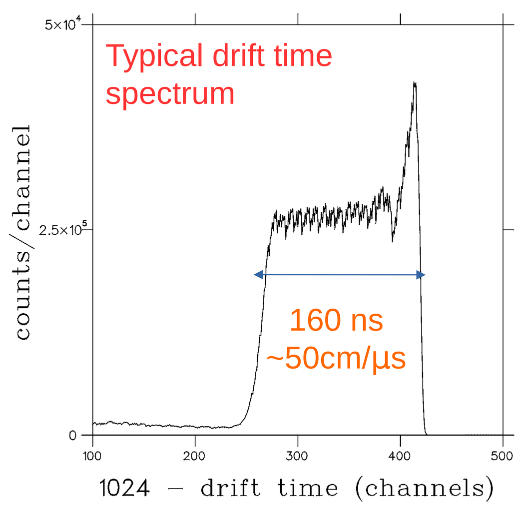
MDFP 35.7°,HDFP 32°w.r.t central ray
Signal wire- 20 µm Gold-plated W
Guard wire -50 µm gold plated W
Cathode planes 20 µm Al foil
198 (X), 143 (U) signal wires
201(X),146 (U) guard wires
Signal & guard wire spacing 4mm
Cathode-Anode spacing 8mm
1 bar Ar/CO2(90:10) gas
Horizontal & Vertical VDC acceptance -78 cm & 10cm

Scintillating material:Bicron BC-408
Dimensions: 48× 4 ×0.5 (or 0.25) inch³

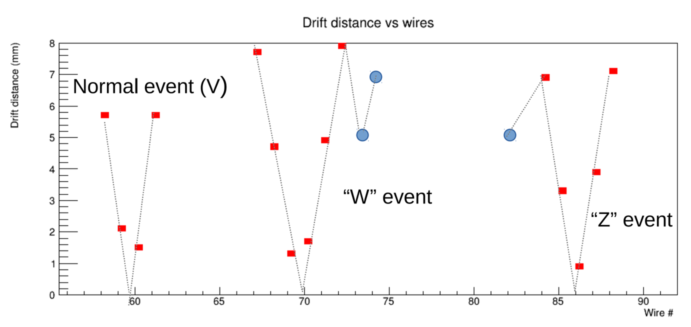
Scintillator used to trigger DAQ and for PID

Scintillator vs TOF



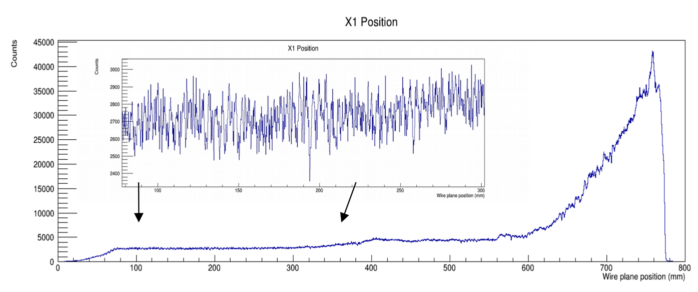


2 XU chambers: 768 channels
P-TM 005 16 channel preamplifier cards:Technoland
VME hardware
TDC: CAEN V1190A
100ps time resolution
MIDAS DAQ



4-8 wires per event
Track crossing of f.p. determined by linear regression
α's and ³He prone to cause "Z" and "W" events

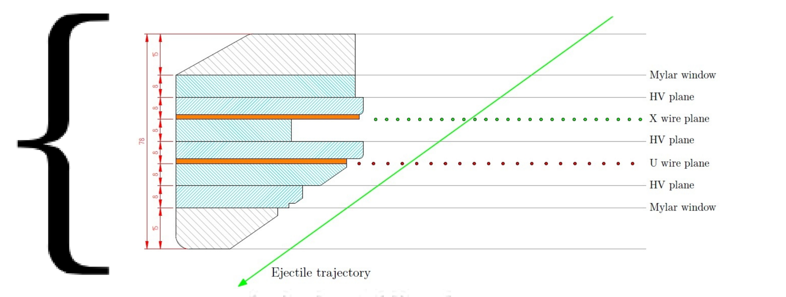
If uncorrected this leads to prominent 4mm structures

