LIDINE Manchester, 28th August 2019

The NEXT-DEMO++ detector: R&D for low diffusion mixtures

Neus López March
on behalf of the NEXT collaboration

Outline

- Neutrino Experiment with a Xenon TPC

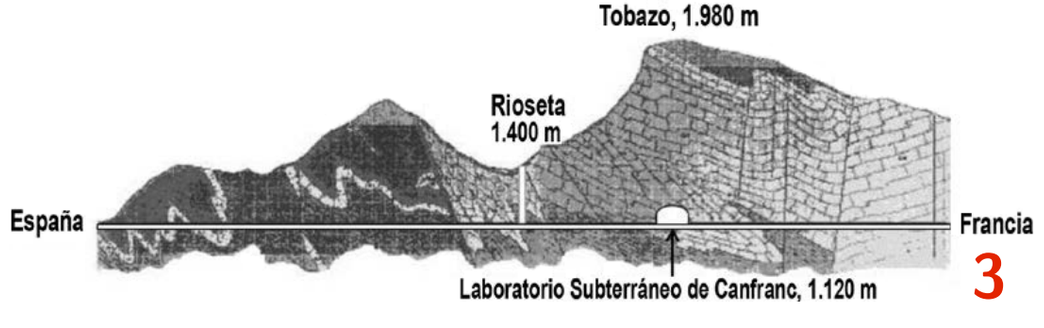
- R&D with the DEMO++ detector
- Preliminary results with pure Xenon and Xe + He admixture
- Conclusions and Future plans

next : Neutrino Experiment with a Xenon TPC

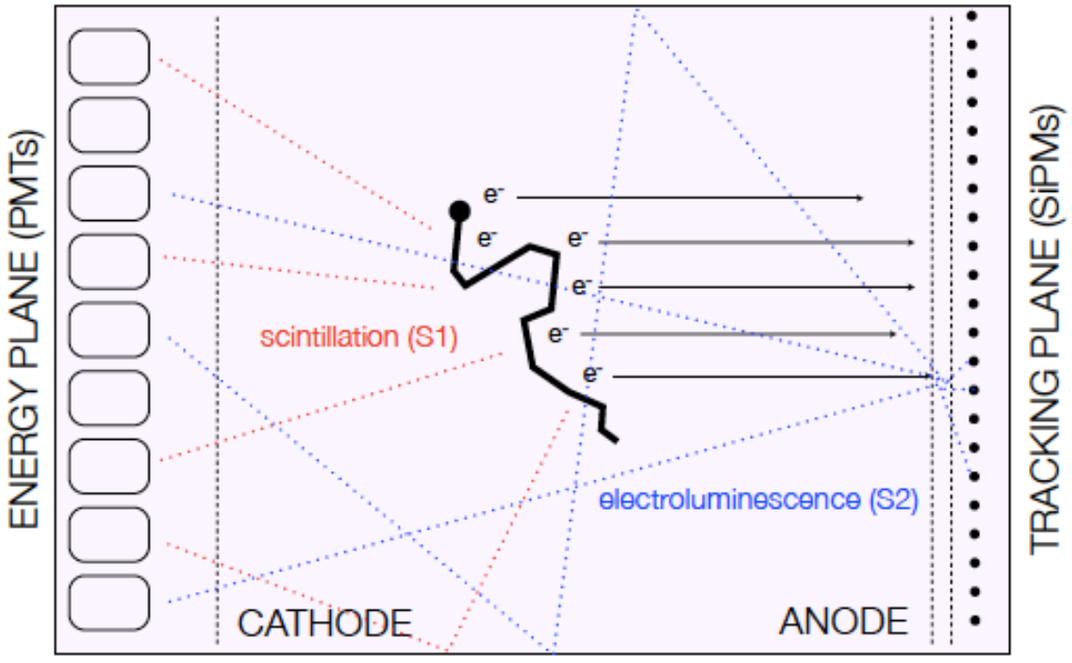
- **High pressure ^{136}Xe gas, electroluminescent TPC with readouts for calorimetry and imaging.**

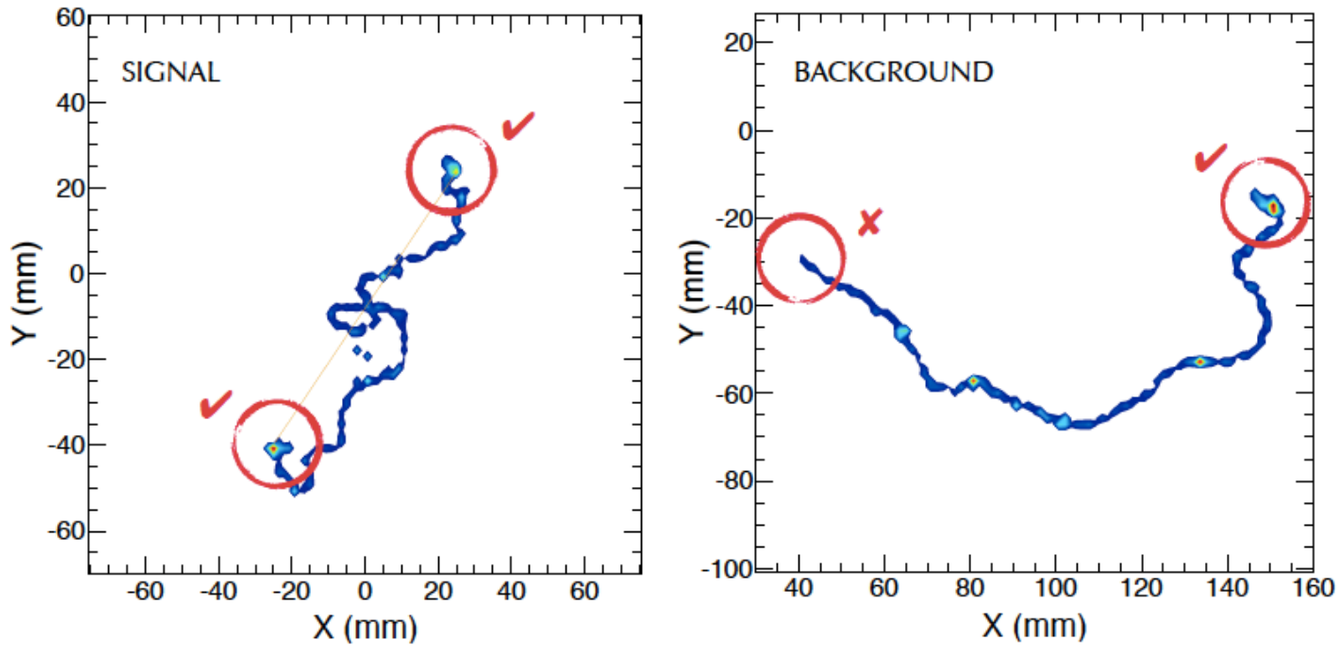
LSC
Laboratorio Subterráneo de Canfranc

- Operating NEXT-White detector with enriched ^{136}Xe(91%) since February 2019 [arxiv:804.02409]
- **Excellent energy resolution:** NEXT-White detector resolution **<1%** FWHM at the Q-value [arxiv:1905.13110]
- **Event topology reconstruction:** electrons travel 15cm each (15bar) on average . NEXT-White results gives background (signal) acceptance a 20%(72%) [arxiv:1905.13141]. DNN give bkg/sig acceptance: 16% / 84 %
- Low background rate validated in NEXT-White: 4x 10^{-4} cts keV^{-1} kg^{-1} yr^{-1} validated in NEXT-White [arxiv:1905.13625]
- Single Molecule Fluorescent imaging for **Barium tagging** PRL120(2018),132504 [arxiv:1711.04782]



NEXT detector: working principle





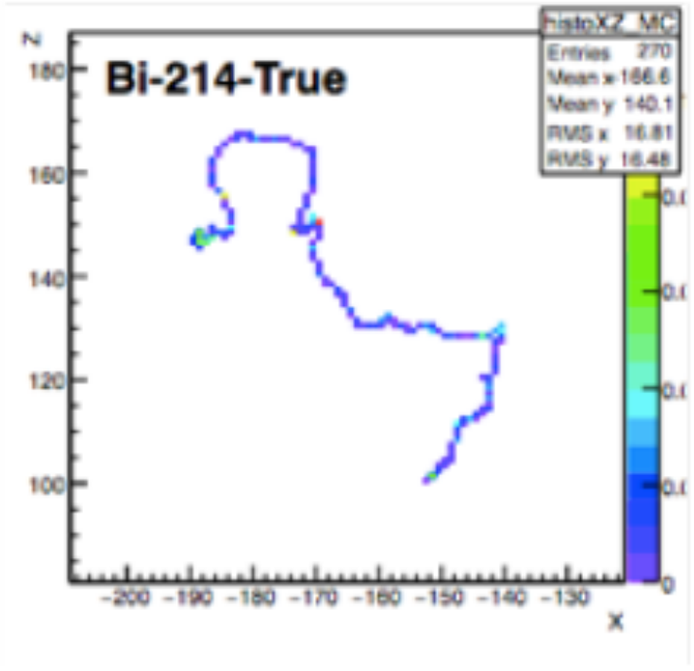
- **Energy plane** made of PMTs measures energy and start of the event (t0)
- **Tracking plane** made of SiPMs, reconstructs the event topology.

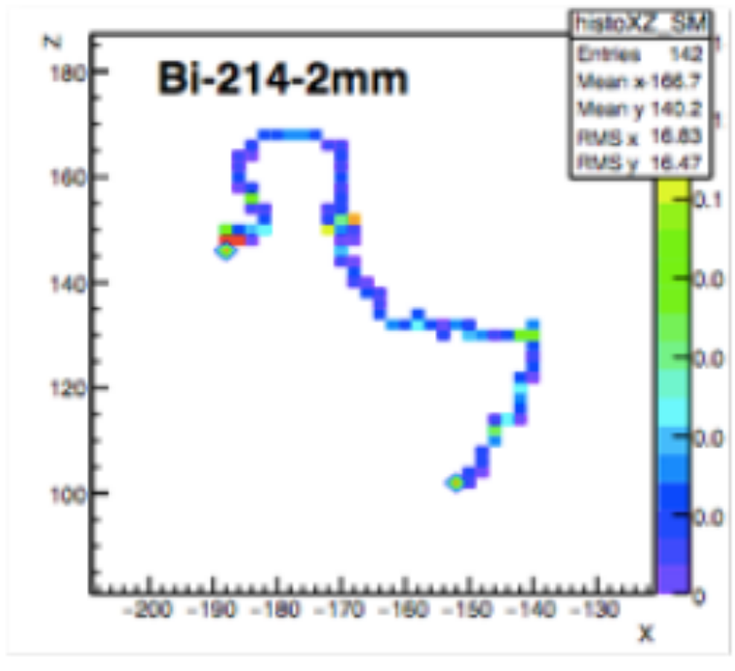
- Energetic electron leaves a high-density deposition at the end of its track
- Results in distinct topological signatures for signal and background events of the same energy

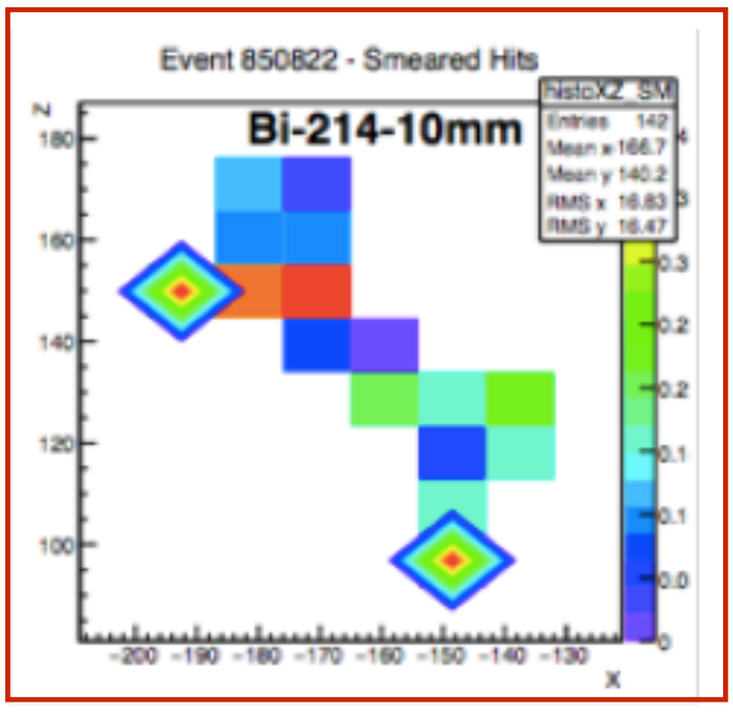
Diffusion in NEXT

- In pure xenon diffusion of drifting electrons is very large. After 1 m of drift the electron cloud has a **transverse** rms of **∼10mm** and **longitudinal** rms of **∼5mm**
- Spatial resolution is dominated by diffusion in NEXT (detector configuration of tracking plane and EL are sub-dominant)

