CYGNUS negative ion gas study

Kentaro Miuchi
Kobe Univ.

CYGNUS 2019
12 July 2019

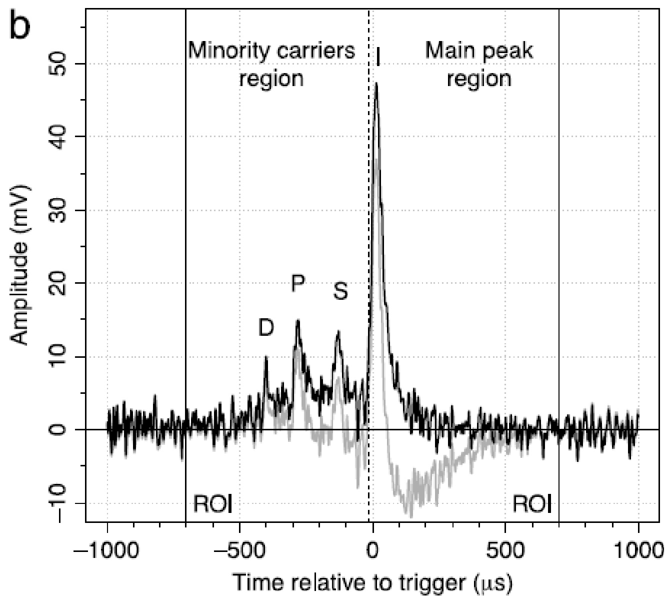
SPECIAL thanks
Dinesh Loomba,
CYGNUS gas WG

JSPS 二国間事業
「ガス飛跡検出器を用いた暗黒物質探索実験」

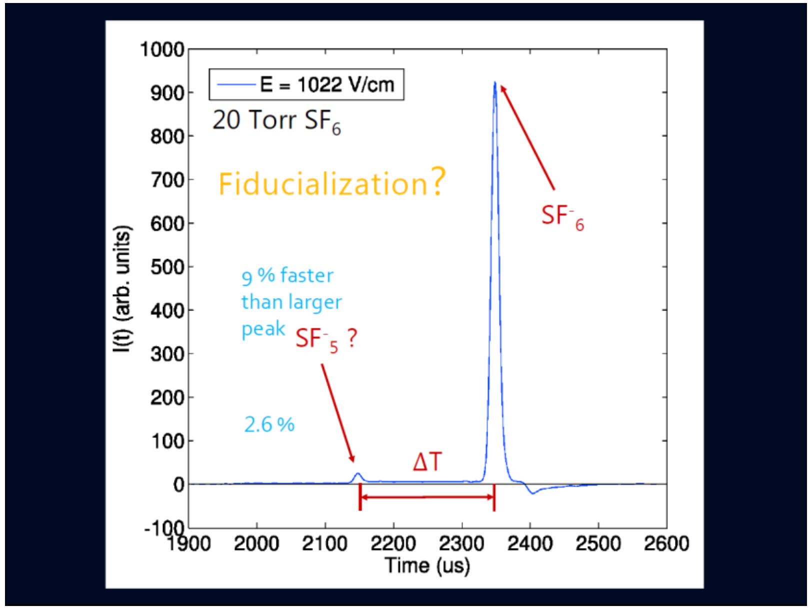
Negative ION gas for direction-sensitive DM search

- Pioneered by DRIFT group ⇒ small diffusion
- Minority carrier discovery (CS_2+O_2, Occidental group).
- SF6 discovery (2015, UNM group). ⇒ fiducialization

⇒ several groups are working together exchanging information.



J.B.R. Battat et al. / Physics of the Dark Universe 9–10 (2015) 1–7



CYGNUS2015
2017 JINST 12 P02012

- CYGNUS gas meetings
  - 4 meetings in 2019 next: Aug. 8th, 2019
  - 10 meetings in 2018
  - 10 meetings in 2017
  - 2 meetings in 2016 (started Sep. 2016)

  - started for SF6 study
  - recently for variety of topics
    - electron-drift TPC status
    - join-work status reports
    - columnar recombination reports
    - resistive sheet TPC R&Ds…

Updates on SF6 (and negative ion TPC)

- New Mexico
  - SF_6 + CF_4 (Randy, Dinesh Sep 2018)
  - Tilted 2D GEM readout CF_4+CS_2 gas (Randy, Dinesh, Mar 2019)
- Sheffield
  - Micromegas
  - Thick GEM + wire (Warren, Nov 2018)
- Kobe
  - Garfield++ (Ishiura, Oct 2018,)
  - Electronics()
- Hawaii
  - GEM and related gas study (Tom Oct, 2018)
- Italy
  - LEMON test (Elisaebetta, June 2018)

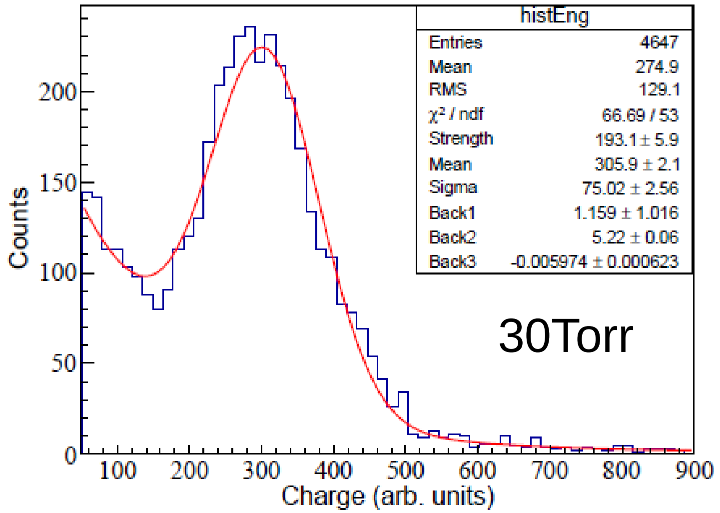
Updates on related R&D topics

- Kobe
  - Resistive Sheet TPC (Miuchi, Nov 2018, PTEP 2019 (2019)063H01)
  - columnar recombination (Nakamura, June 2018, 2018 J. Inst. 13 P07015)
- Hawaii
  - GEM and related gas study (Tom Oct, 2018)
- Italy
  - LEMON test (Elisaebetta, June 2018 1905.04066)

SF6 fundamental studies:
55Fe spectrum and gain curves with GEMs

New Mexico
(JINST12(2017)P02012)

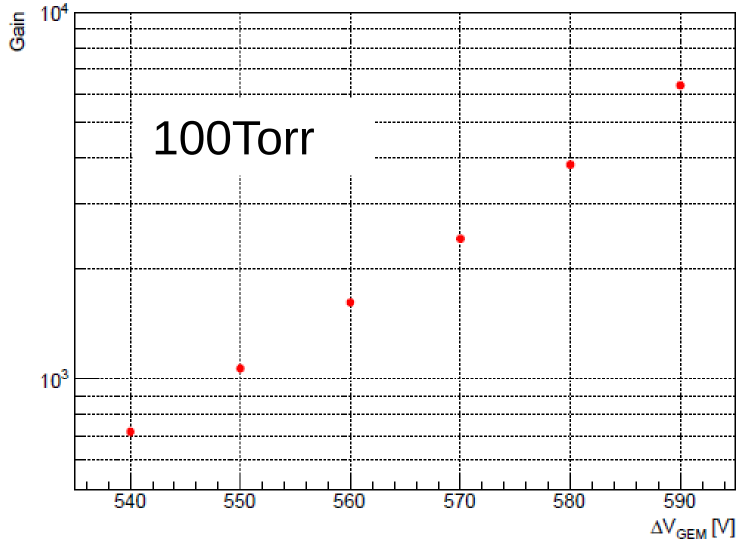
CERN 400μm-thick GEM



(a) Raw spectrum

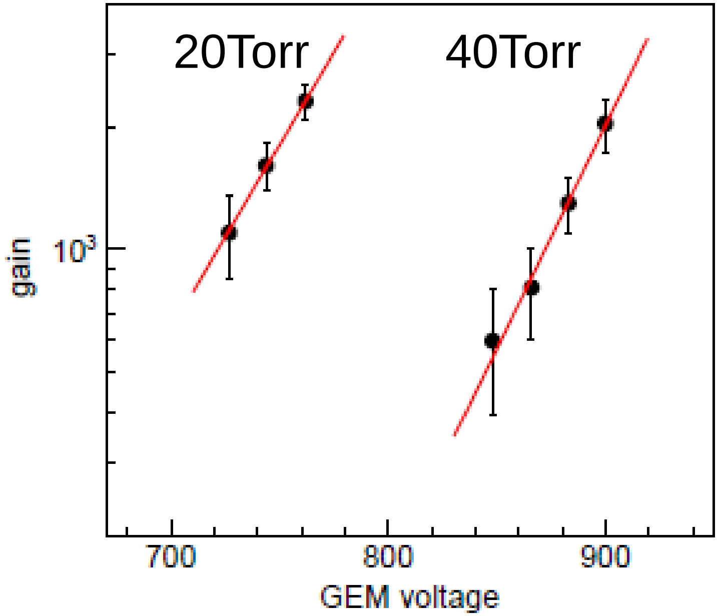
gain ~3000
σ/E 25%
30-60Torr

Kobe
(MPGD 2019)
Siceneregy 2 × 100μm-thick GEM



gain ~7000
σ/E 25%
100Torr
(60-120Torr with triple GEM)