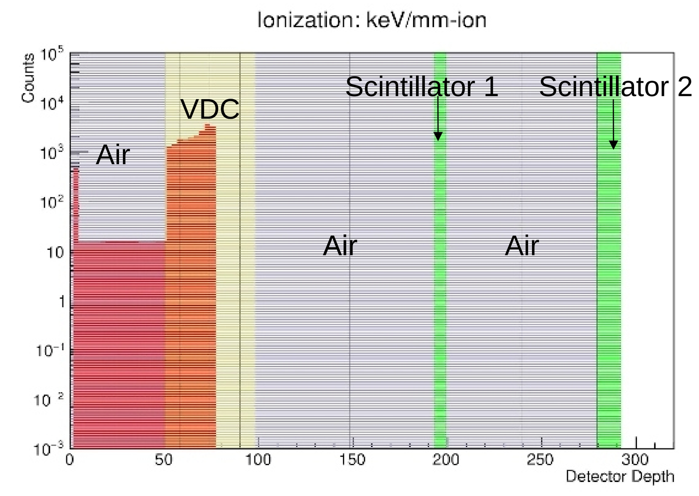


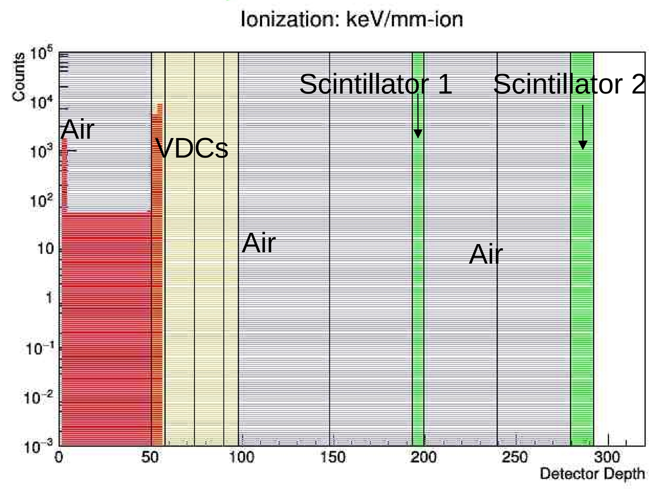
LIMITATIONS OF CURRENT FPD

Current FPD is designed for high E Z≤2. As a consequence:
- Inability to detect low energy particles (energies less than 30 MeV/u)
- Inability to detect heavy ions(Z>2) at energies available from the SSC

Material that constitute the current VDC that the particle must traverse before an event is registered.







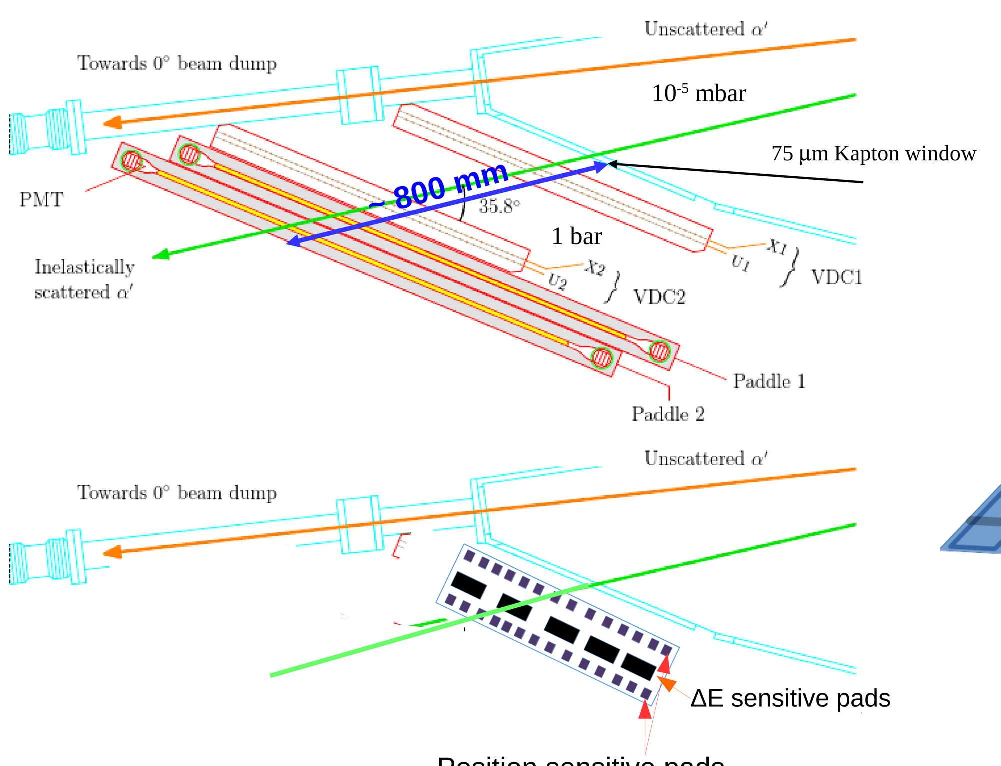
SRIM calculations for 60 MeV alpha (left) and 50 MeV Li (right) illustrating limitations of the current detection system