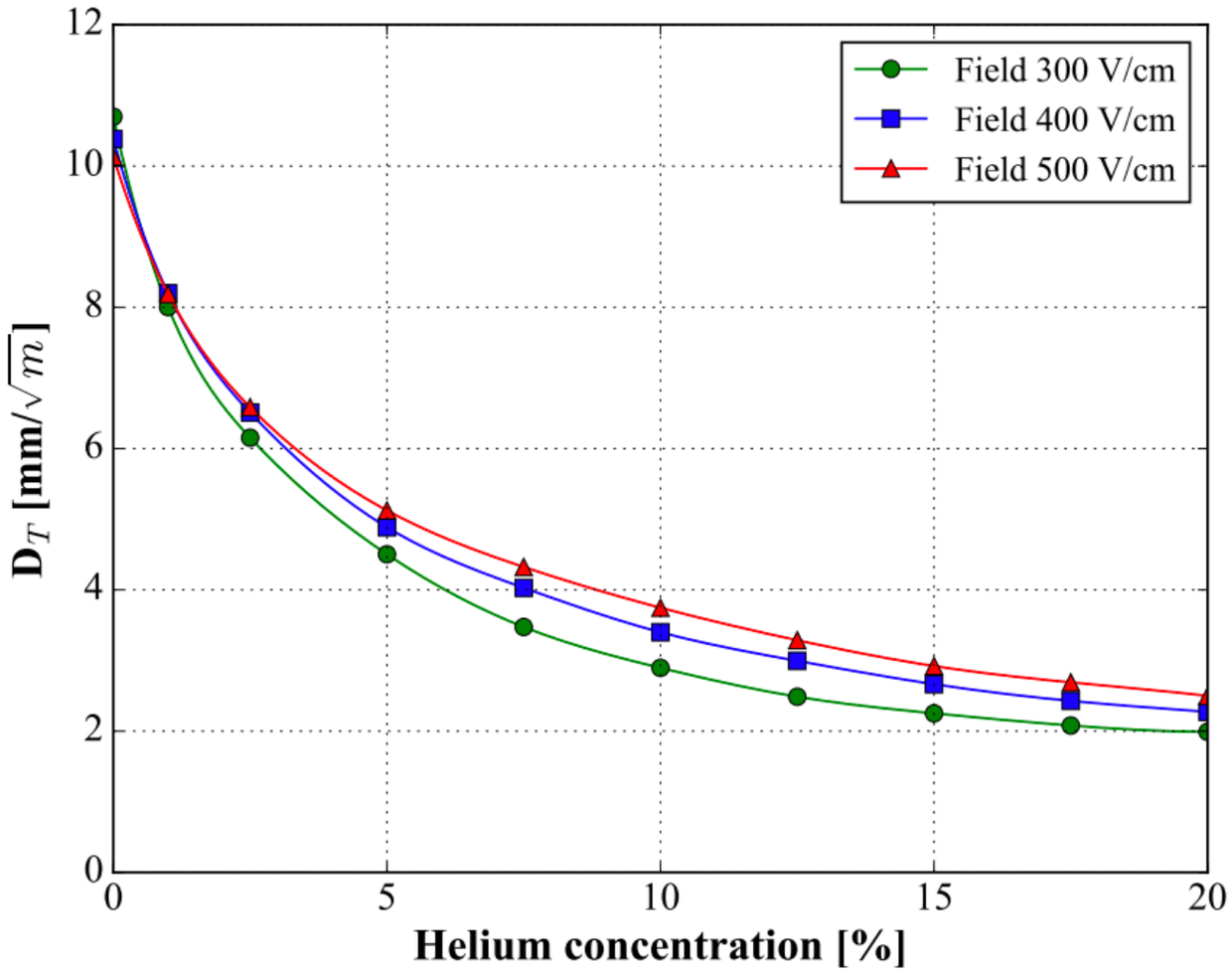
Background event ⟶ **Fake signal**







Reduce diffusion with Xe+He(~15%)



- According to [arxiv:1710.05600], **Xenon+Helium** mixtures, with 10-15% Helium may reduce drastically the transverse diffusion down to 2.5 mm/$\sqrt{}$m from the 10.5 mm/$\sqrt{}$m of pure Xenon

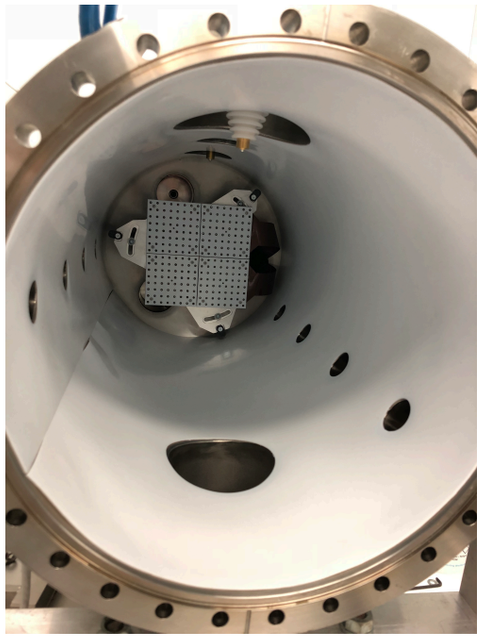
The Demo ++ detector

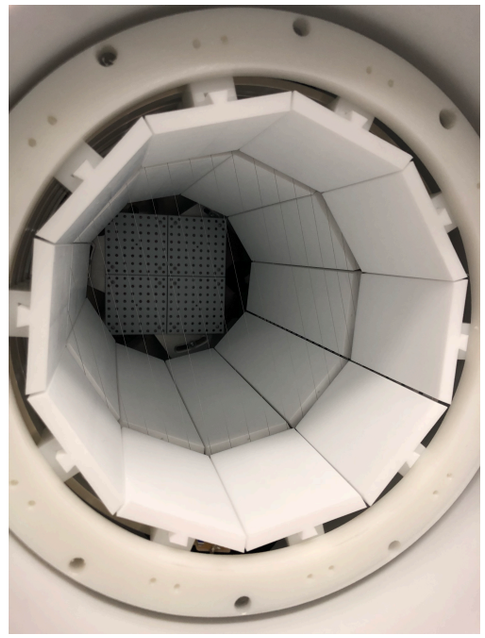
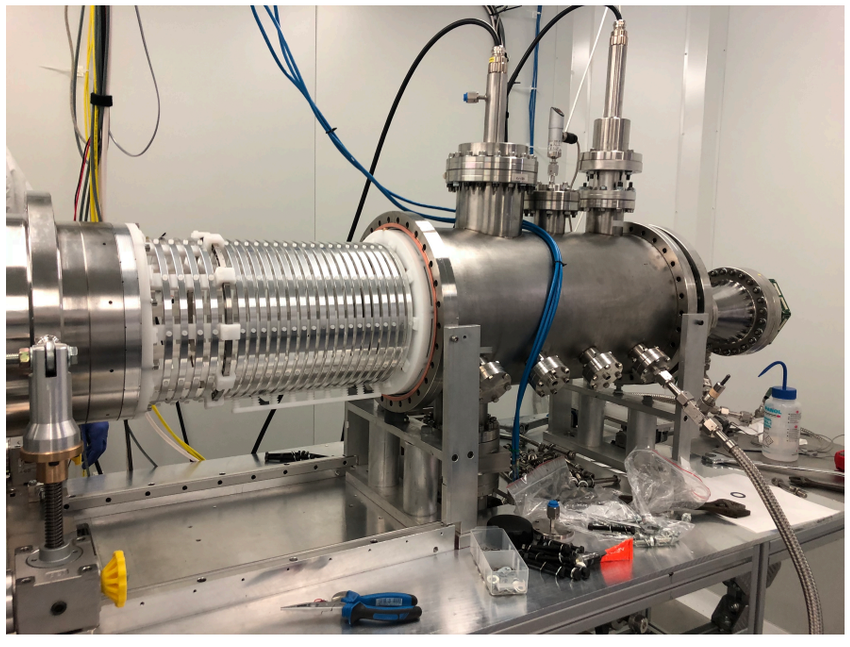
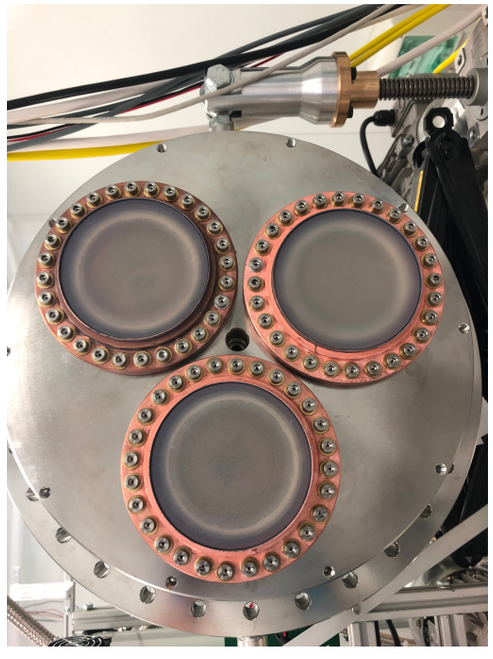
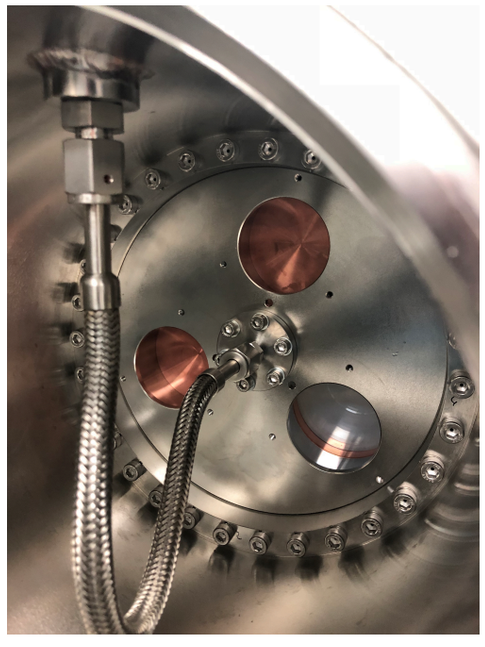
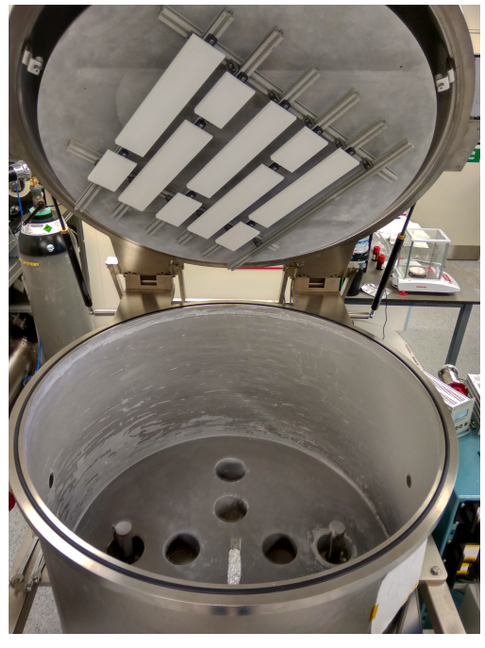
- Demo++ has been designed to measure energy resolution and tracking performance with reduced diffusion up to **10 bar** (Kr, Cs, Na, Th sources) with a timescale favorable to reduce diffusion for the first upgrade of the NEXT100 detector.

- Re-used original NEXT demo prototype vessel: 1.5 kg Xe at 10 bar.
- Active region dimensions: 23 cm height with 30 cm drift, 9-10 mm EL.
- Nominal values for HV: **11.5 kV cathode, 26 kV gate**
- E field in Drift region: **483 V/cm**
- Reduced E field in EL region: **1.15 kV/cm/bar** (450 photons/e-)

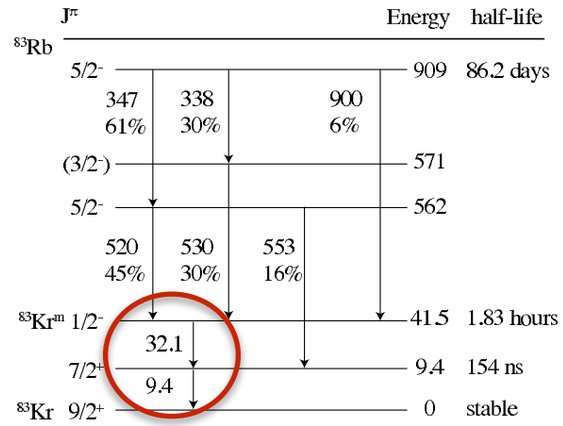
The Demo ++ detector

- Same sensors as NEXT-White and NEXT100 detectors
- Performed Helium permeability studies
- Pmts kept at vacuum
- TPB coating here in Manchester!



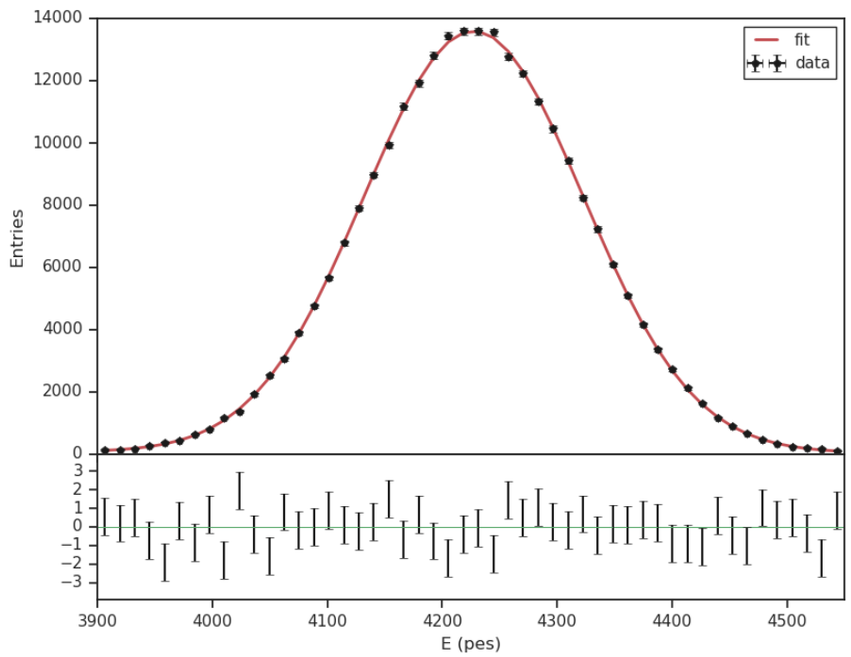
Detector performance 9.1 bar pure Xenon



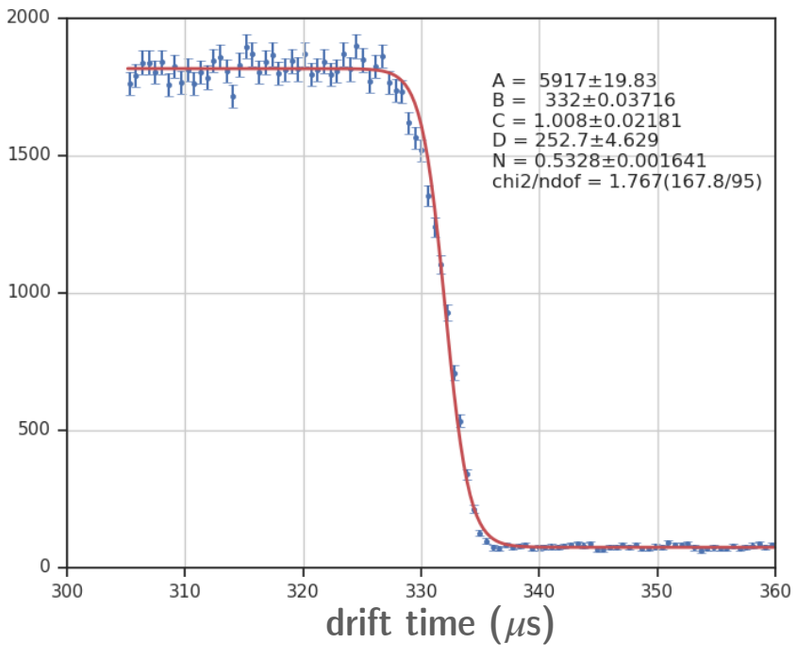
- Kr leaves a **point-like** deposition of **41.5 keV**, uniformly distributed in the detector (followed same procedure as for NEXT-White detector calibration [arxiv:1804.01780])
  - Detector characterization:
    - Kr peak clearly visible (resolution studies ongoing)
    - Drift velocity: **0.927** ± 0.005 (stat) mm/μs. (0.935(0.8%) Magboltz)
    - Electron lifetime: more than 50 times the chamber's length!