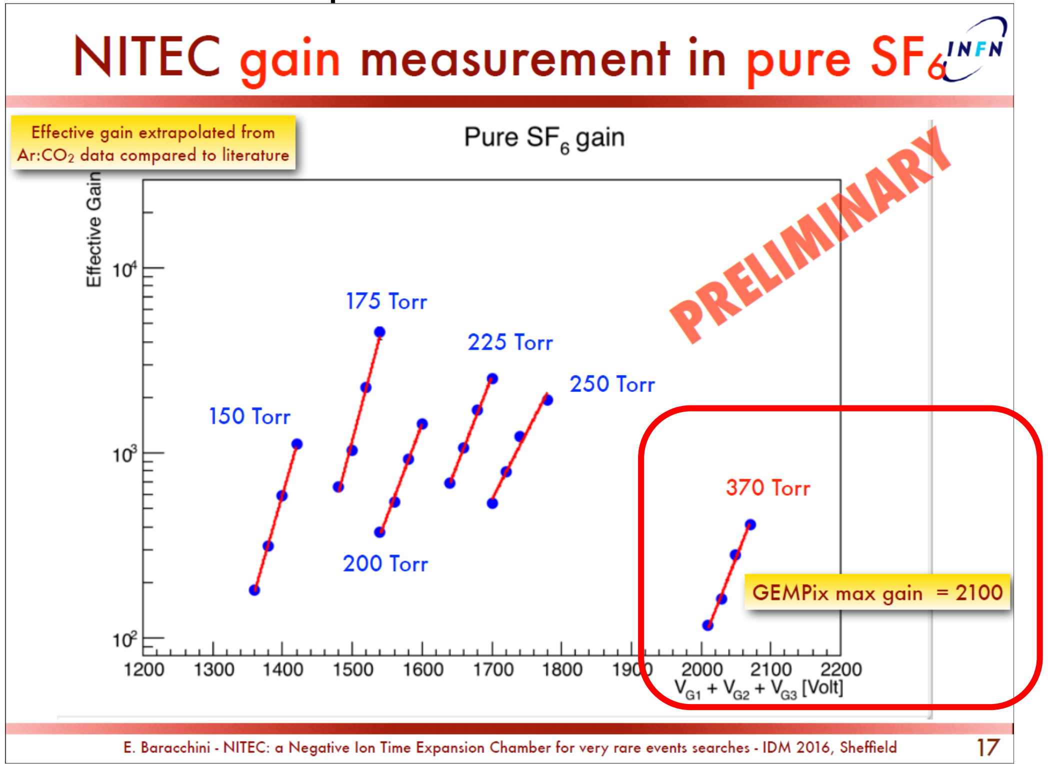
Hawaii
(T. Thrope PhD thesis 2018)
CERN 400μm-thick GEM



gain ~3000
σ/E 35%
20-40Torr

SF6 fundamental studies:
55Fe spectrum and gain curves (contn'd)

Italy
(IDM 2016)
CERN 3 × 50μm GEM



gain 2100
200-370 Torr
Landau spectrum

Sheffield
(gas meeting Jun. 2017)
thick GEM
gain ~9000
20-50 Torr

Wellesley
(gas meeting, Jun 2017)
256 μm gap CERN micromegas
gain 1500
30 Torr

Thick GEM for low pressure
Thin GEMM for high pressure
Micromegas needs some more study
Energy resolution not as good as electron-drift gas

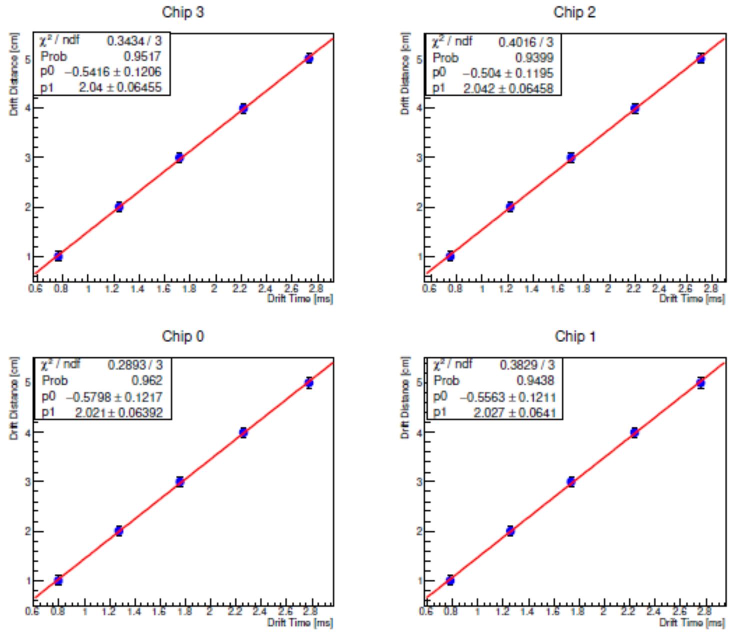
SF6 fundamental studies:

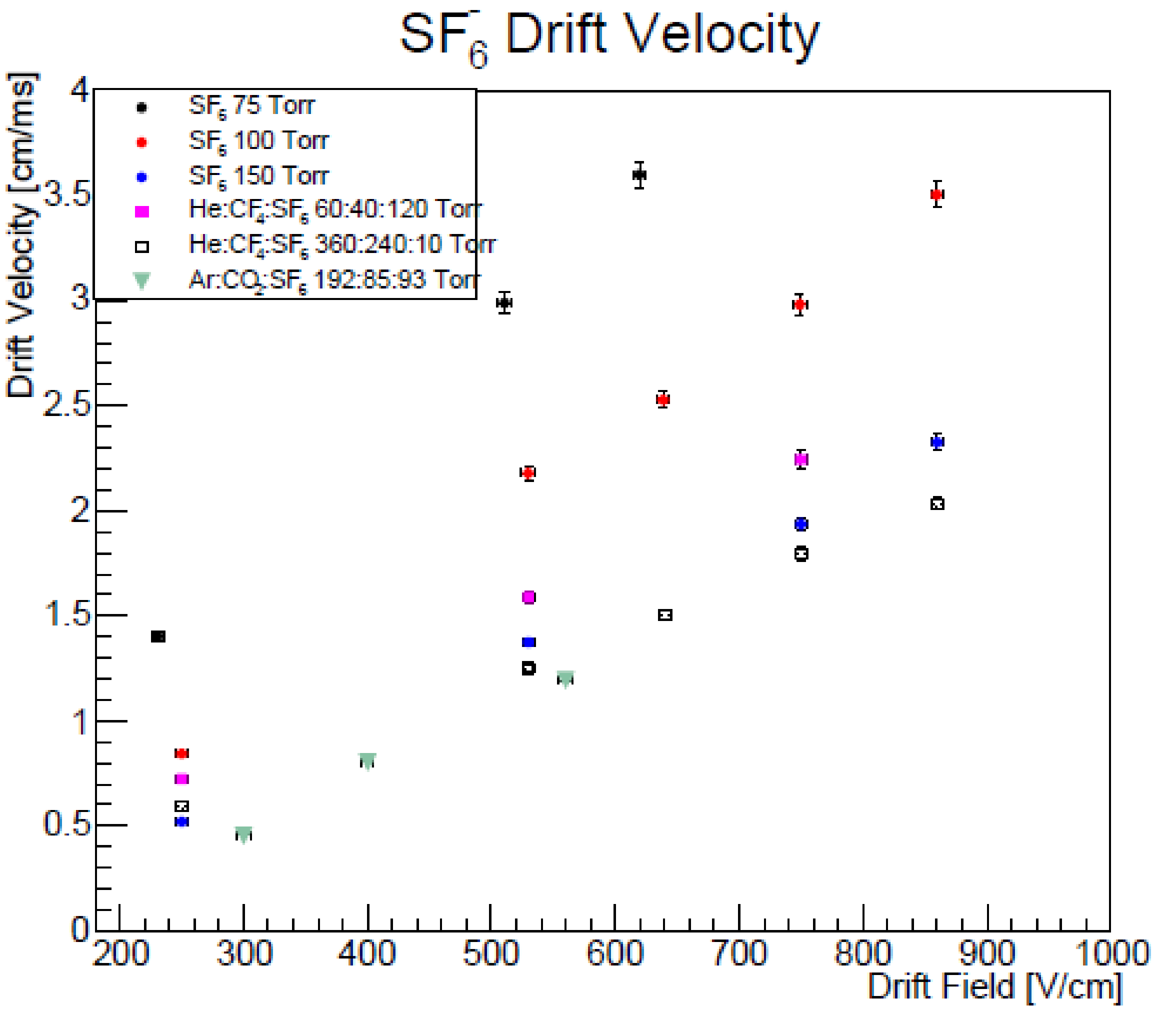
drift velocity measurement @ nearly atmospheric gas mixture