INTEREST TO DO THE FOLLOWING MEASUREMENTS:

- Investigation of the evolution of the proton gap through the single-nucleon transfer reaction by studying the ^{70}Zn(d,^{3}He)^{69}Cu reaction: 66.3 MeV <E_{3He}<74.3 MeV (~22MeV/u -25MeV/u)
- Accessing low-lying 0+ states in shape coexistence studies through inelastic (α,α') scattering: Eα = 60 MeV (15 MeV/u)
- Probing mutli-particle multi-hole structures: E_{6Li} = 50 MeV (~8 MeV/u)
- Study of proton occupancies :E_{3He} =30 MeV (10 MeV/u)

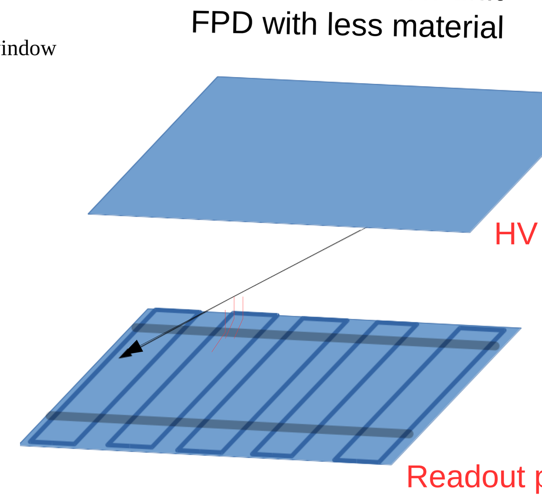
NEW FOCAL PLANE DETECTION SYSTEM

Must have less material to allow access to lower particle energies



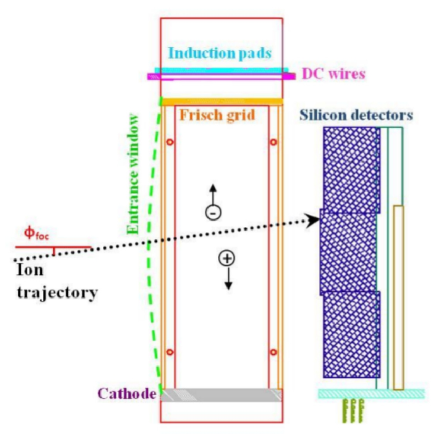
Position sensitive pads

Sketch of the new drift FPD with less material

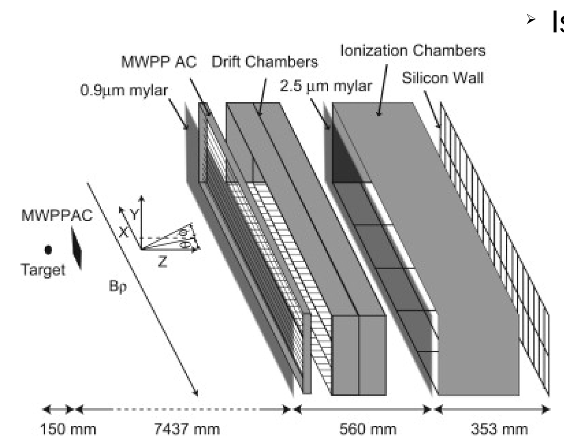


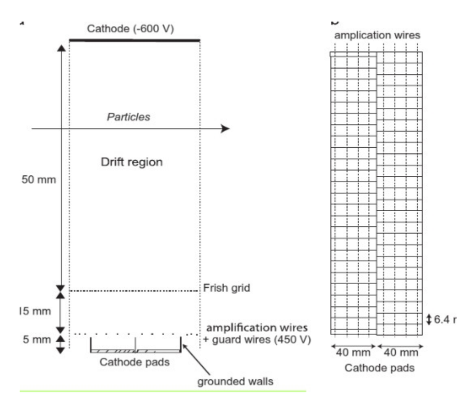
REVIEW OF OTHER DETECTION SYSTEMS

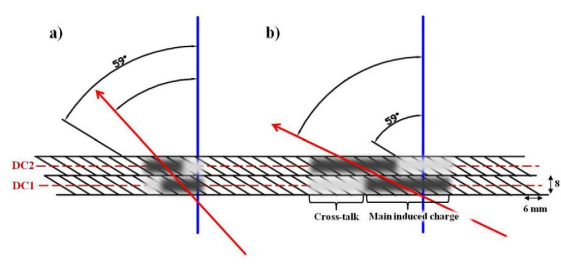
- **MAGNEX** focal plane detection system 59.2° w.r.t the central ray
- Proportional counters and a wall of Silicon detectors
- Horizontal and vertical position resolution =0.6 mm
- Angular resolution capability = 0.3°
- Isobutane (5-100 mbar)



MAGNEX
- Read out Induction pads (224)
- Typical drift speed 5cm/µs
- Signal processed by 16 channel GASSIPLEX chips







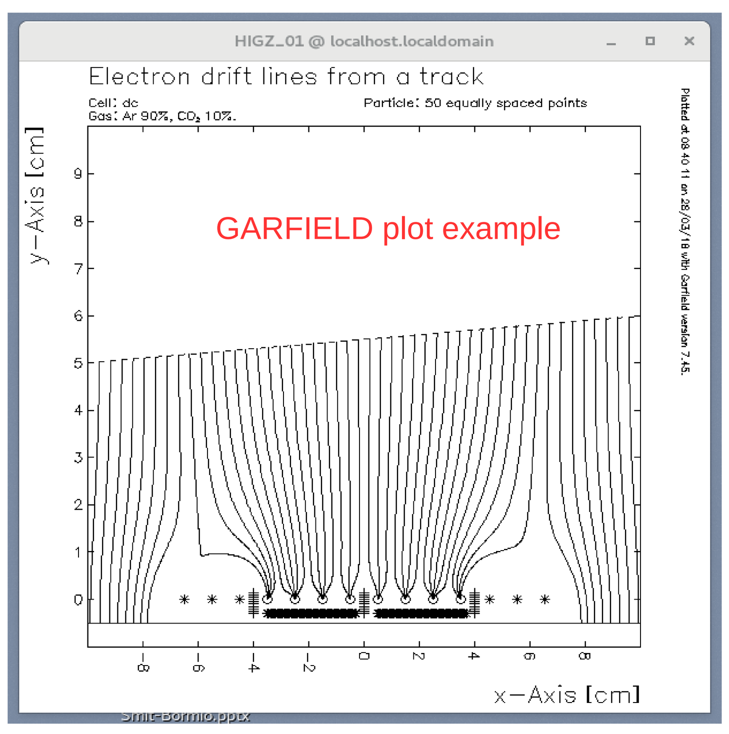
VAMOS++ detection system