Preliminary

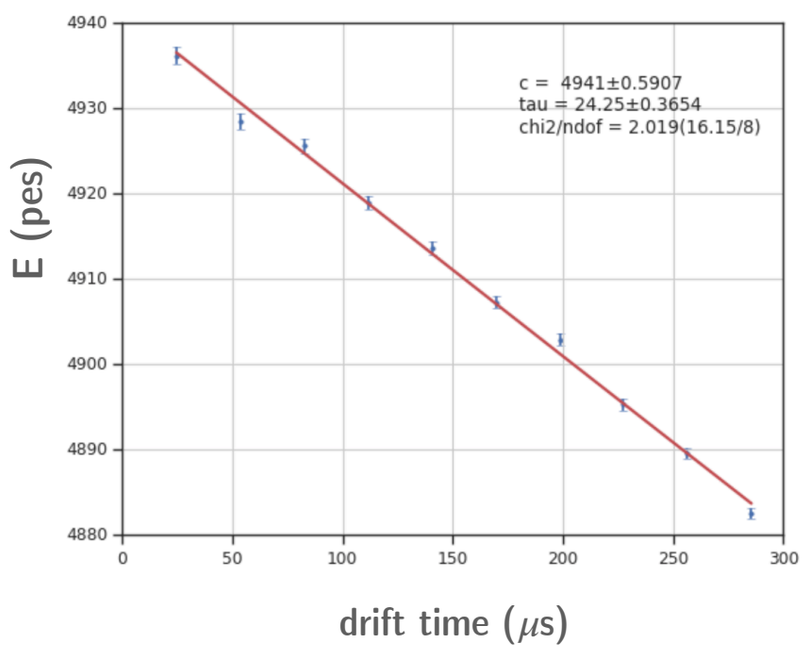
Kr energy peak



drift time distribution



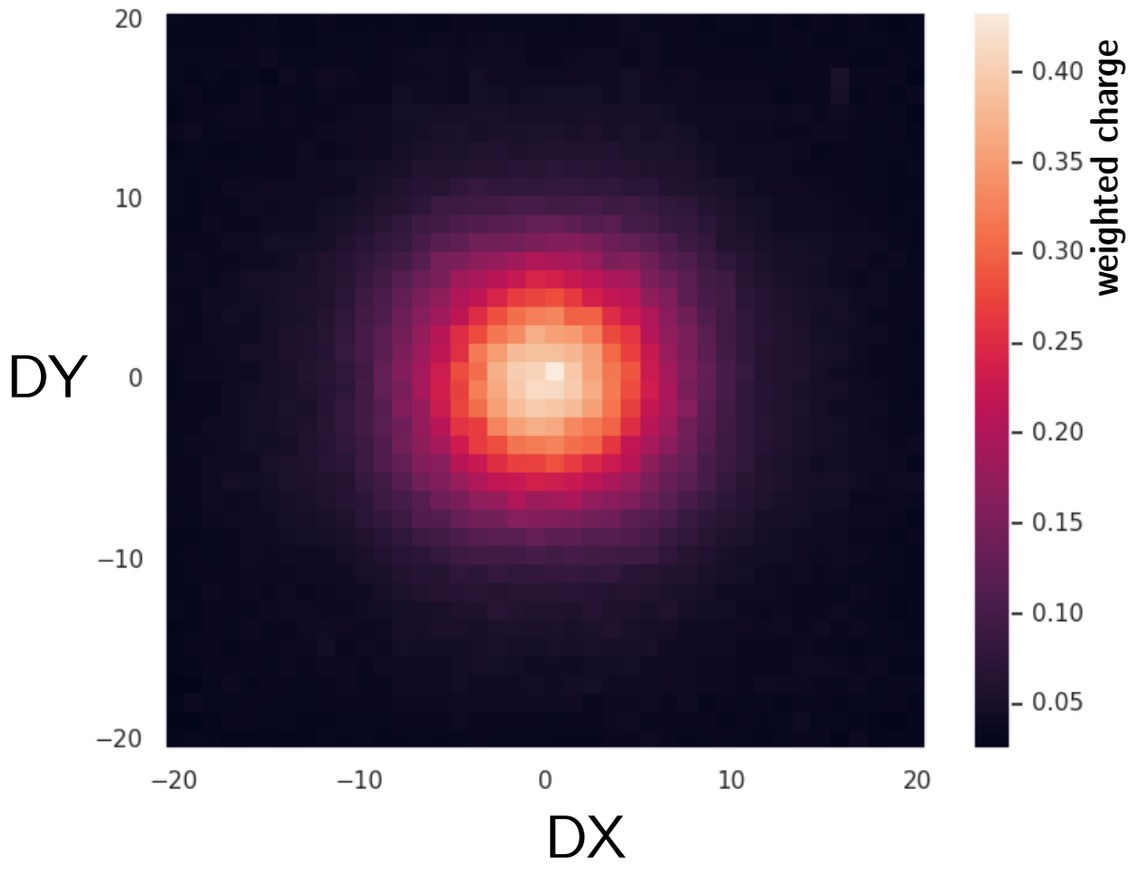
energy vs drift time



Measurement of Transverse Diffusion

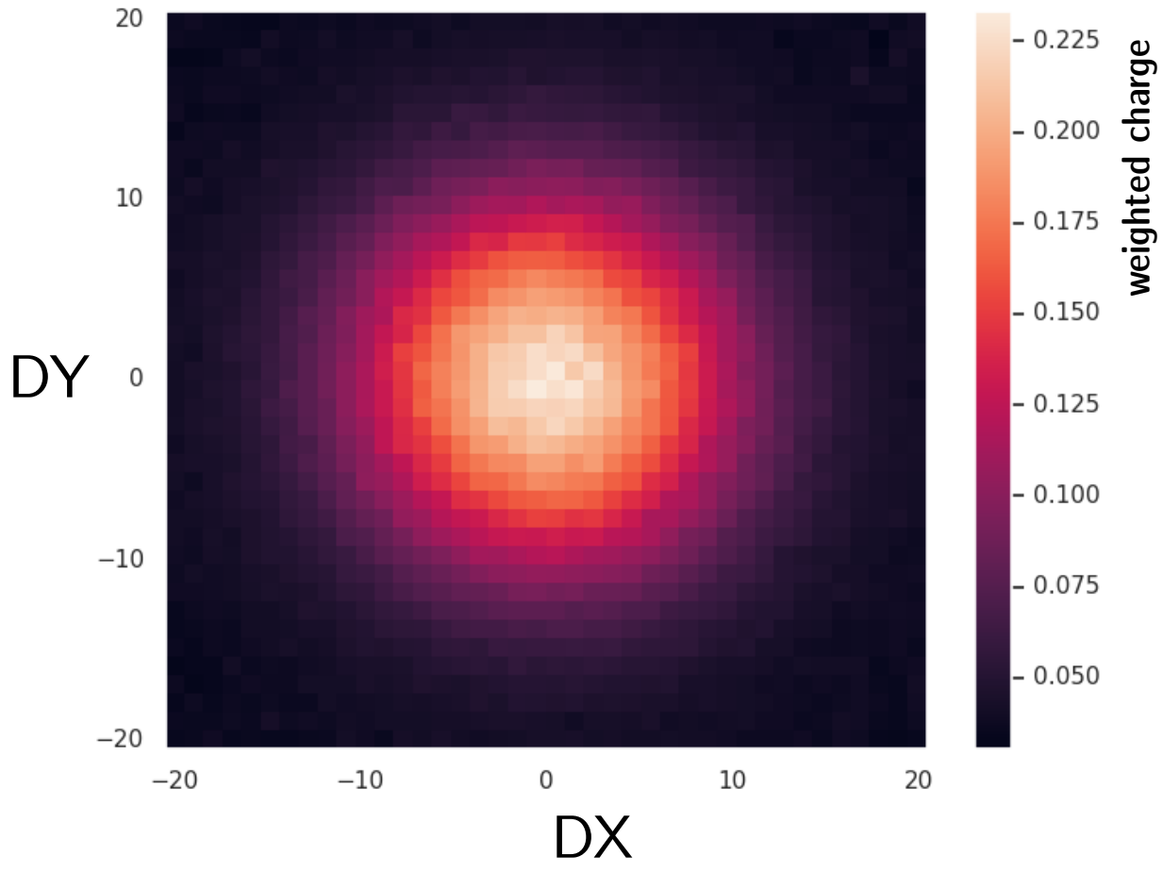
- Distance of sipms position with respect to baricenter weigthed by charge (DX,DY) → sensitive to the xy spread of the signal (charge from sipms)
- Enhancement of this spread with respect to drift time clearly visible → diffusion

10 < t < 3 0 μs



2D profile of the weighted charge

280< t < 300 μs

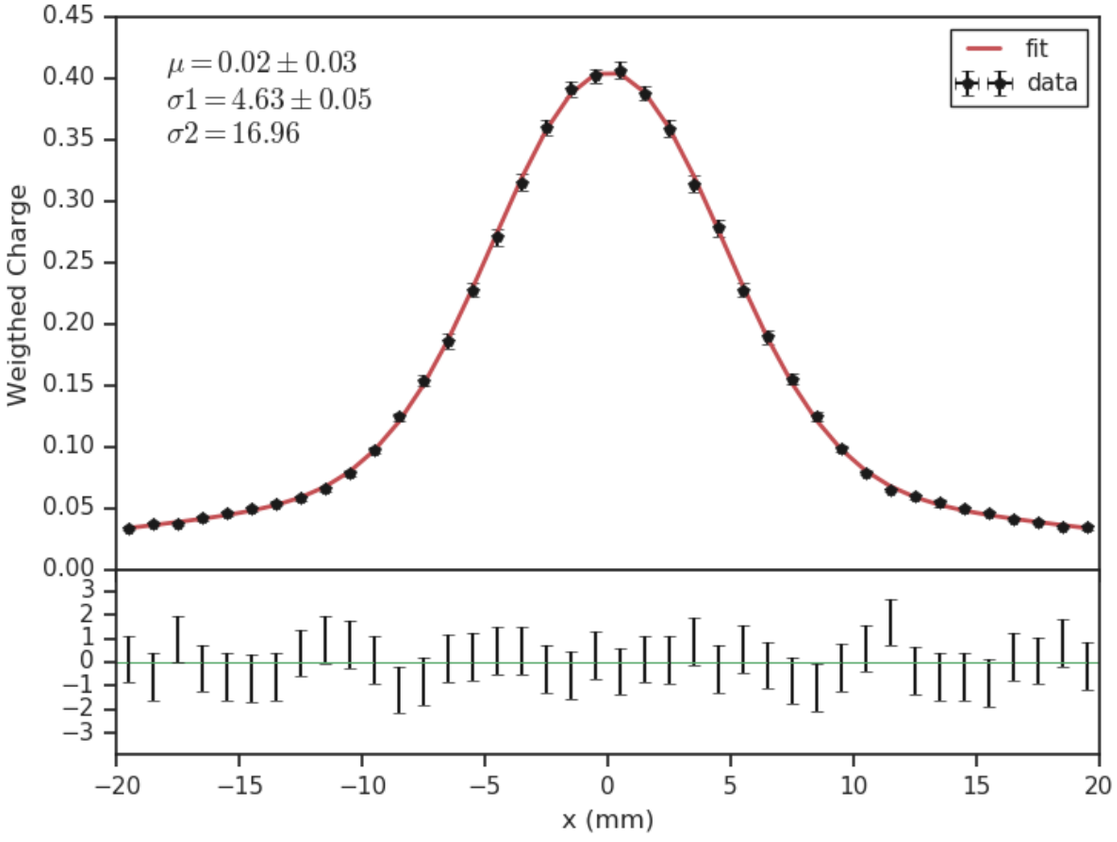


2D profile of the weighted charge

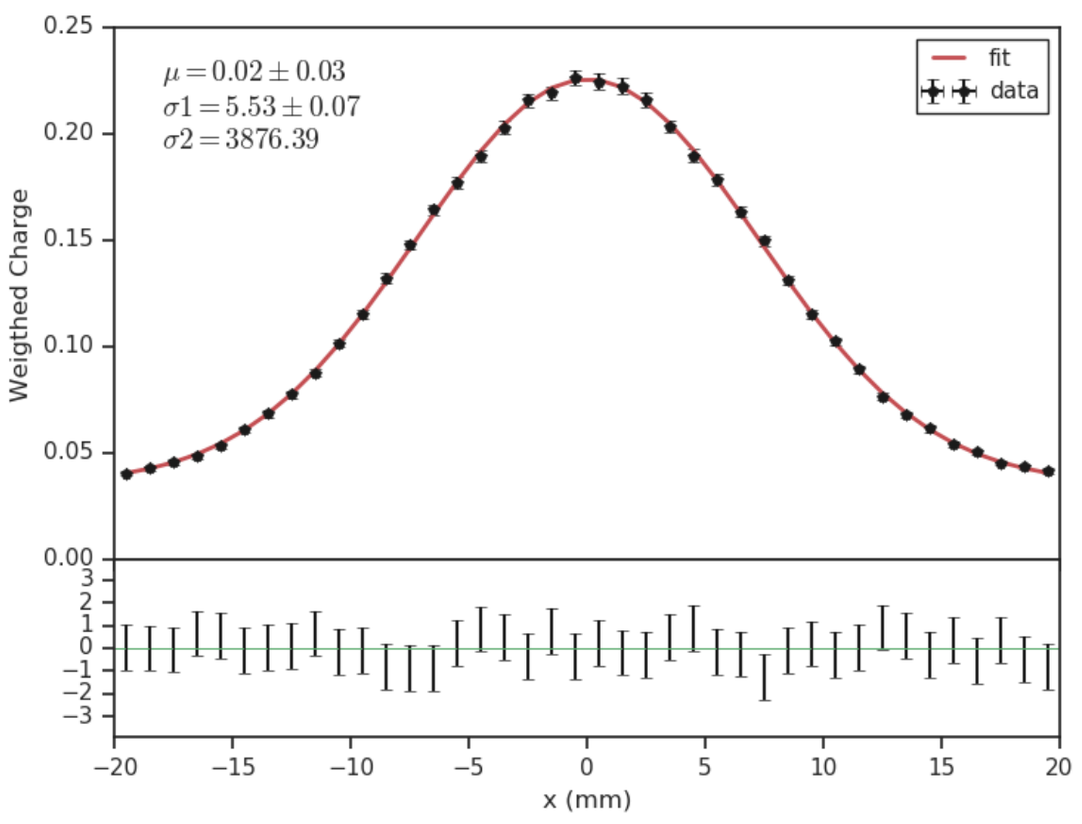
Measurement of Transverse Diffusion

- Distance of sipms position with respect to baricenter weigthed by charge (DX,DY) $\rightarrow$ sensitive to the xy spread of the signal (charge from sipms)
- Enhancement of this spread with respect to drift time clearly visible $\rightarrow$ diffusion