Italy (JINST13(2018)P04022)
CERN 3×50μm GEM
He:CF4:SF6 360:240:10
electron beam 25-750 MeV

drift velocity
mobility

TOA results

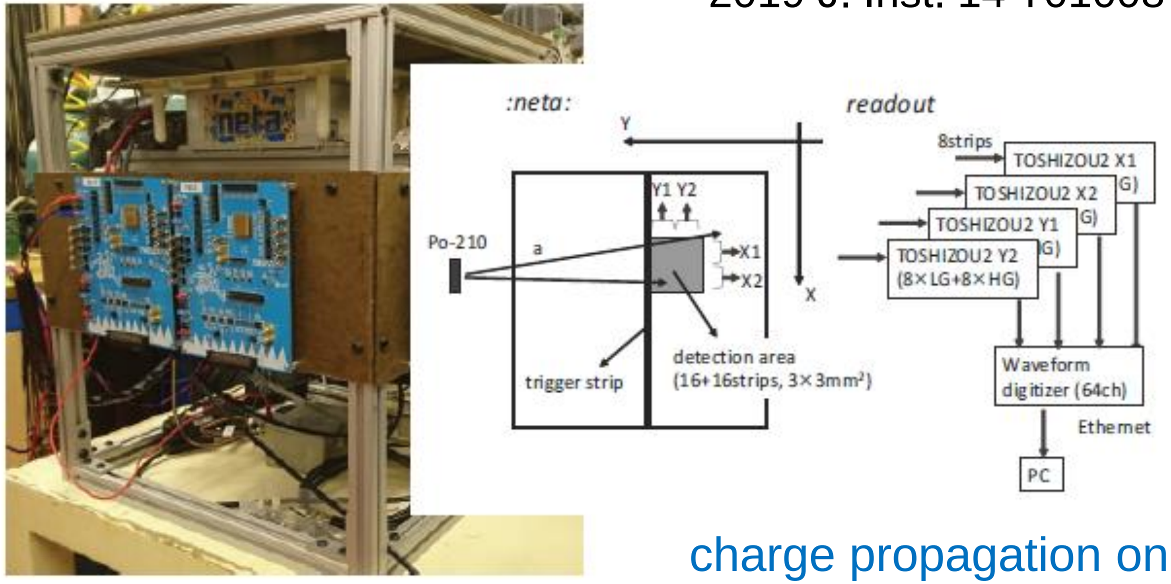




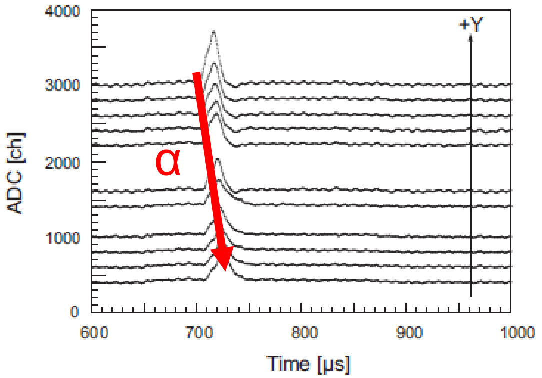
SF6 tracking: electronics for multi-channel charge-readout

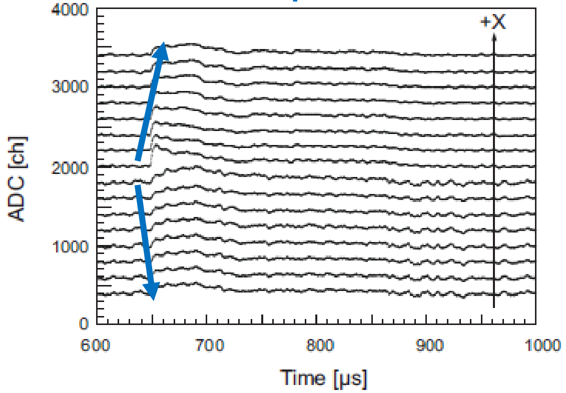
LTARS2016 + Wellesley's micromegas resistive-strip readout

2019 J. Inst. 14 T01008

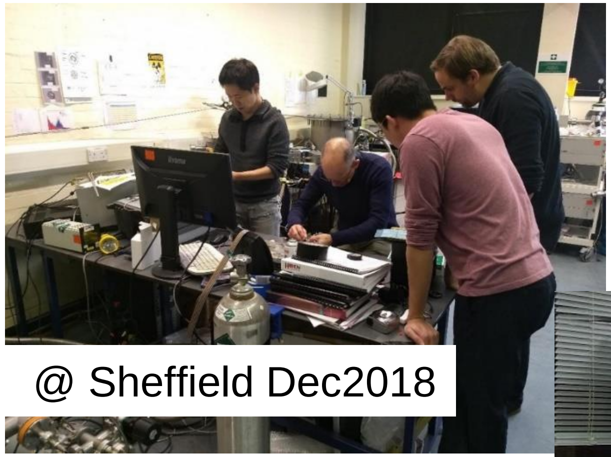


charge propagation on resistive strip were seen

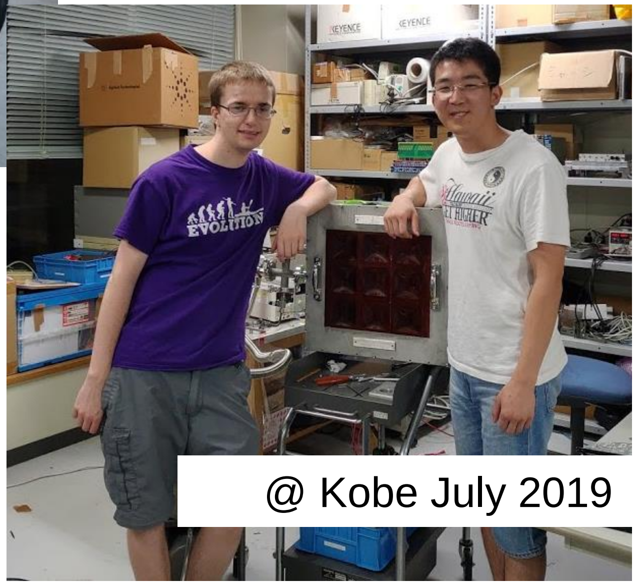




new: LTARS2016 + Sheffield detectors (wires, micromegas)