- Hybrid detector
- Dispersive plane position resolution ~270µm
- Drift direction position resolution ~ 350µm
- Isobutane = 6 mbar

MAGNEX induction pads
- Inclined 59° w.r.t DC wires
- Each pad is 6mm wide and 15 mm long
- Second and fourth sets are offset by ~3mm

CURRENT WORK

iThemba LABS has a spectrometer with good resolving power: (p/Δp = 28000)
To exploit that we need a detector with good resolution: (at least 0.35 mm FWHM)
VAMOS has this resolution, but central ray is perpendicular to detector which is not the case in the K600

THE MAIN QUESTIONS:
- What best resolution can be achieved with slanted pads, similar to MAGNEX?
- The K600 has multiple focal planes, what is the impact of fixed pad rotation?
- Staggered pad configuration: size? Stagger pattern?
- Pad size for measurement of induced signal?
- VAMOS & MAGNEX use low pressure gas: what is the lower limit of gas pressure and what will its effect be on the detection capabilities?
- Simulations required to try and answer these questions
    - GARFIELD software to be used for simulation
    - Simulation provides drift velocity, induced signals, x(t) relations, arrival time distributions,drift velocity and diffusion in gas mixtures
    - Shortfall: 2D simulation of drift chambers



OUTLOOK

- Do simulations with GARFIELD++
- Advantage: 3D visualization of drift track