10 < t < 3 0 μs

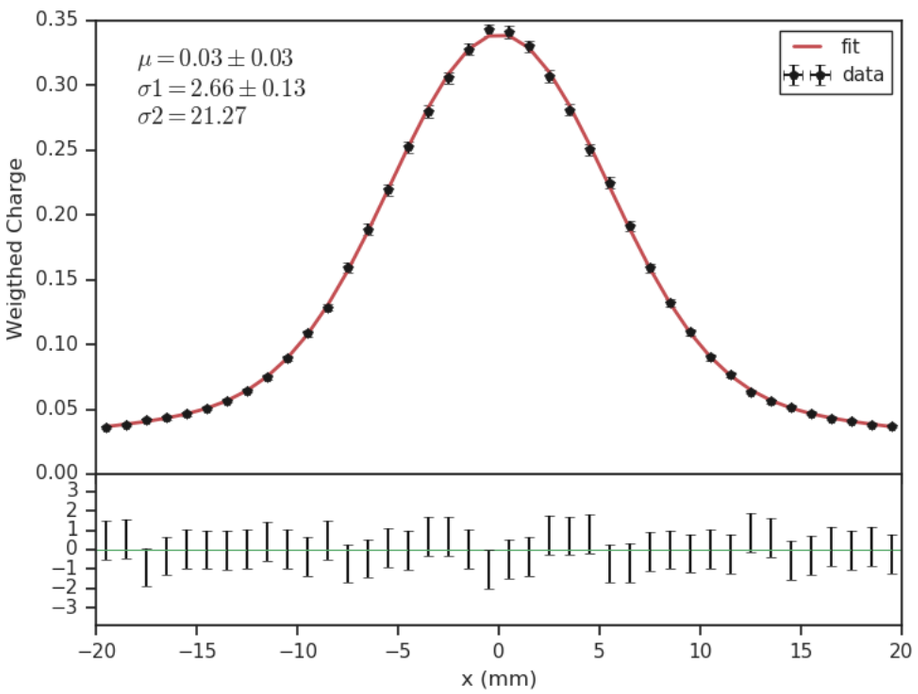


280< t < 300 μs

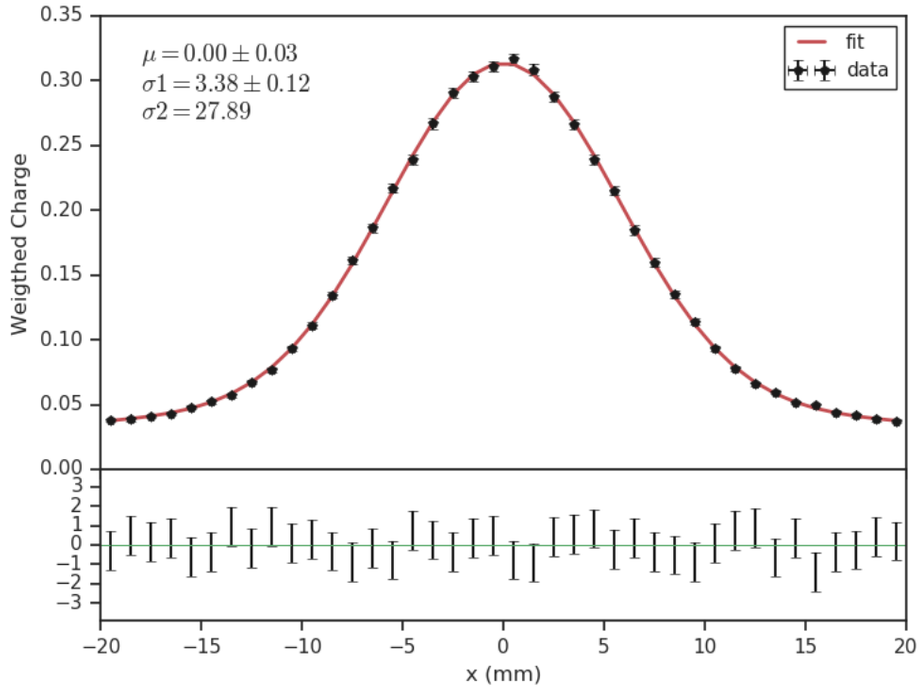


Diffusion fit. - fitting slices

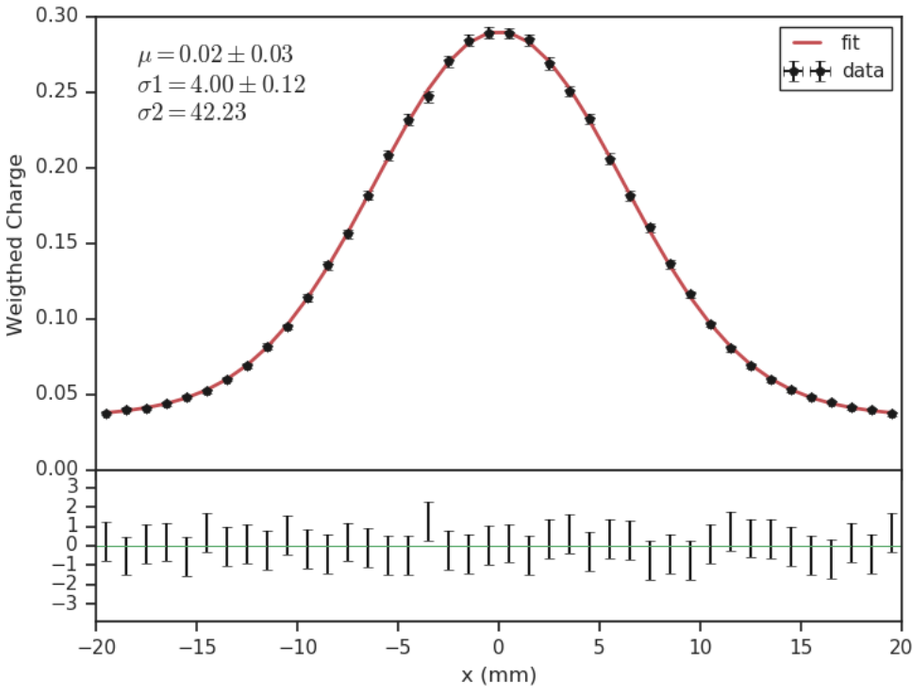
70 < t < 90 μs



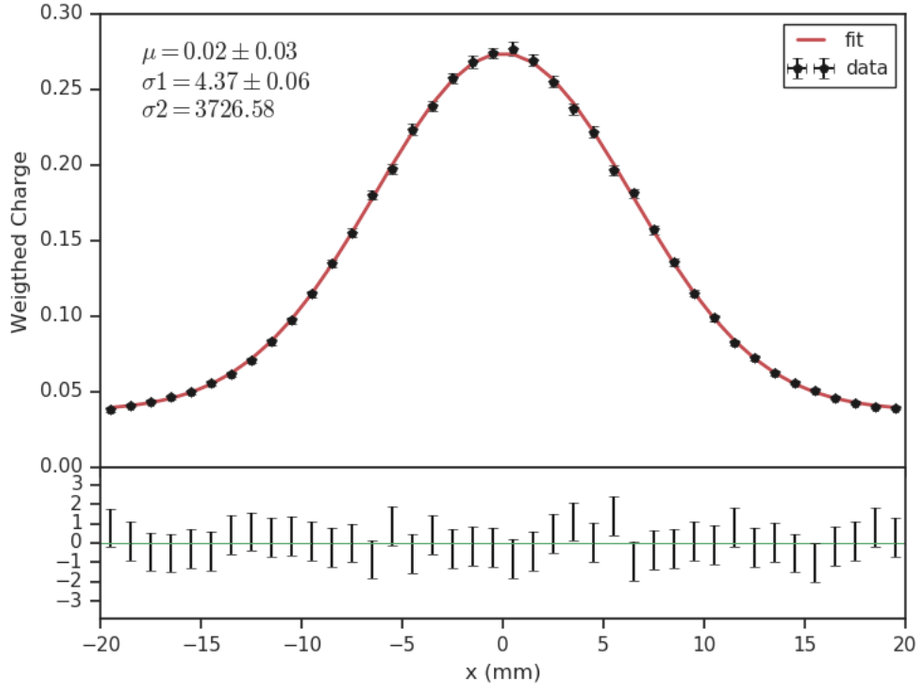
100 < t < 120 μs



130 < t < 150 μs

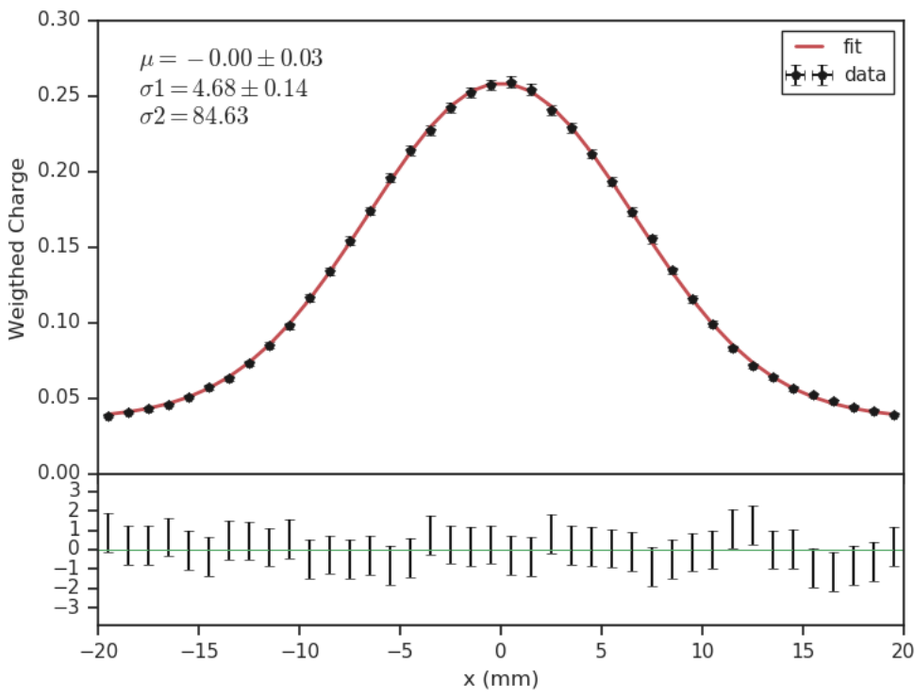


160 < t < 180 μs

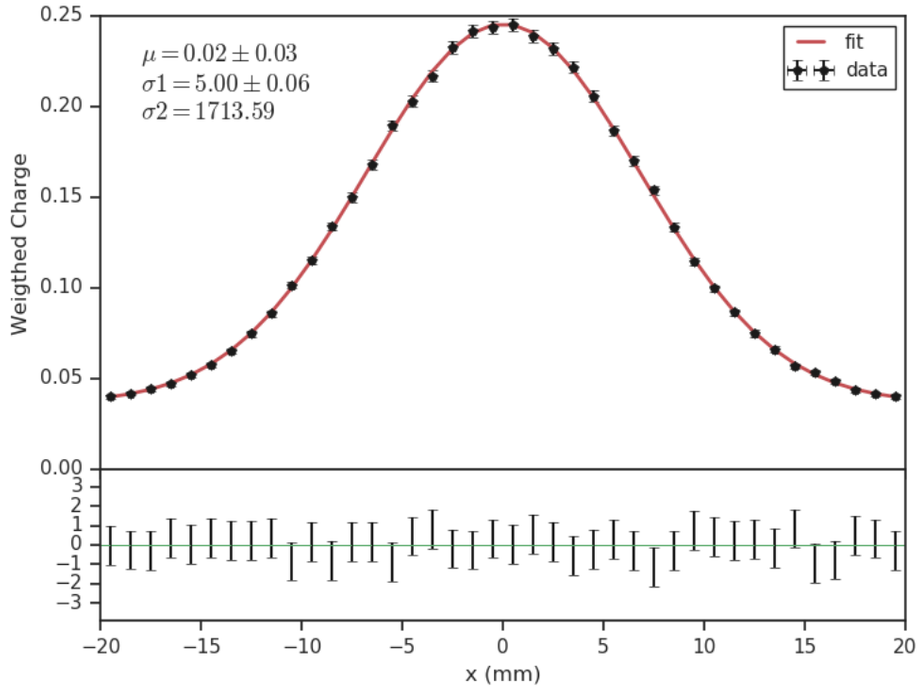


Diffusion fit. - fitting slices

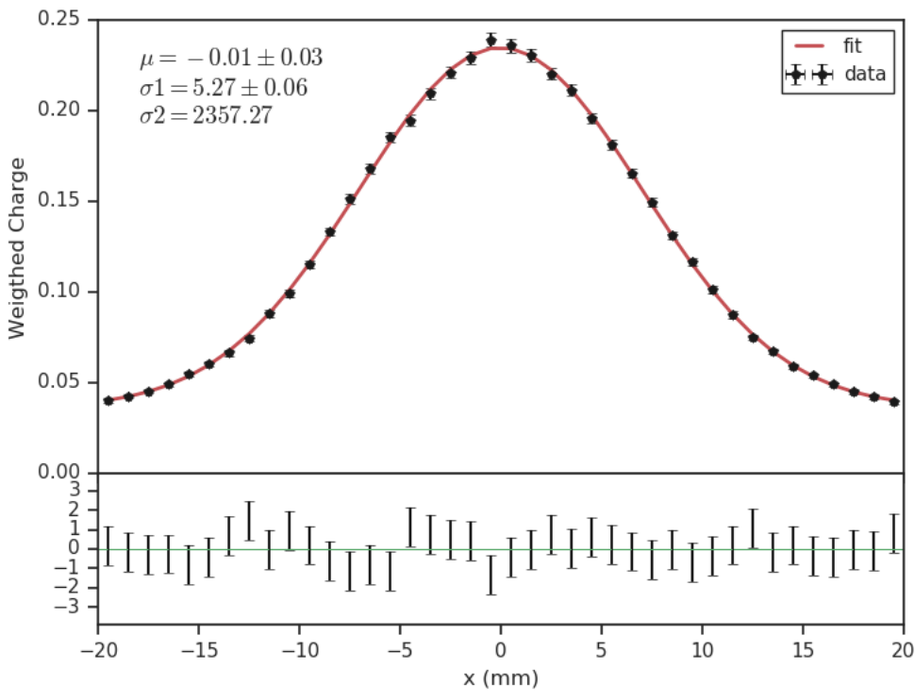
190 < t < 210 μs



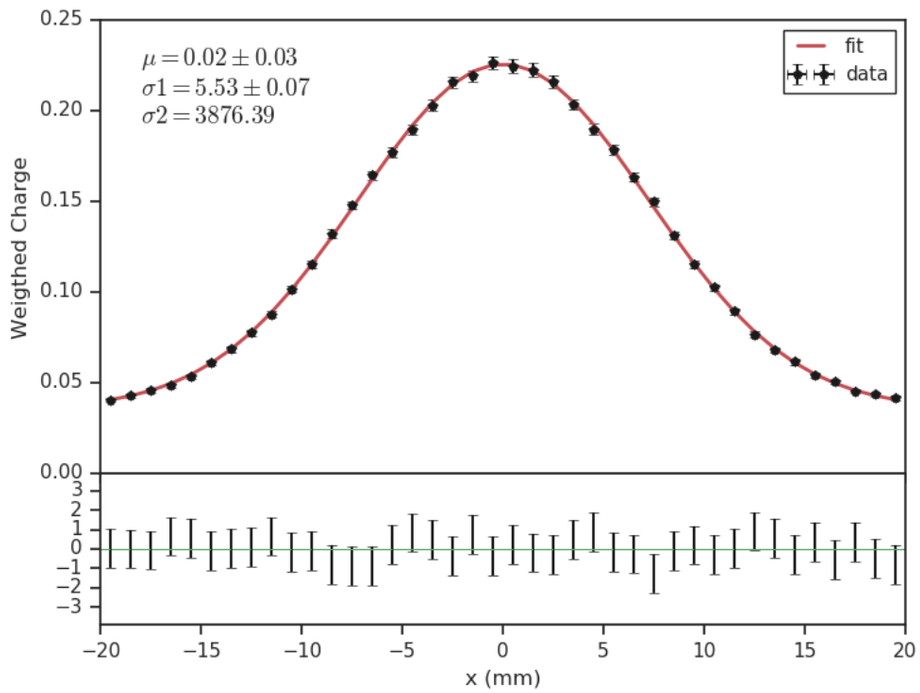
220 < t < 240 μs



250 < t < 270 μs

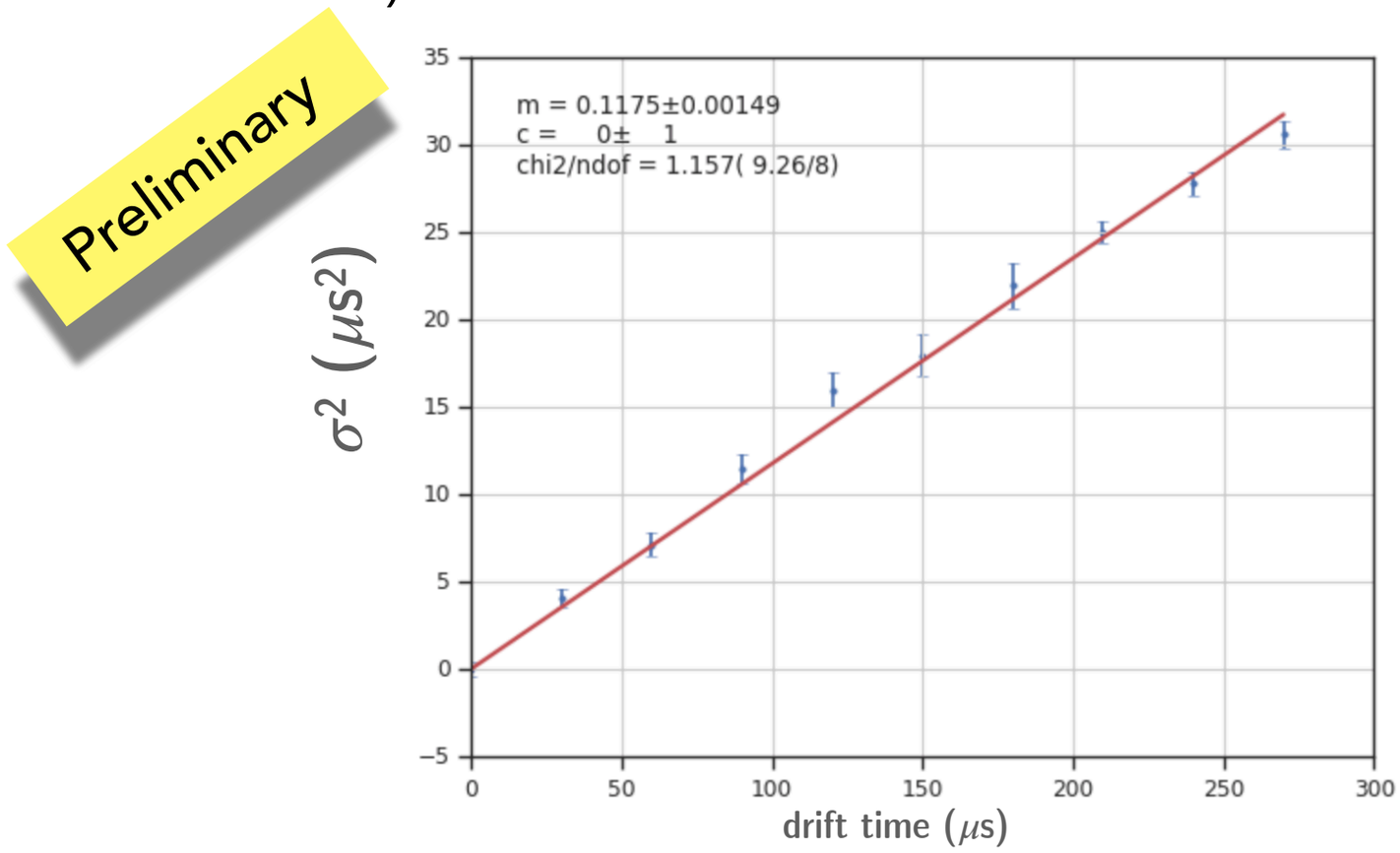


280 < t < 300 μs



Measurement of Transverse Diffusion

- **10 drift time regions** selected of 20 μs, spaced 10 μs from each other (10-300 μs)