@ Sheffield Dec2018

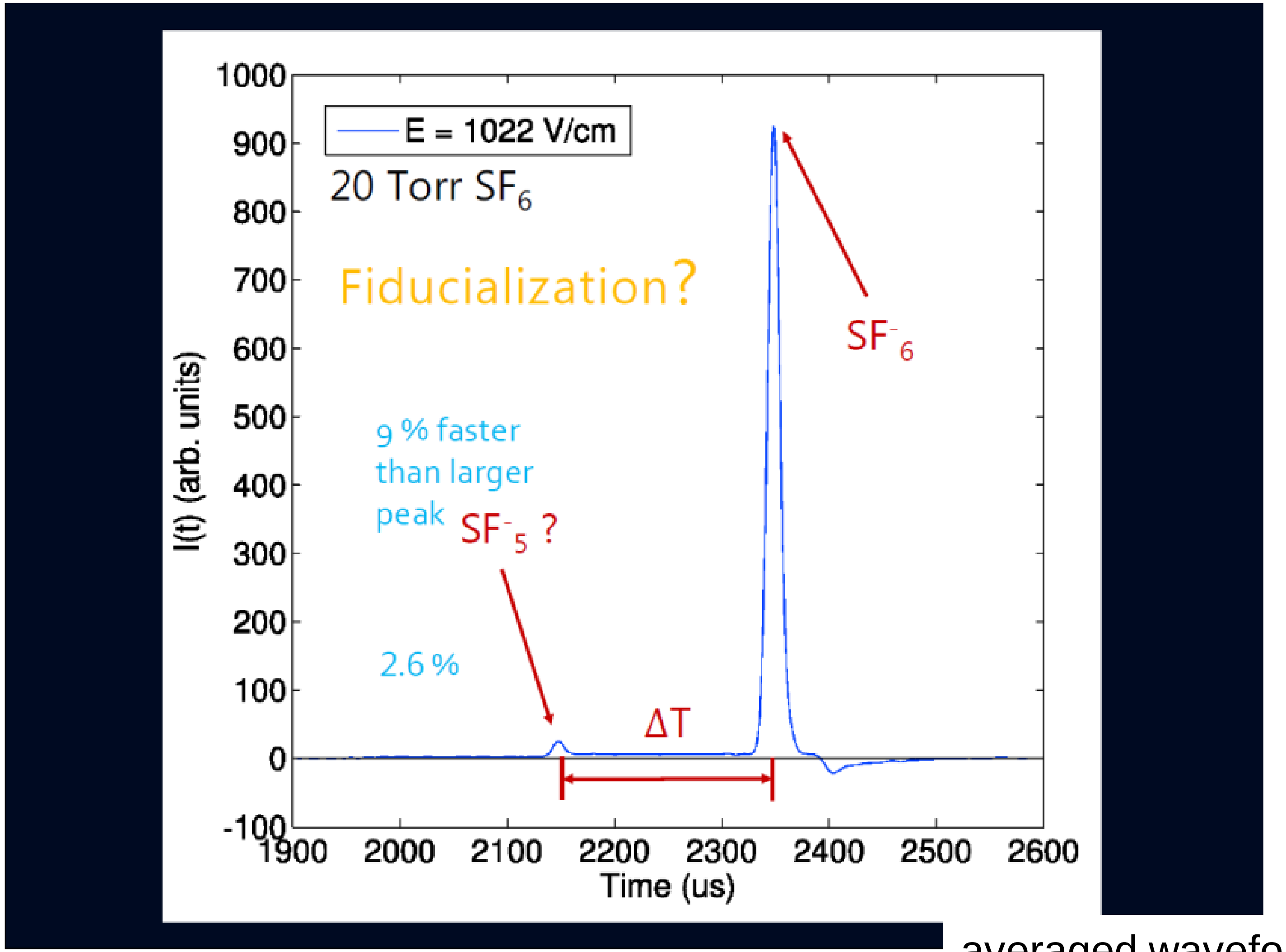


@ Kobe July 2019

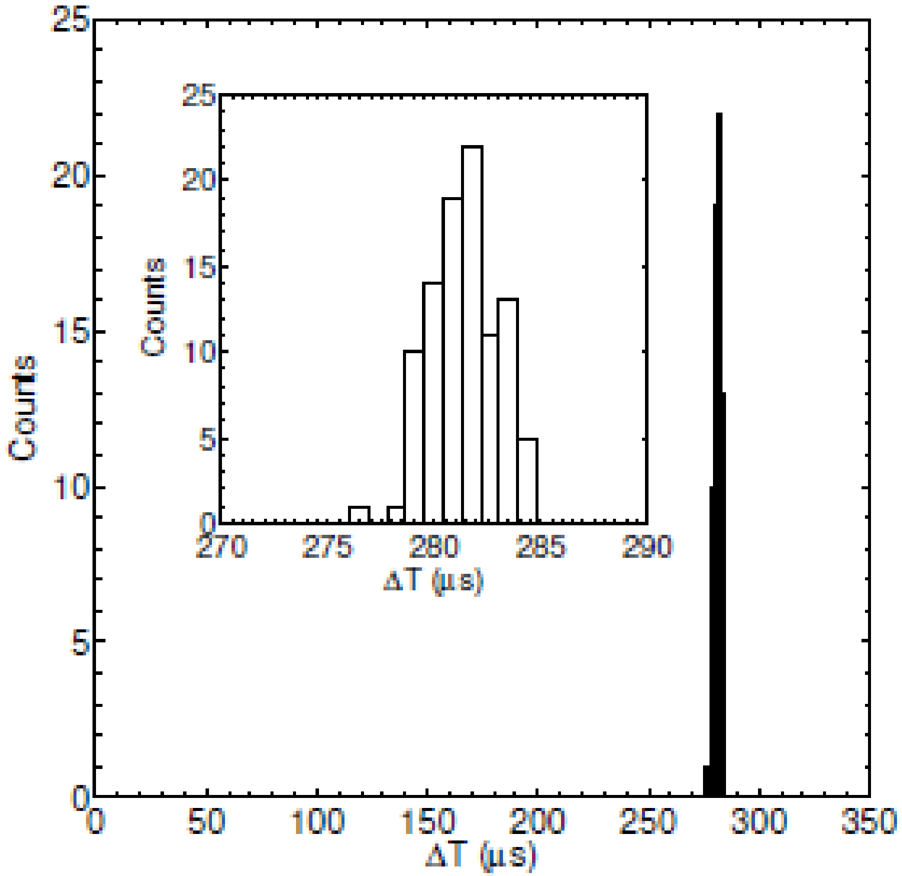
See Callum Eldridge's talk

SF6 fiducializtion studies:

New Mexico
(JINST12(2017)P02012)



averaged waveform



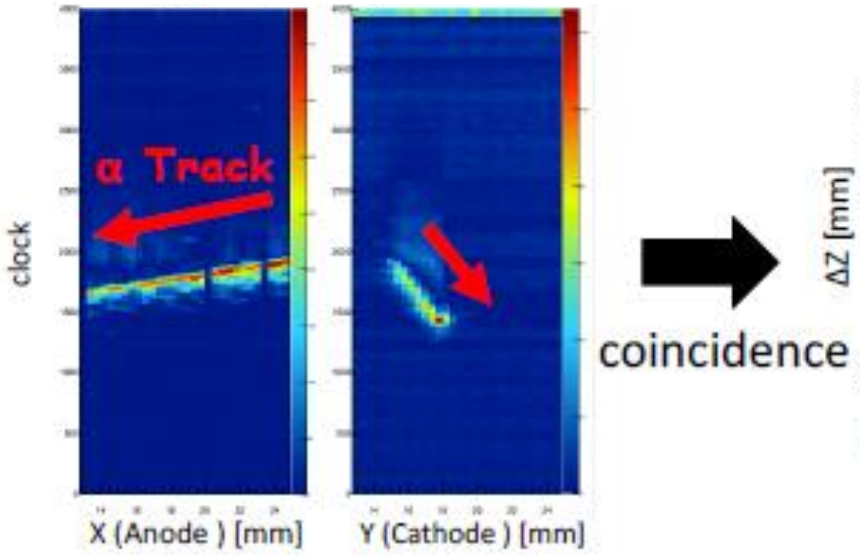
(a) ΔT laser calibration pulses

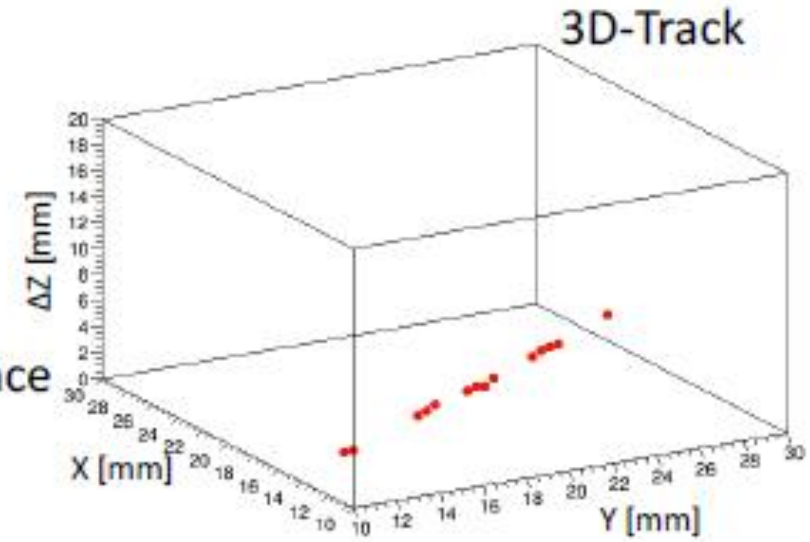
resolution
7.3mm FWHM

SF6 fiducializtion studies: with 3D tracks

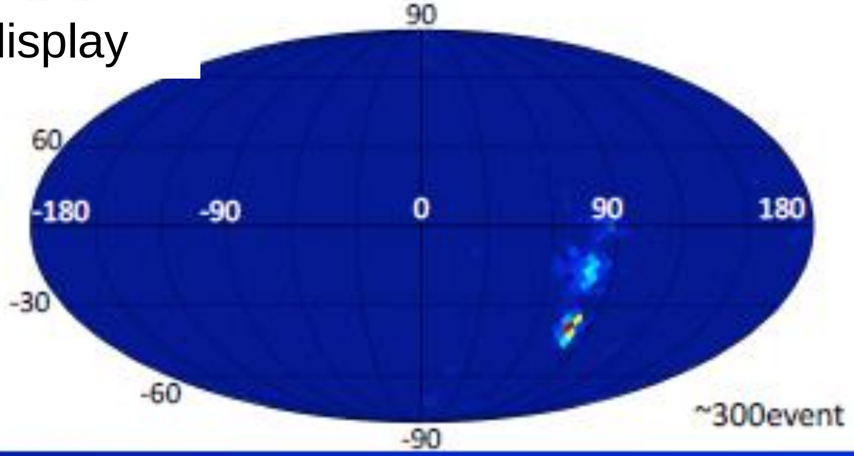
Tomonori Ikeda (Kobe)
JPS Mar2018
paper in preparation

event display (waveform)

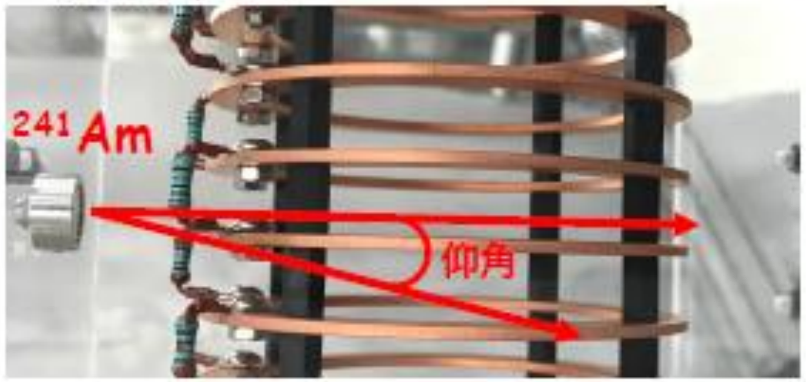




event display



configuration



SF6 for low BG: Molecular Sieve study

See Rob Gregorio's talk

Demonstration of radon removal from SF_6 using molecular sieves

JINST 12(2017) P09025

A.C. Ezeribe, W. Lynch, R.R. Marcelo Gregorio,[1] J. Mckeand, A. Scarff and N.J.C. Spooner