- **Fit procedure**: Fit 1: select EL region [10,30] fit a G (plus another G to describe tails) to extract sigmaEL. Fit 2: fit to G with sigma_tot^2 = sigmaEL ^{2} + sigma^2 (plus 2nd G for tails)



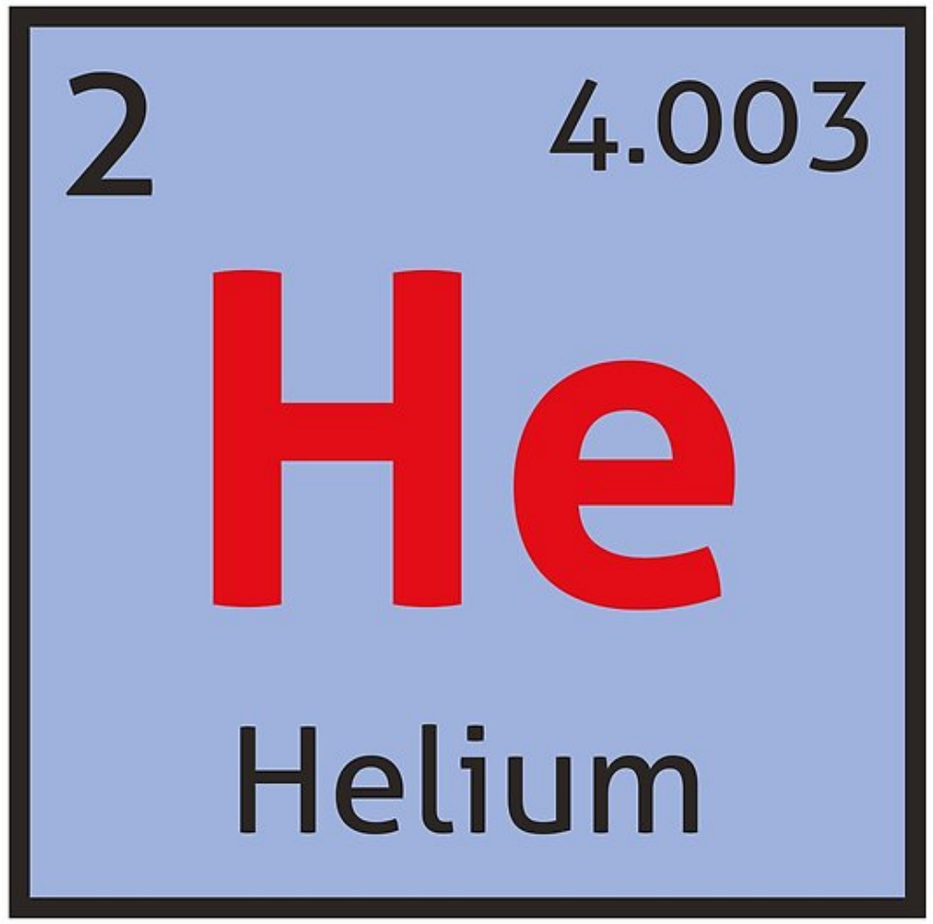
$$\sigma^2_{L,T} = \sigma^2_{0_{L,T}} + 2 \cdot D_{L,T} \cdot (t - t_{EL/2})$$

- **Measurement** of transverse diffusion coefficient: 3553 $\pm$ 21(stat) $\sqrt{\text{bar}}$ μm/ $\sqrt{\text{cm}}$
- **Magboltz** transverse diffusion coefficient: 3620 $\pm$ 30 $\sqrt{\text{bar}}$ μm/ $\sqrt{\text{cm}}$

85 %

15 %

+



Same total pressure: 9.1 bar (7.7Xe + 1.4He)

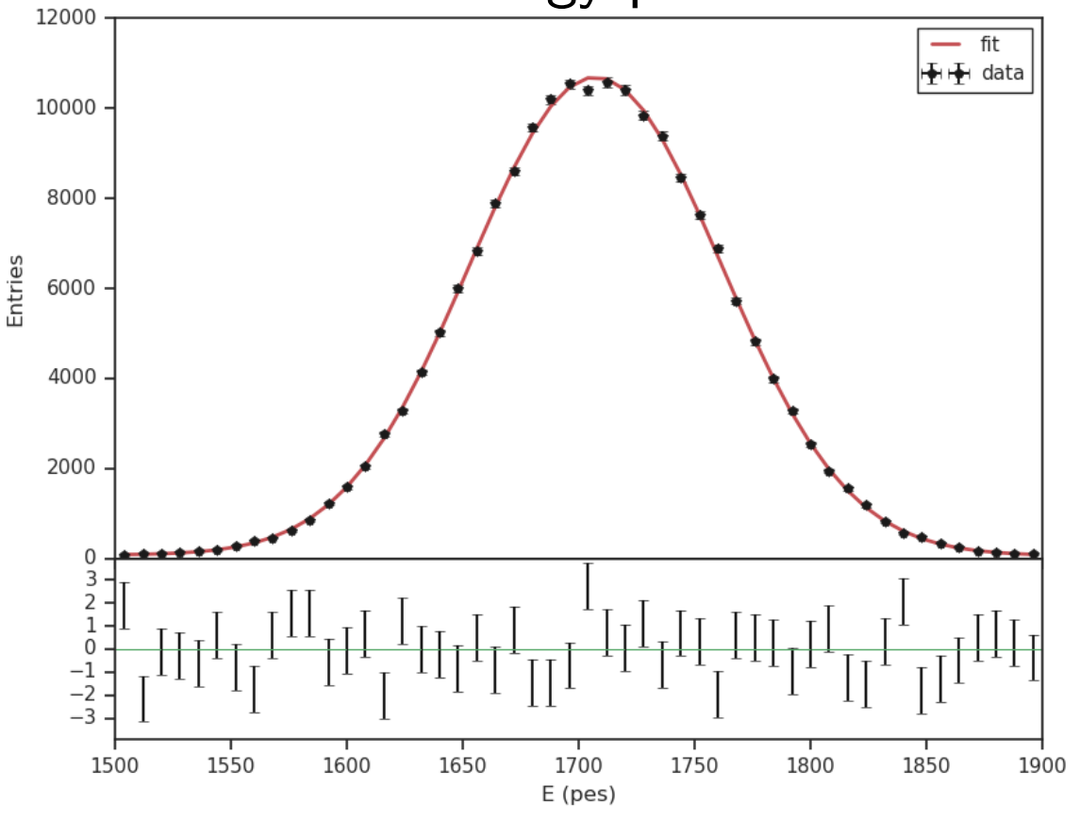
Same E field conditions: Edrift= 483 V/cm, ELfield = 1.15 kV cm^{-1} bar^{-1}

Detector performance in Xe + 15% He admixture

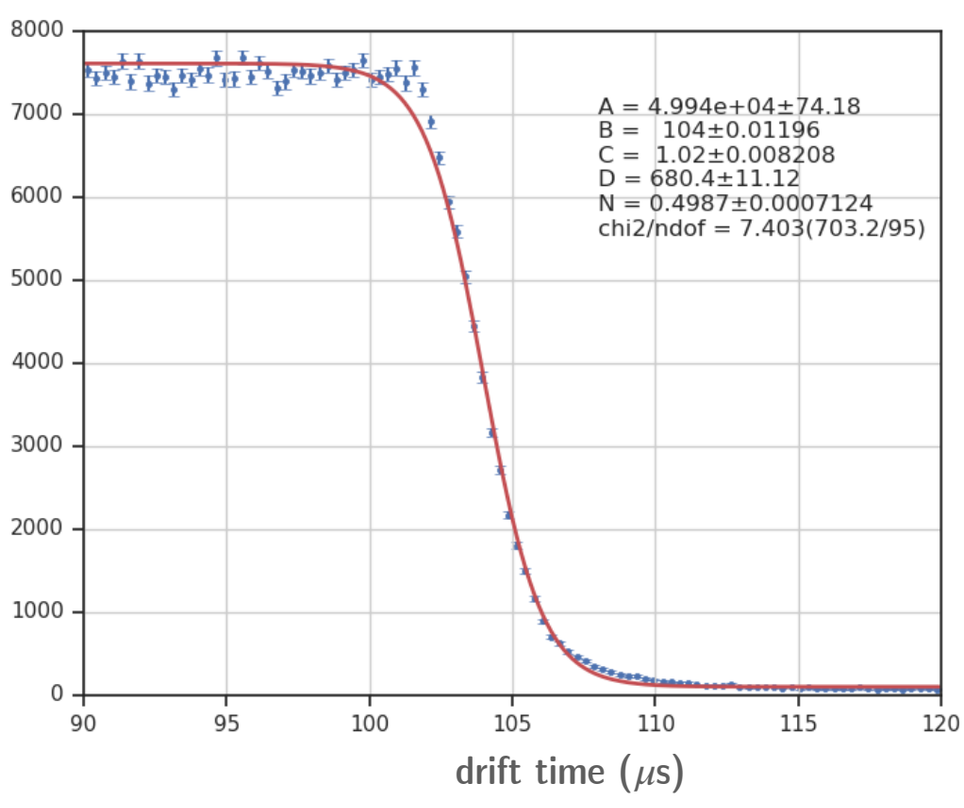
- Detector characterization in the mixture:
  - Krypton signal clearly visble. A reduction of a factor **x2.5 in light yield, observed, Magboltz predicts a factor of ~3.**(Energy resolution studies ongoing)
  - Drift velocity: **2.98** $\pm$ 0.02(stat)mm/μs → **increased by a factor of 3**, **in agreement with Magboltz 3.2 (4%)** mm/μs
  - Electron lifetime: more than 50 times the chamber's length!

Preliminary

Kr energy peak

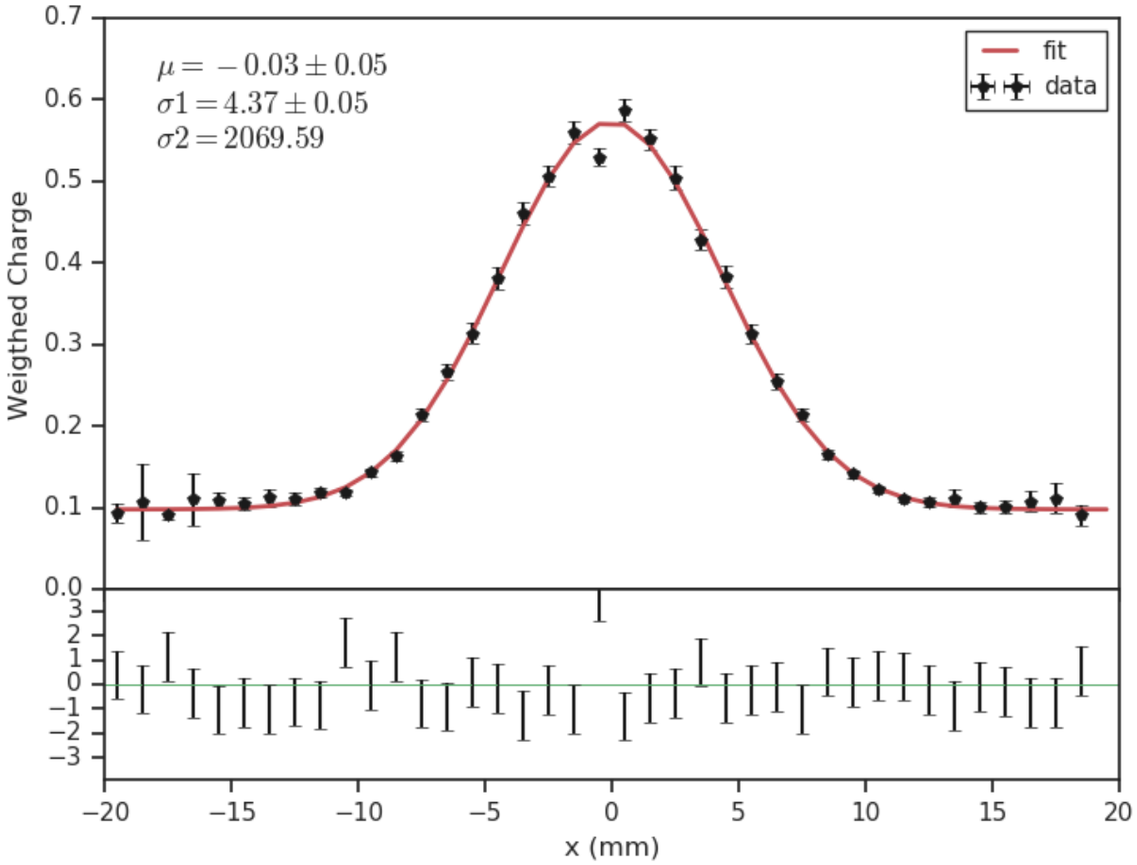


z event distribution

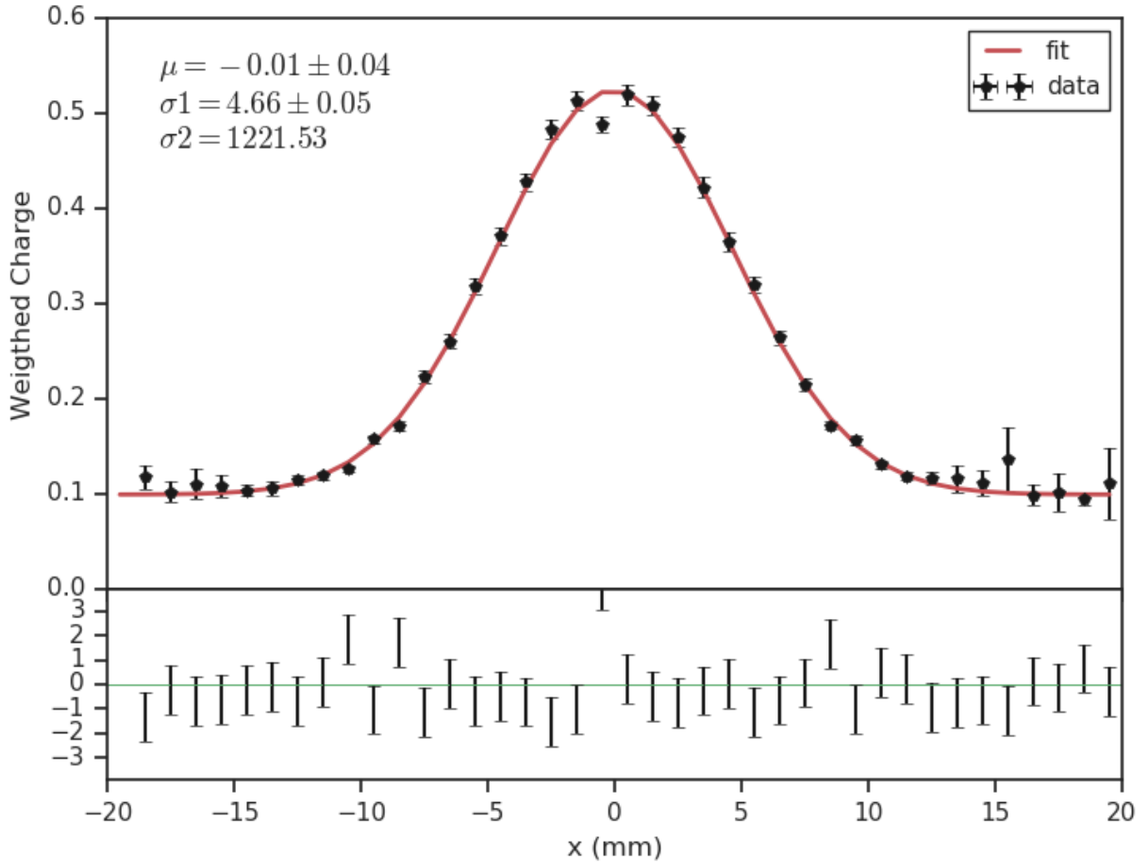


Transverse diffusion at 15% He mixture

40 < t < 60 μs

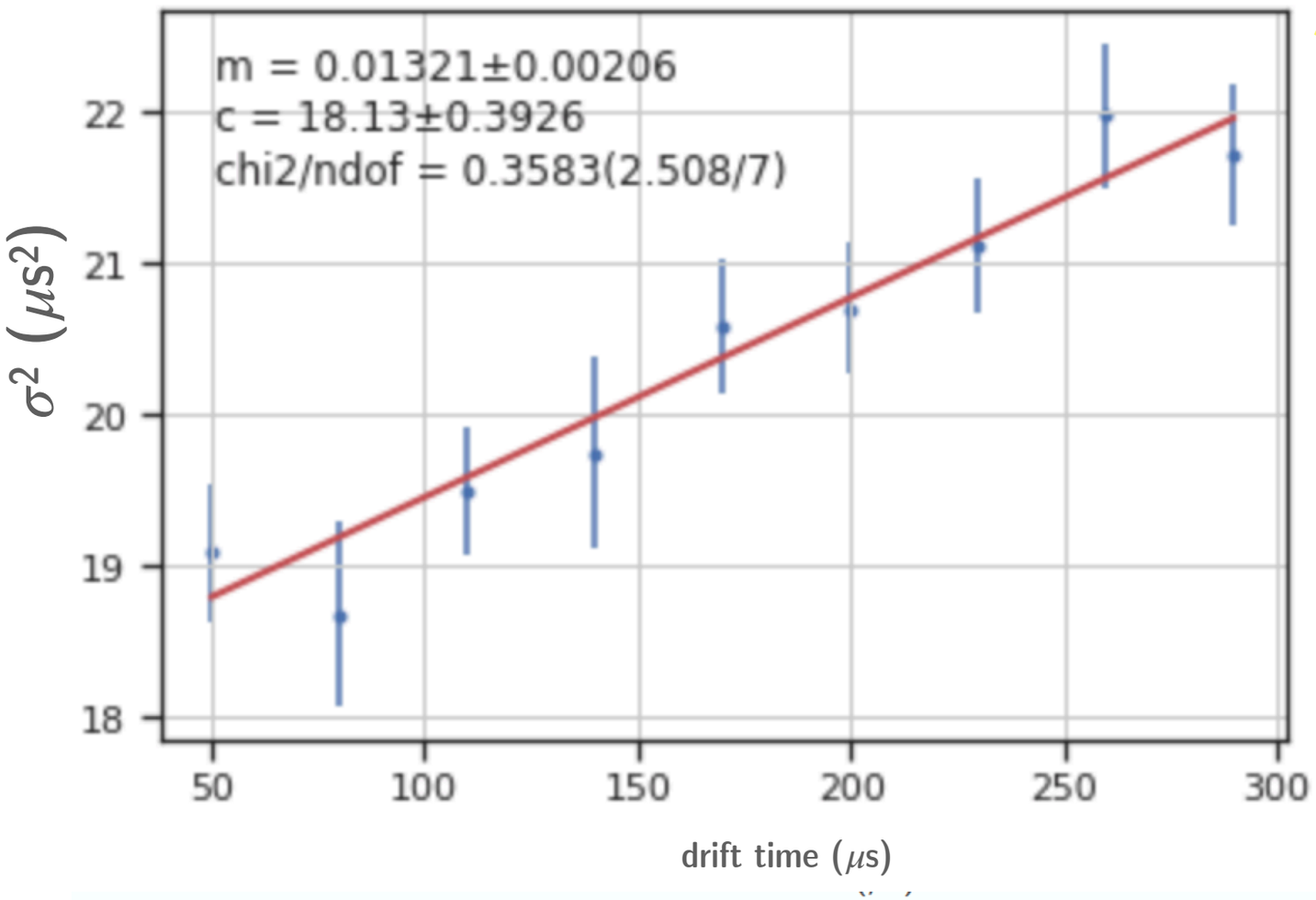


280< t < 300 μs



- Spreads in transverse plane similar at high and low drift, analysis ongoing!!

Transverse diffusion at 15% He mixture



VERY PRELIMINAR!

- **D_T Measurement:** 1102 $\pm$ 80 (stat) $\sqrt{\text{bar}}\mu\text{m}/\sqrt{\text{cm}}$
- **D_T Magboltz:** 1297 $\pm$ 3 $\sqrt{\text{bar}}$ $\mu\text{m}/\sqrt{\text{cm}}$

- Factor of 3 reduction on the Transverse diffusion with respect to pure Xenon D_T (pure xenon)= 3553 $\pm$ 21(stat) $\sqrt{\text{bar}}$ $\mu\text{m}/\sqrt{\text{cm}}$
- Following steps: study the effect on the discrimination power between sig and bkg due to the topological signature

Conclusions and future plans

The DEMO++ detector is running smoothly and starts to provide promising physics results

- 15 % Helium xenon mixture studied
- A reduction in the light yield collected as predicted in Magboltz simulations is observed
- The transverse diffusion is reduced a factor 3 as predicted by Magboltz

- Plan is to study several mixtures: 2.5, 5, 7, 10% helium
- Study the light yield at different amplification fields
- Measure Transverse/ Longitudinal diffusion as a function of the drift field
- Topological signature studies using Na, Th sources

Exciting data is already ahead of us! stay tune!