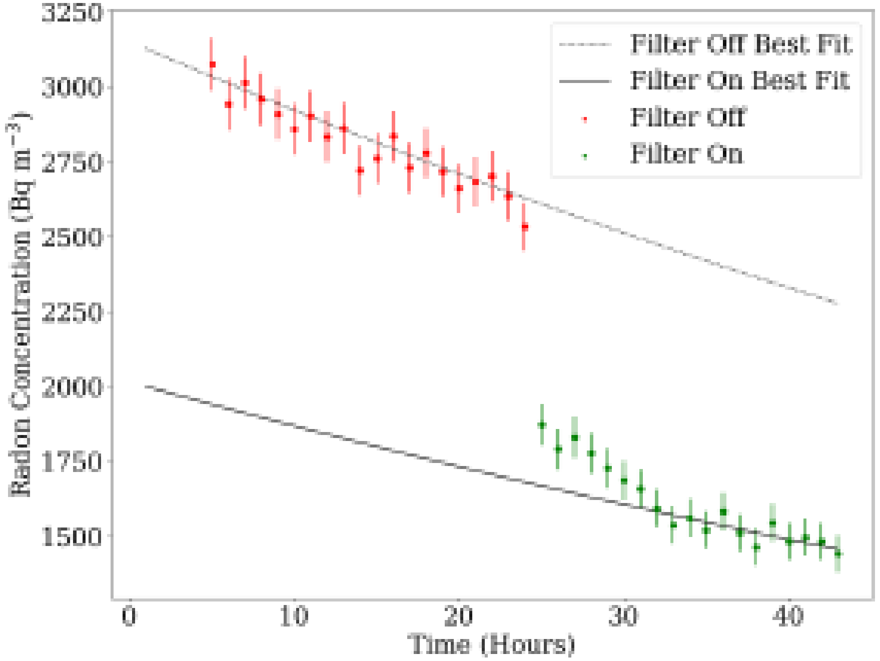


Table 1. Properties and specifications of the molecular sieves that were examined.

Molecular Sieve	Molecular Formula	Pore Size (Ångströms)	Approx. Bead Size (mm)
3Å	$0.6K_2O \cdot 0.4Na_2O \cdot Al_2O_3$	3	2
4Å	$Na_2O \cdot Al_2O_3 \cdot 2.0SiO_2$	4	2
5Å	$0.80CaO \cdot 0.20Na_2O \cdot Al_2O_3 \cdot SiO_2$	5	4
13X	$Na_2O \cdot Al_2O_3 \cdot 2.8SiO_2$	10	4

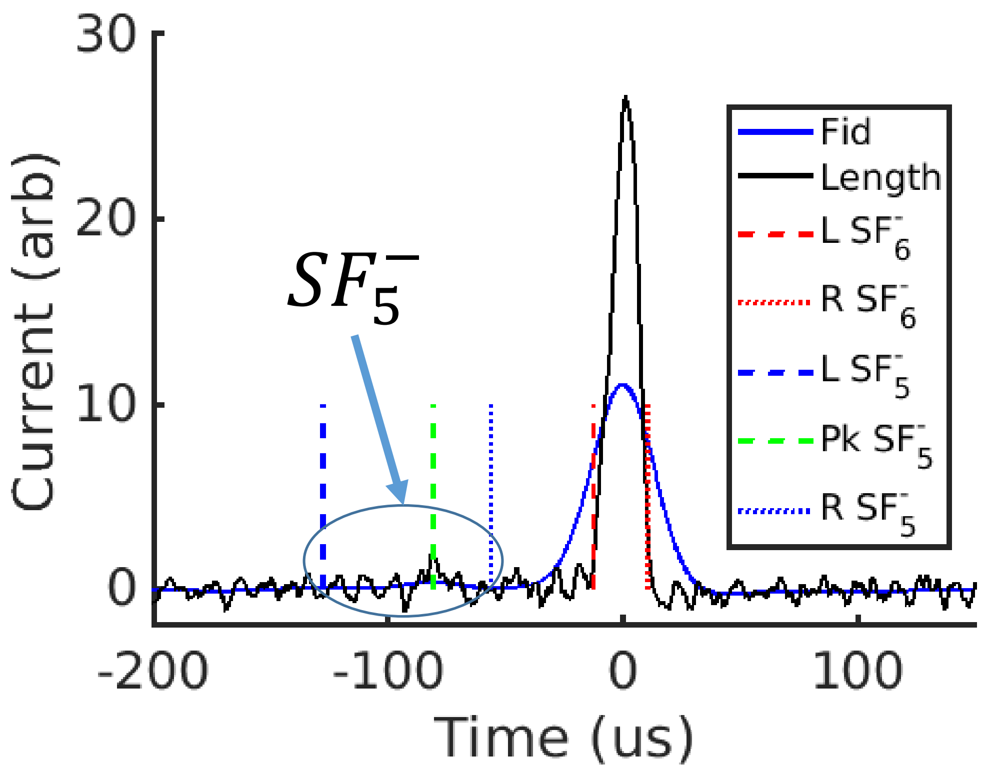
updates:
Sheffield MS with Kobe GEM system (gain monitoring)
Low BG MS development started (Kobe)

highlights

slide by D. Loomba

Issues with SF_6 Gas Fiducialization

- Small SF_5^- Peak
- (2.5% Of Total Charge)
- Solution?



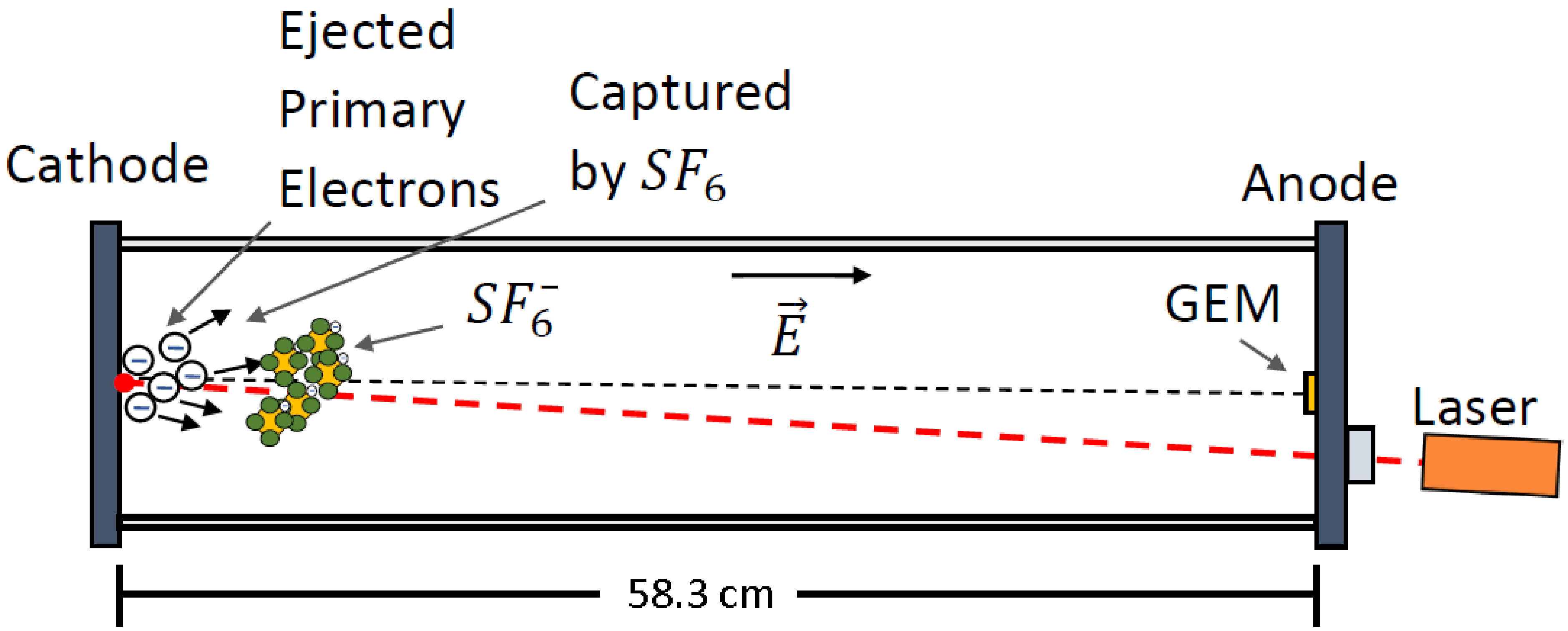
slide by D. Loomba

Search To Enhance Fiducialization In SF_6

Randy Lafler (UNM, PhD thesis)