Thank you!

LSC Laboratorio Subterráneo de Canfranc

next

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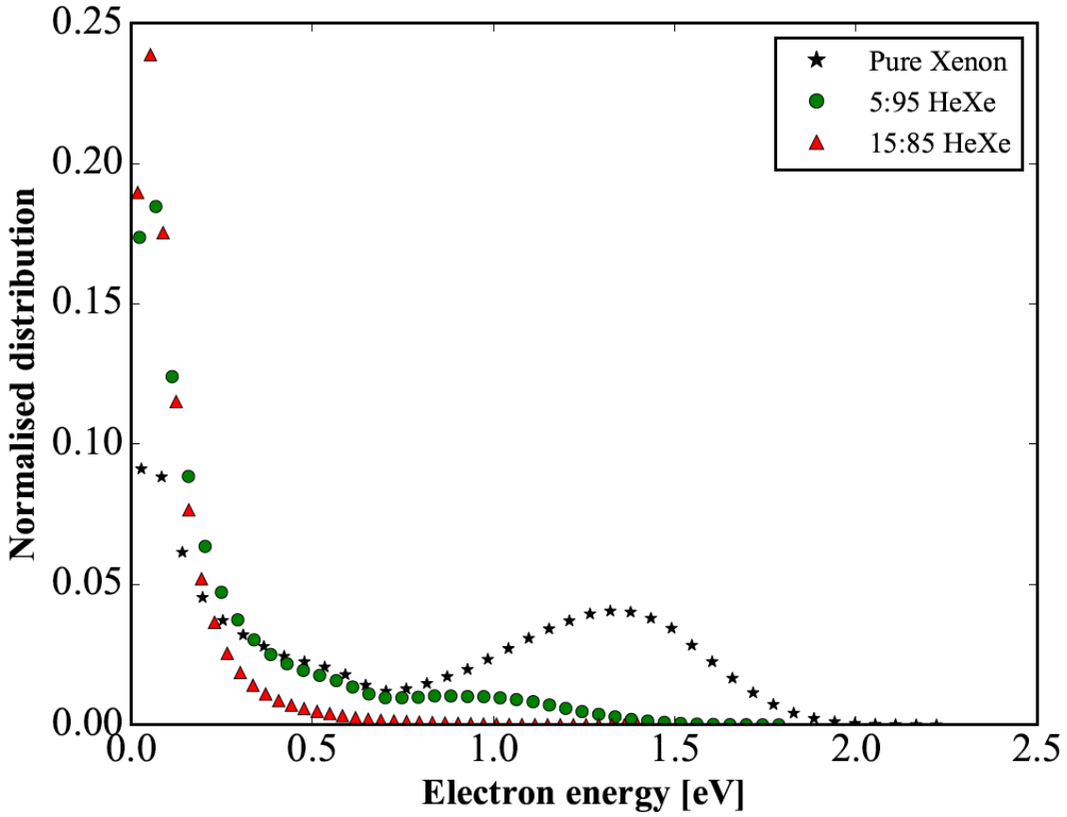
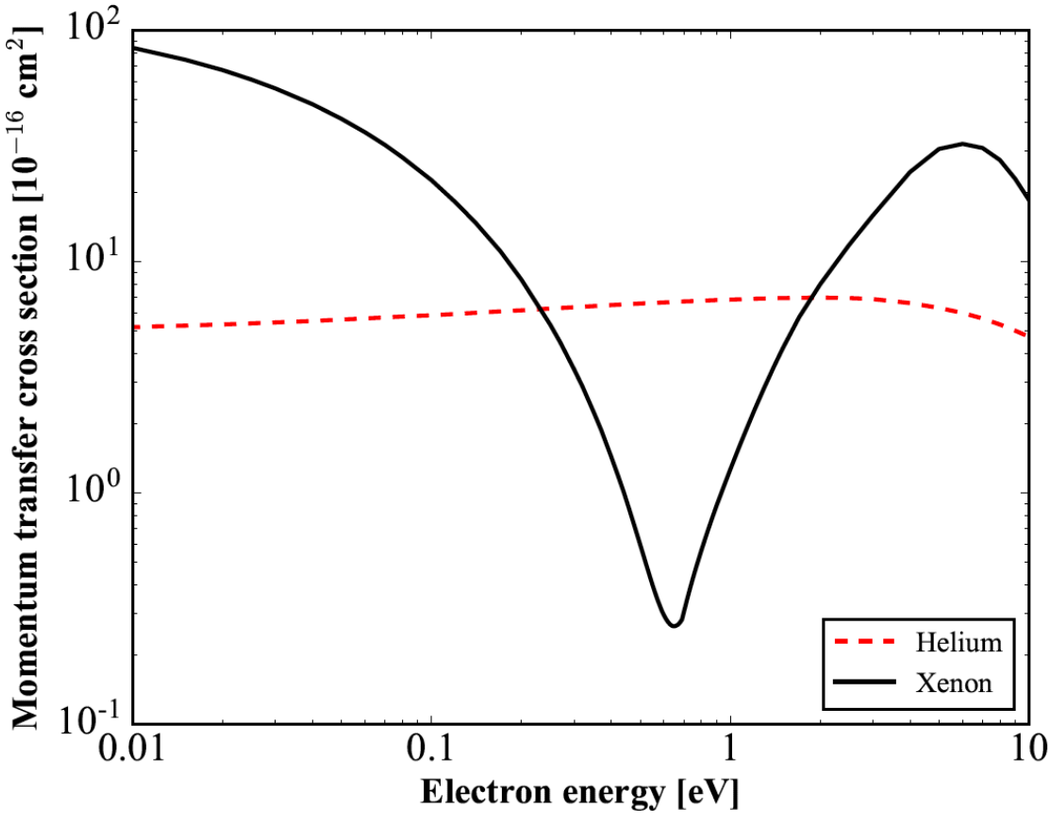
Backup

Helium + xenon

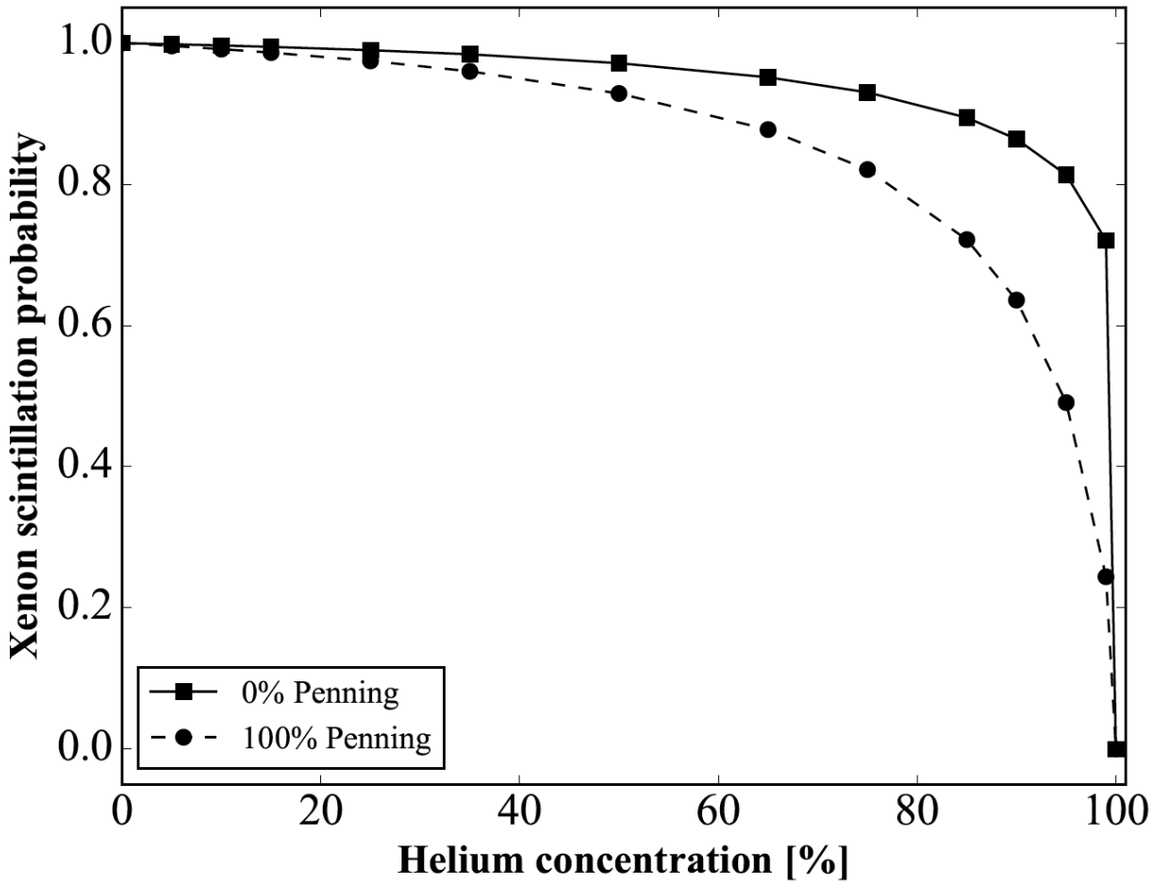


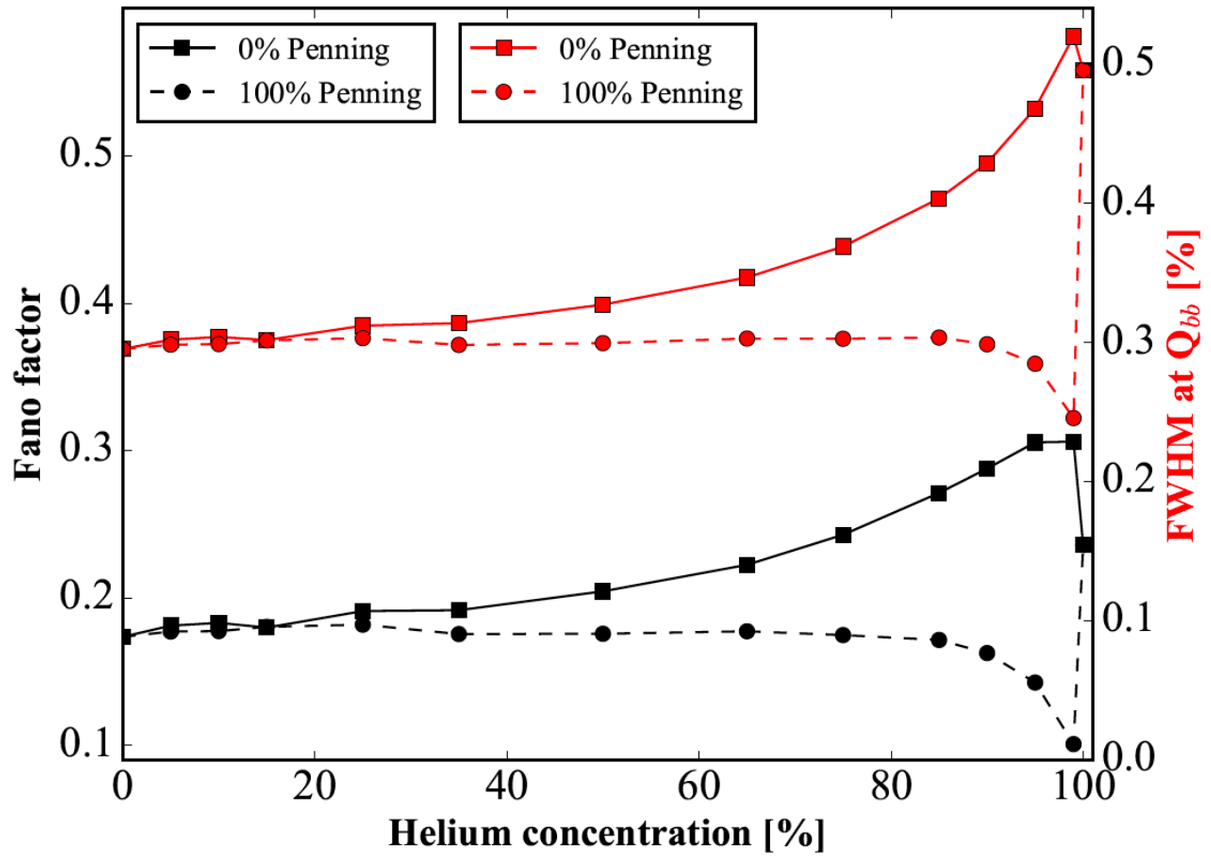


He	$2.74 \cdot 10^{-4}$
Ne	$5.44 \cdot 10^{-5}$
Ar	$2.75 \cdot 10^{-5}$
Kr	$1.31 \cdot 10^{-5}$
Xe	$8.07 \cdot 10^{-6}$