Laser Induced Ionization

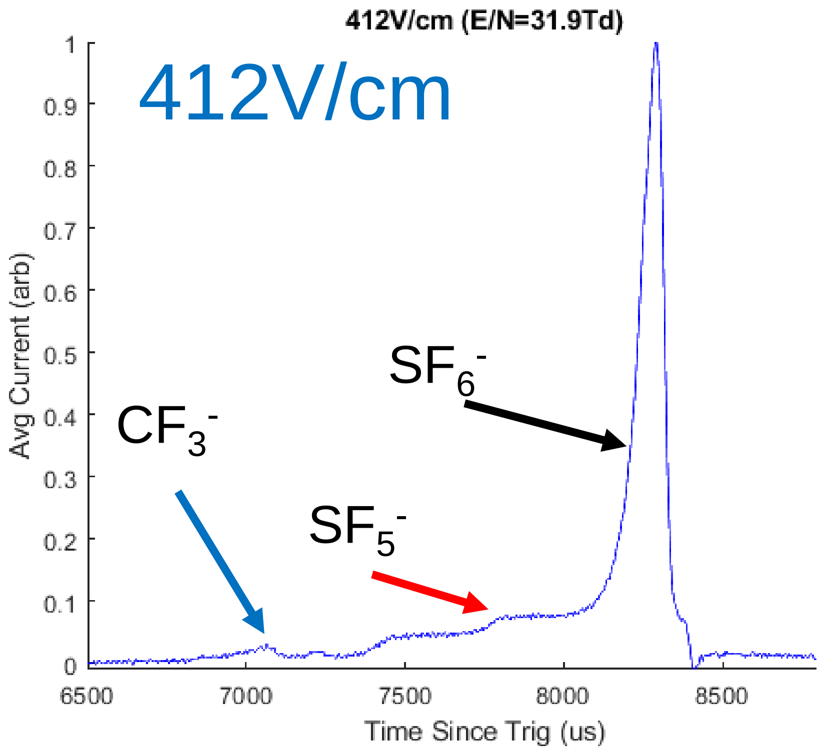
slide by D. Loomba

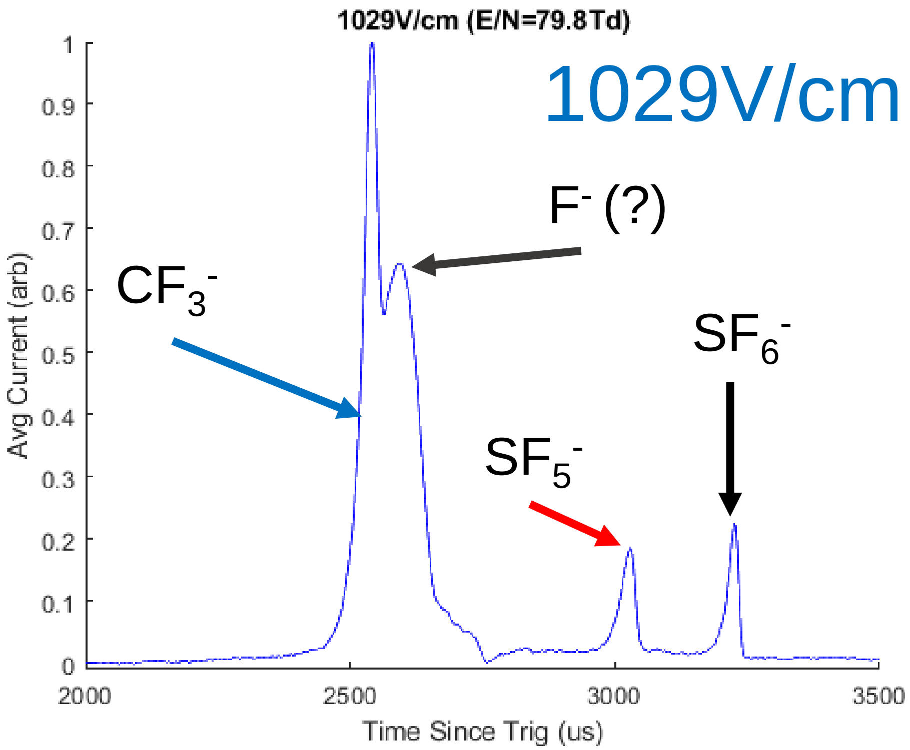


Tunability Of The New Species With Drift Field

slide by D. Loomba

40-0.1 Torr – CF_4-SF_6

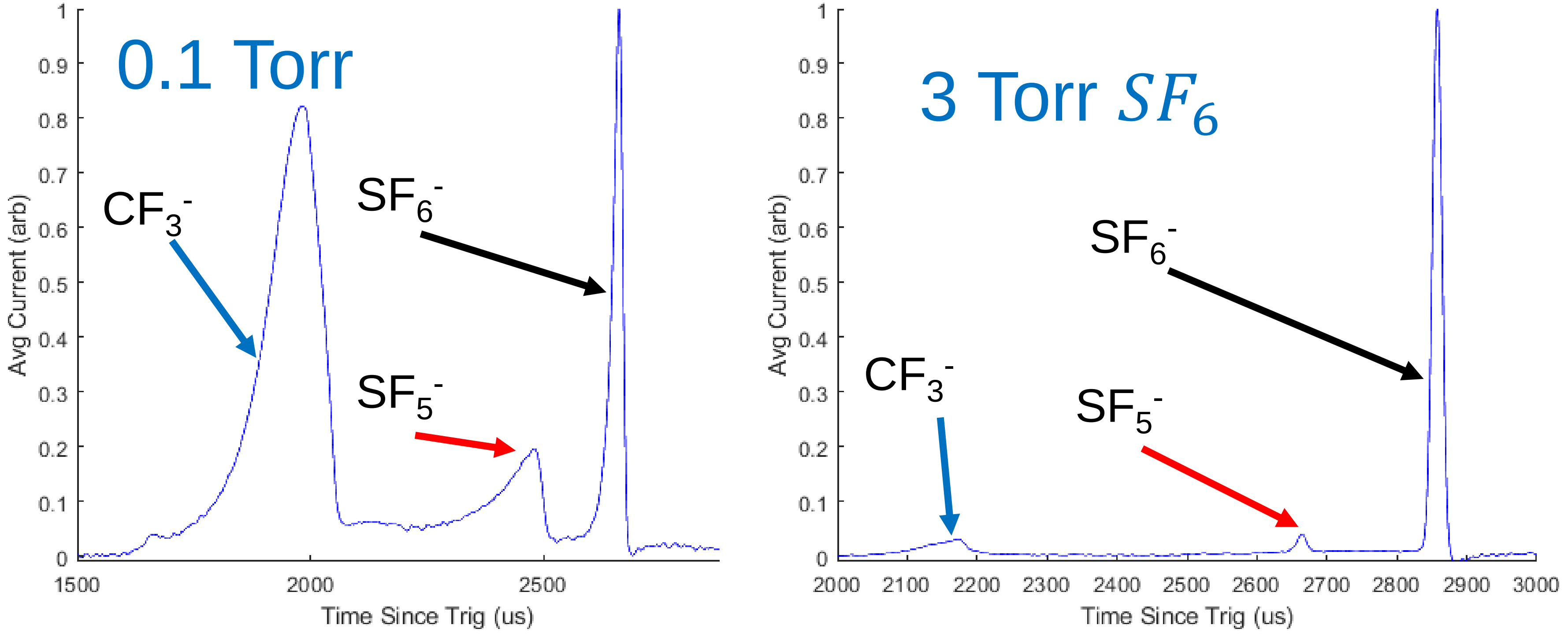