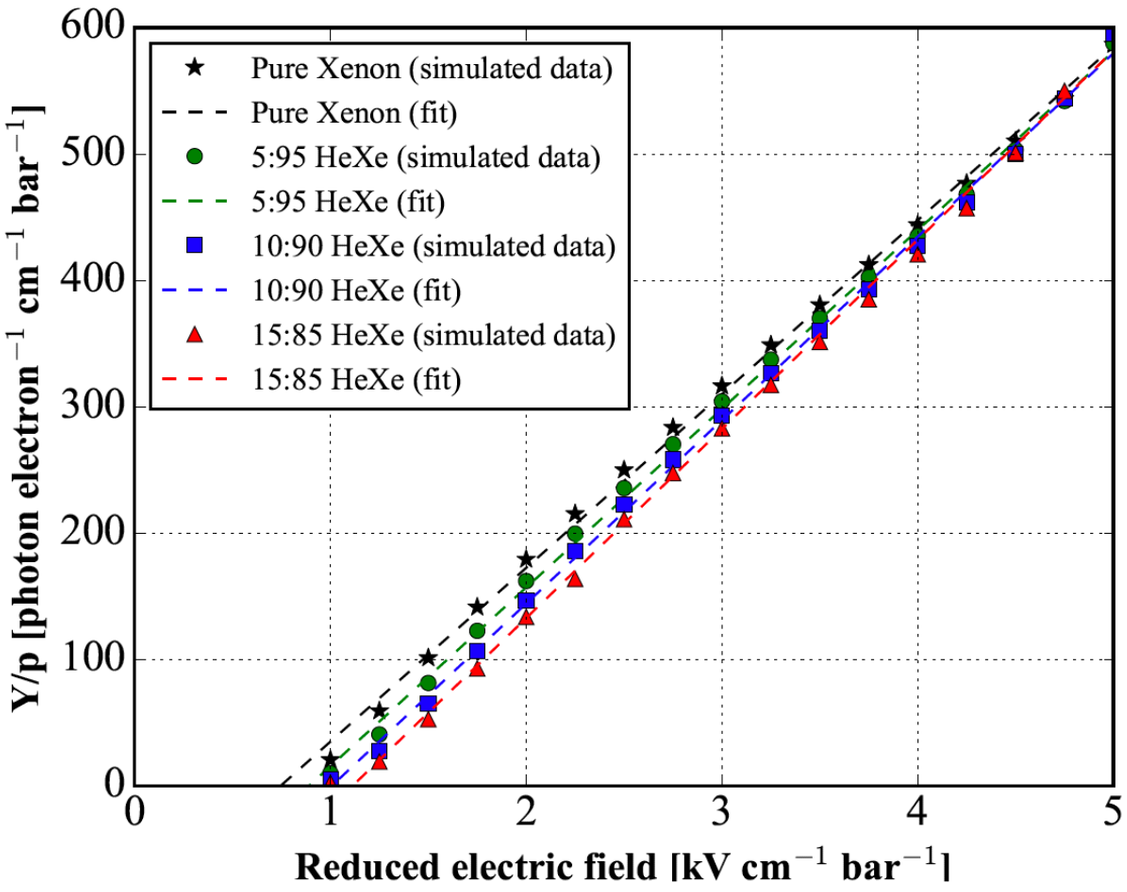
Table A: Mean fractional energy loss of electrons in collisions against noble gas atoms.

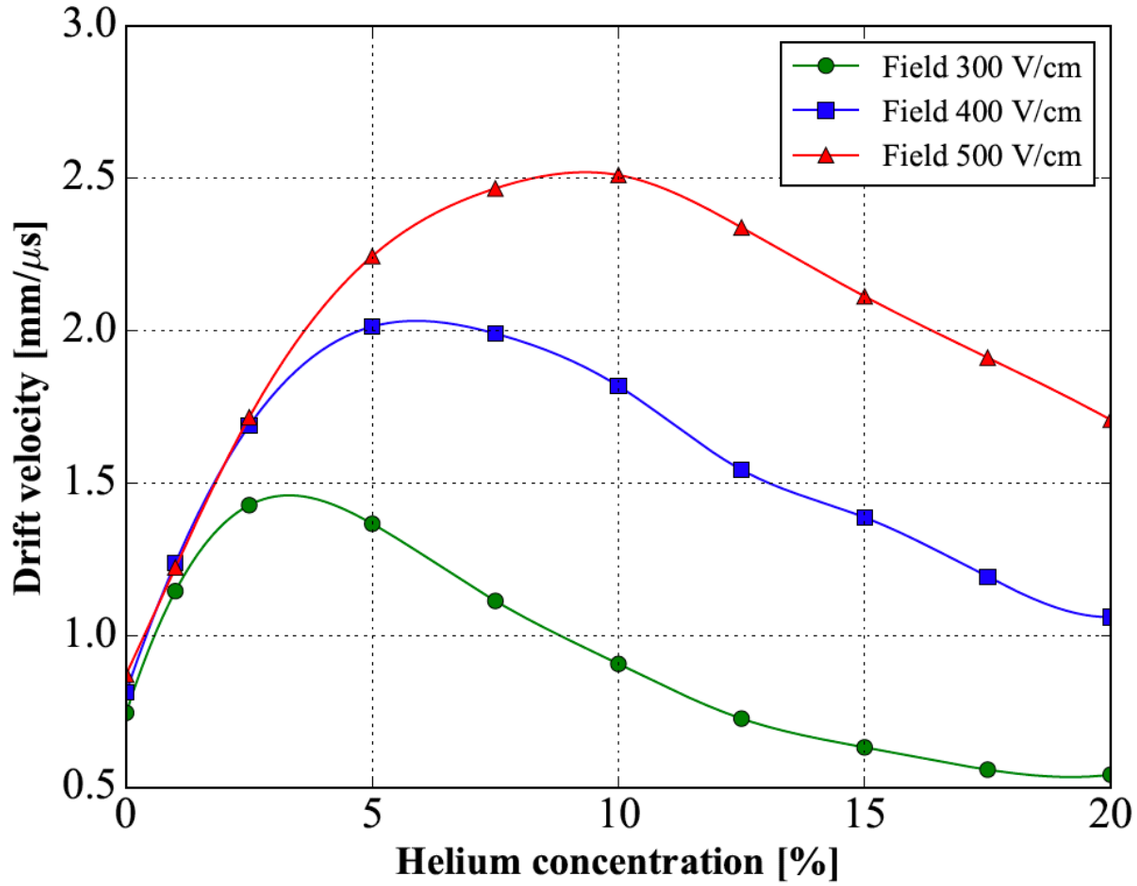
Helium + xenon



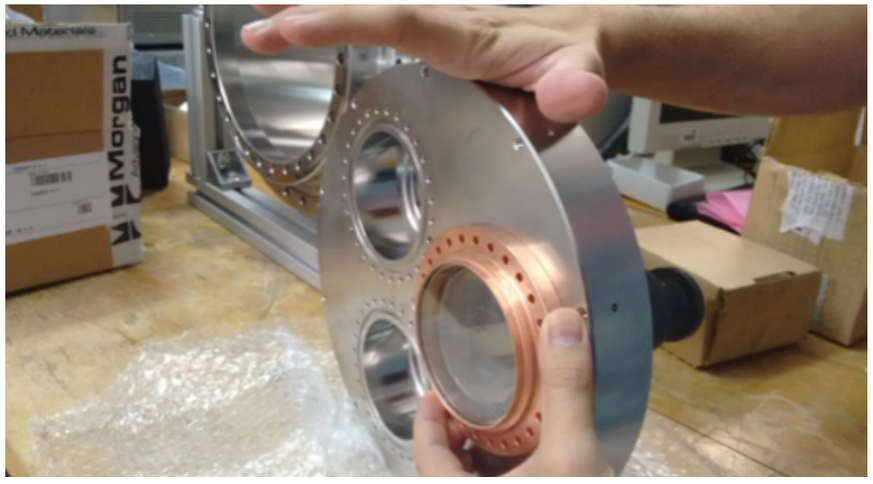


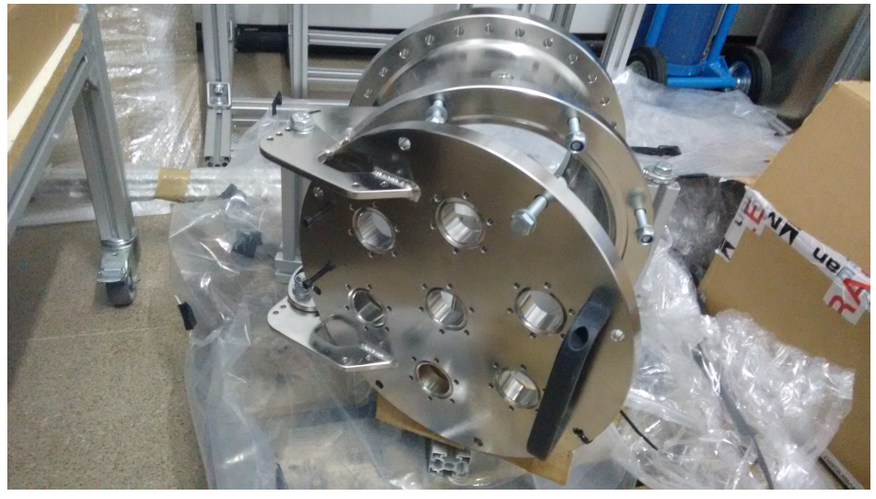
Helium + xenon



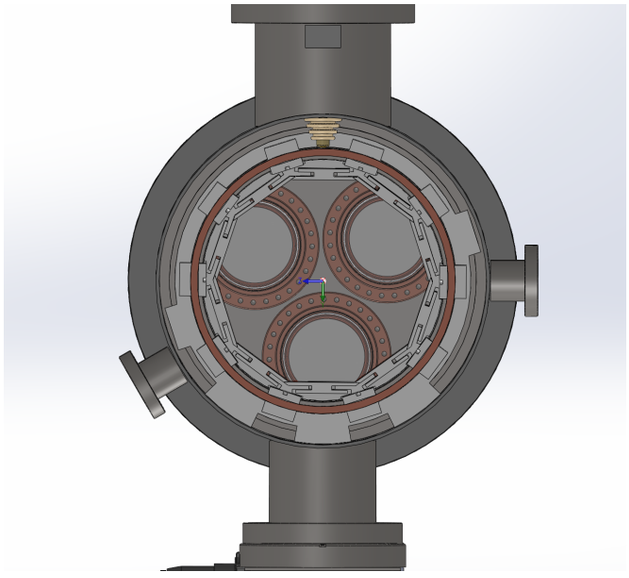


Energy Plane - NEW



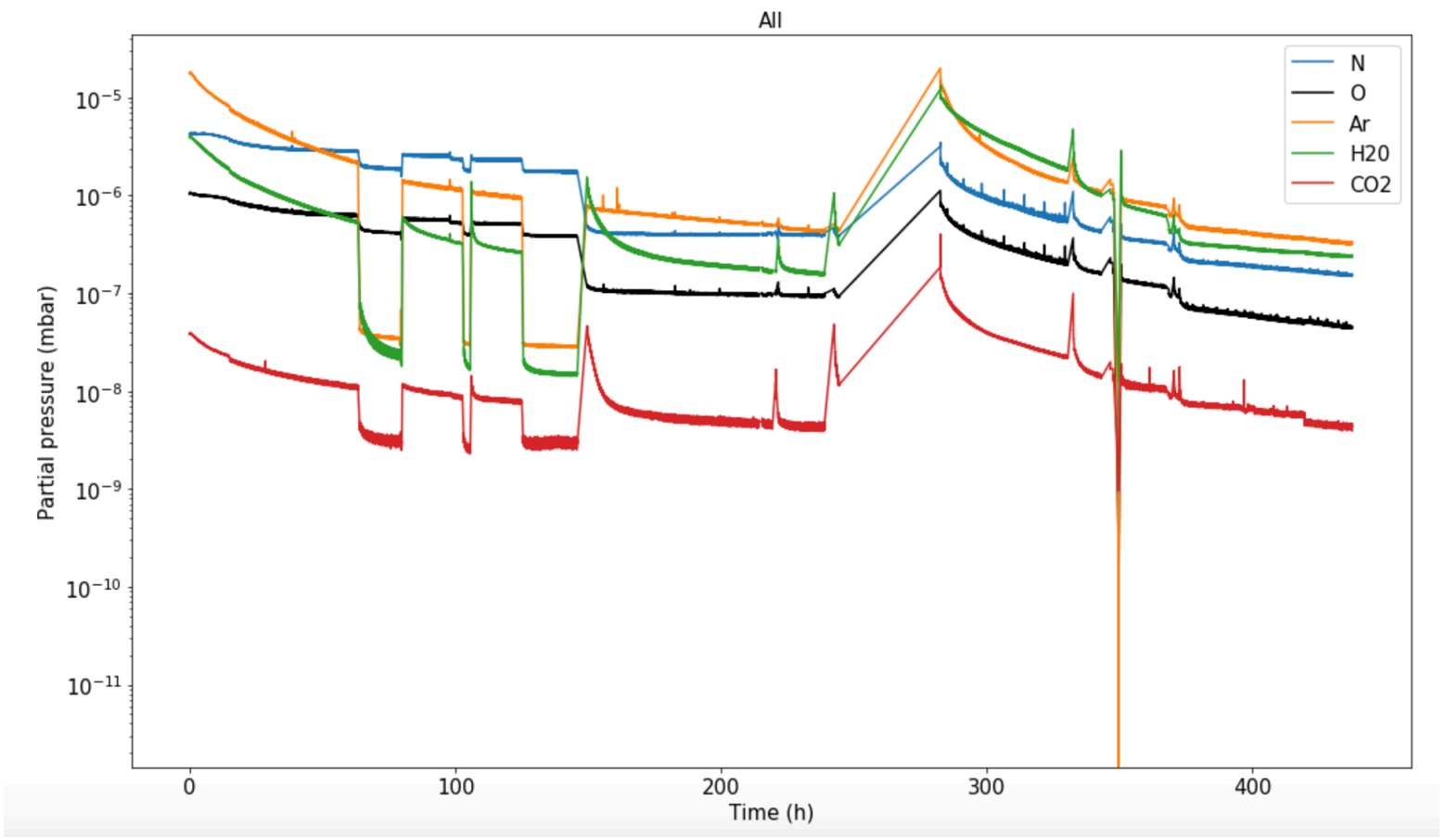


- Interchangeable planes



Run 1 vacuum operation

RUNII - Vacio 5-03-19						
Ptot	3,30E-05	mbar				
ar	4,50E-06	mbar	13,63%	%	Vacuum before fill	1,00E-04
o2	**7,04E-07**	**mbar**	**2,13%**	%	O2 in NEW mbar	2,13E-06
n2	1,84E-06	mbar	5,57%	%	O2 in NEW bar	2,13E-09
h2o	3,14E-06	mbar	9,51%	%	**ppb de O2 1bar**	**2,13**
co2	5,46E-08	mbar	0,17%	%	ppb de O2 10bar	0,21
Xe	2,16E-05	mbar	65,46%	%		



He permeability checks

- Pressurized at 10 bar with He. Joints: o-ring + npt connection. —> from 10^{-12} to 10^{-7} in 16 mins
- Updated connections with Helicoflex and 2 o-ring (no npt)