Tunability Of The New Species With SF6 Concentration

slide by D. Loomba

20-X Torr – **CF_4-SF_6**, E/N = 95Td

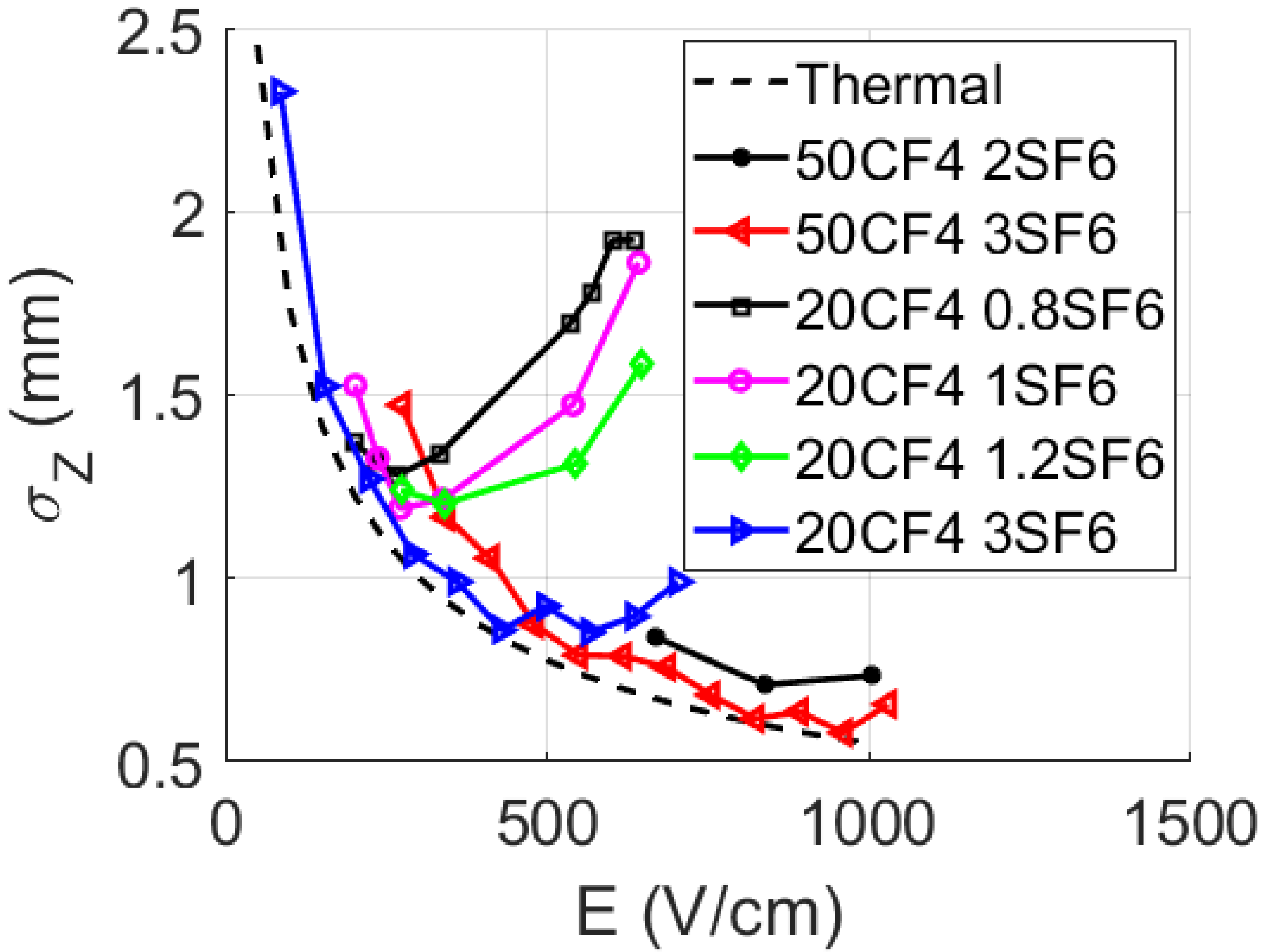


614V/cm

703V/cm

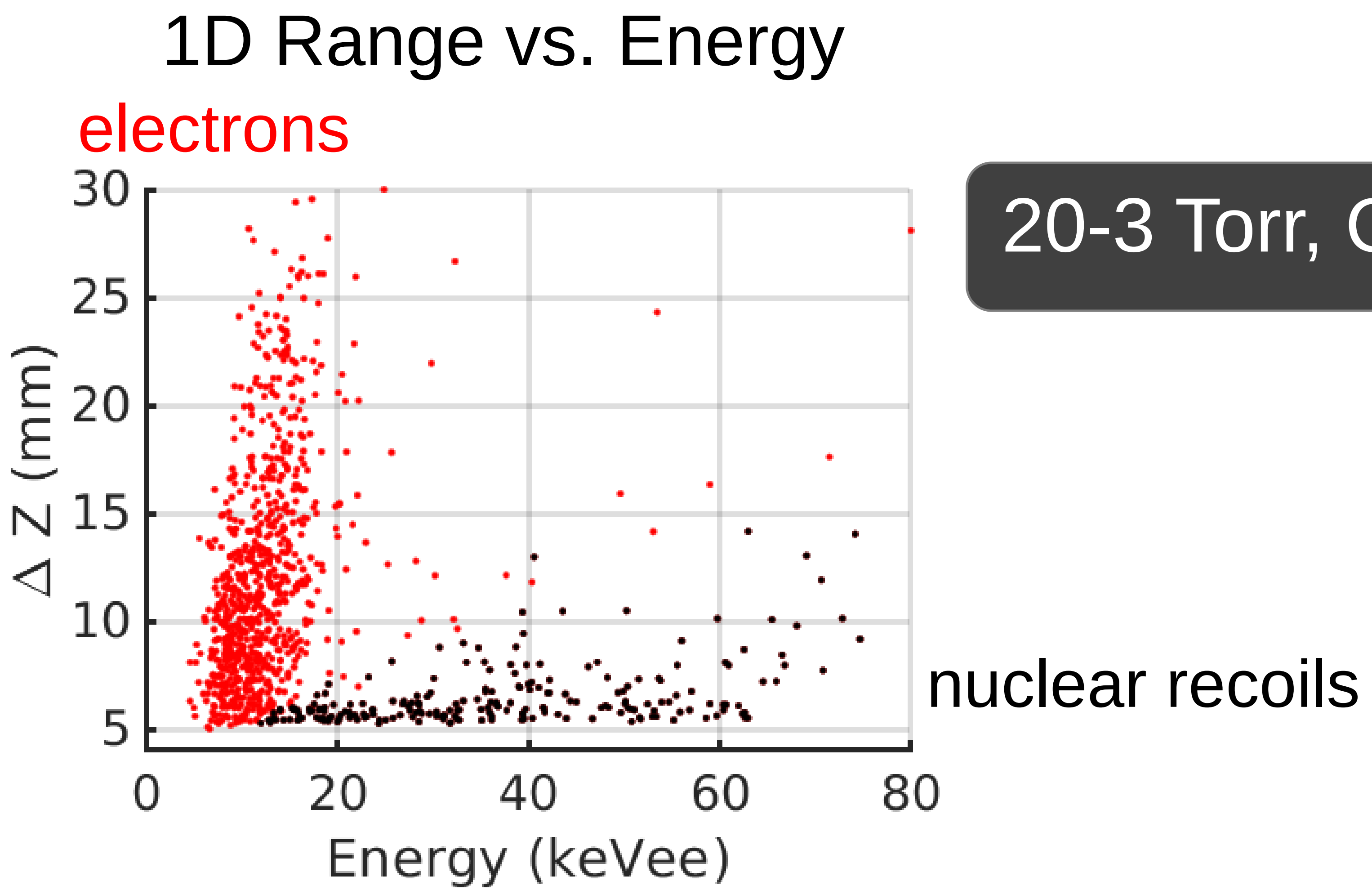
Diffusion vs. Drift Field (E)

slide by D. Loomba



Z = 58 cm

PDS with 1D detector



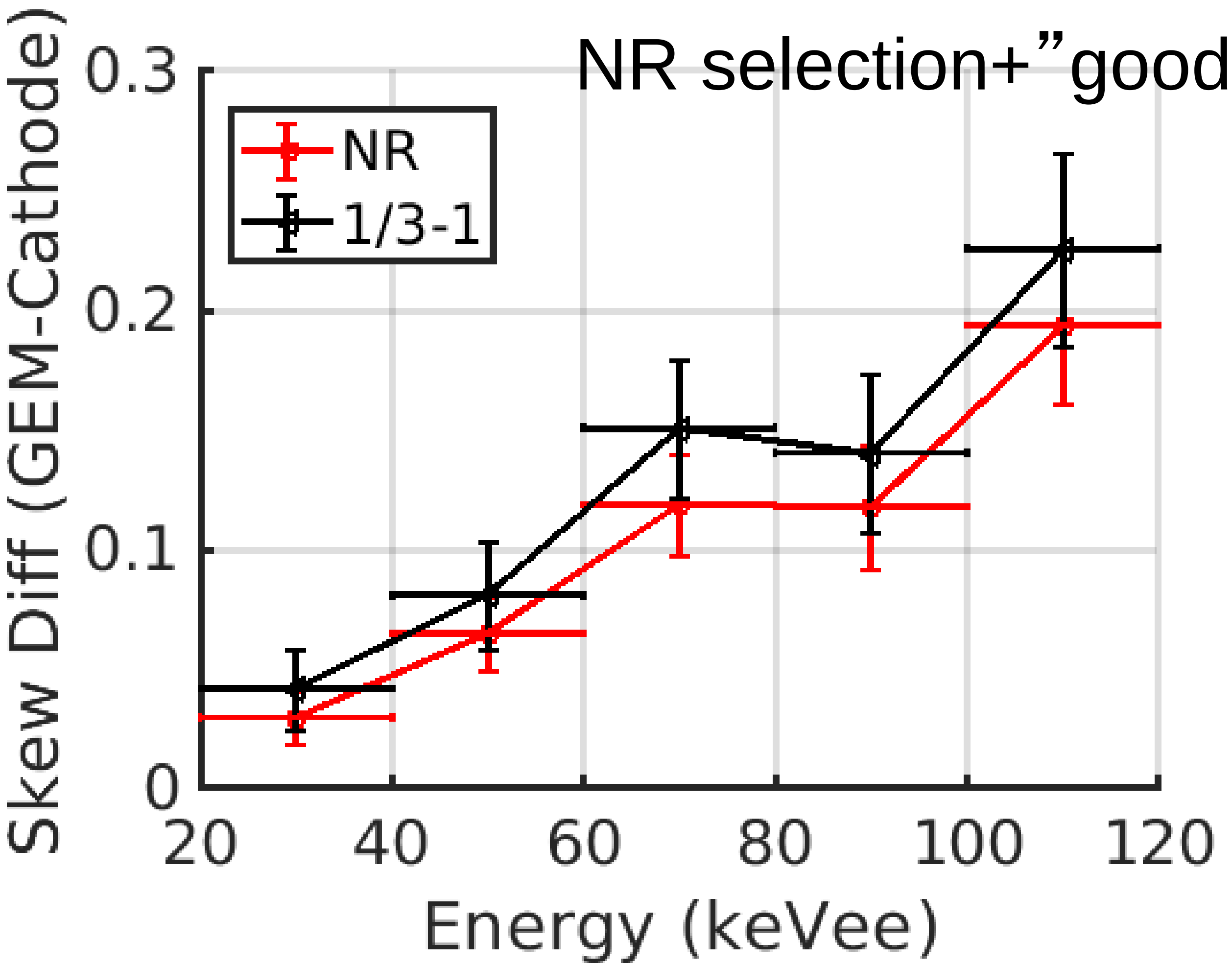
20-3 Torr, CF_4-SF_6

slide by D. Loomba

Head/tail discrimination with 1D detector

NR selection

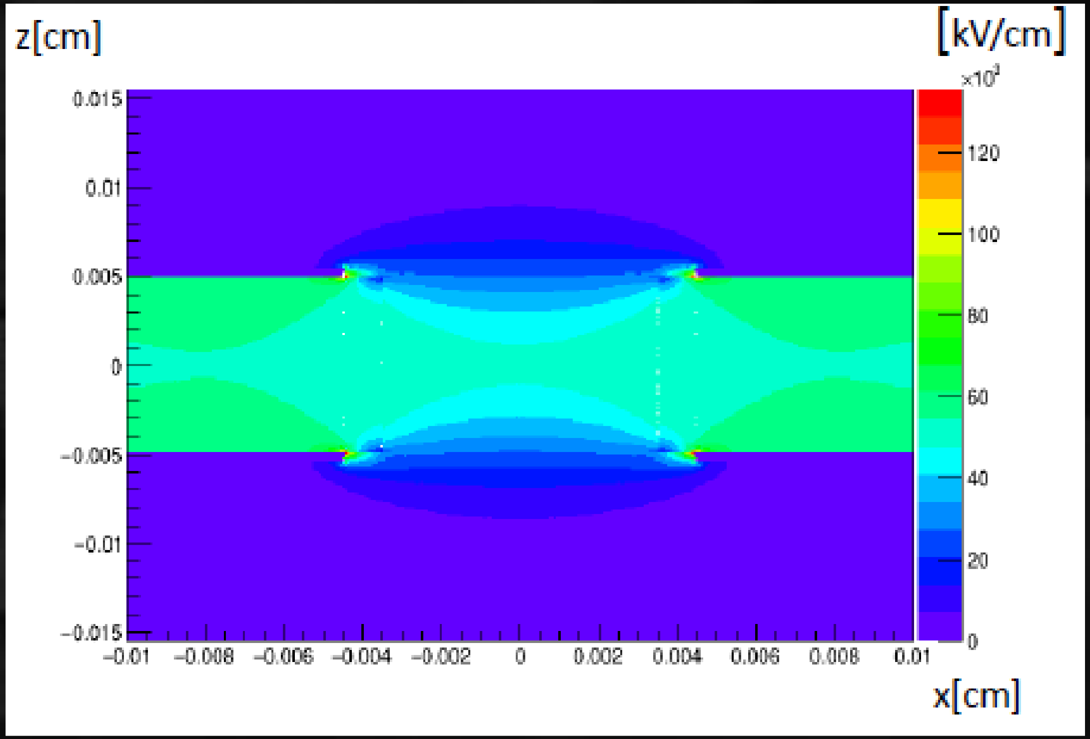
NR selection+"good track selection"

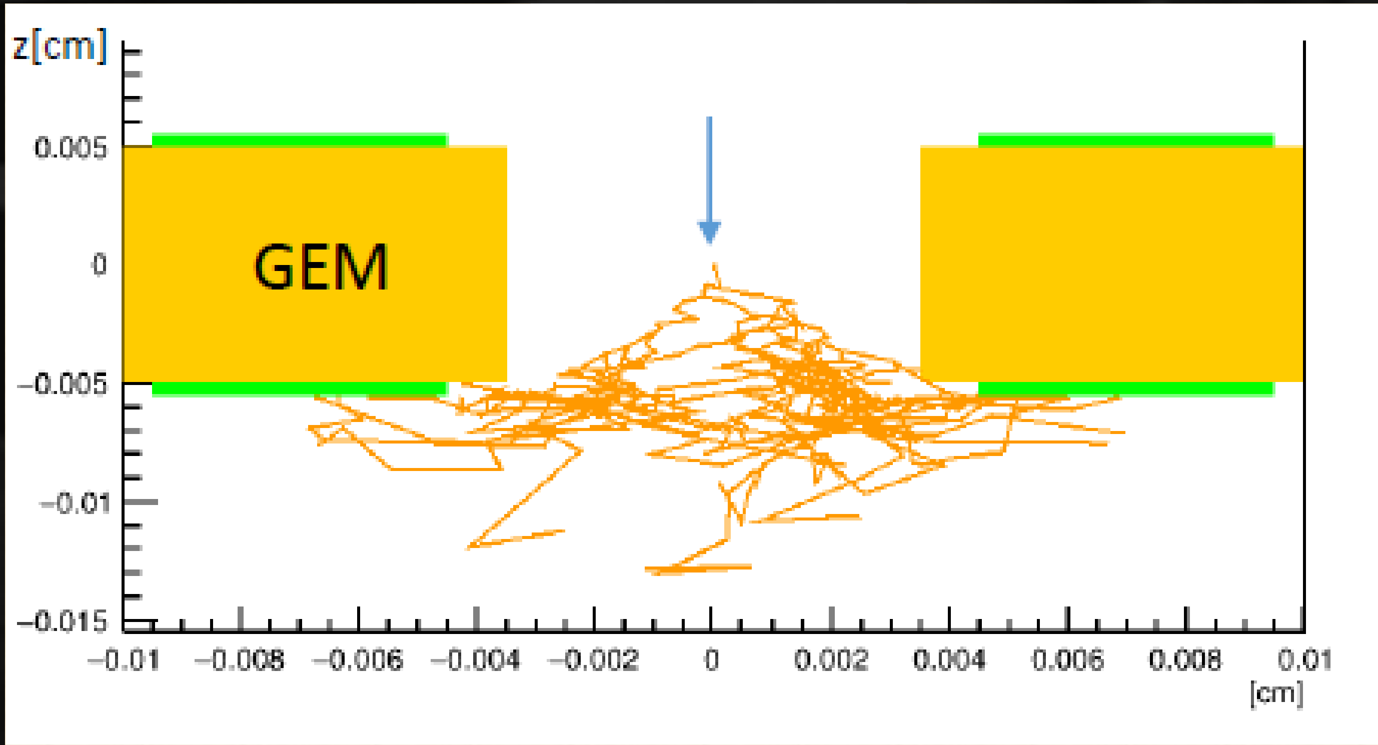


Garfield++ for negative ion

H. Ishiura @MPGD 2019
proceeding in preparation

- First study: to reproduce 100μm GEM gain results
- Most of the process are already in Garfield++
- Detachment process needs to be implemented
- Two detachment models were made





less recombination

Detachment model ① : "cross section model"

H. Ishiura @MPGD 2019
proceeding in preparation

- based on "first principle"
- indirect detachment cross section
  ⇒ calculate detachment probability

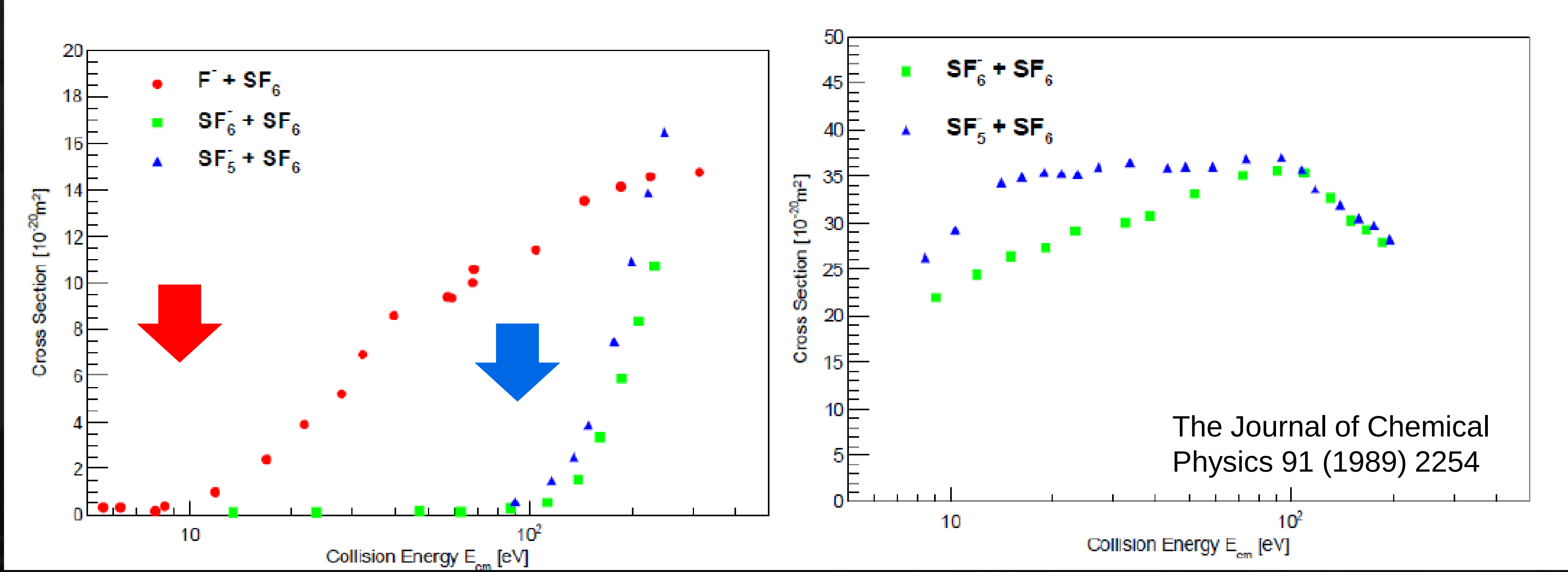
direct detachment

$$SF_6^- + SF_6 \rightarrow e^- + SF_6 + SF_6 \quad (1)$$
$$SF_5^- + SF_6 \rightarrow e^- + SF_5 + SF_6 \quad (2)$$

indirect detachment

$$SF_6^- + SF_6 \rightarrow F^- + SF_5 + SF_6 \quad (3)$$

$$SF_5^- + SF_6 \rightarrow F^- + SF_4 + SF_6 \quad (4)$$
$$F^- + SF_6 \rightarrow e^- + F + SF_6 \quad (5)$$

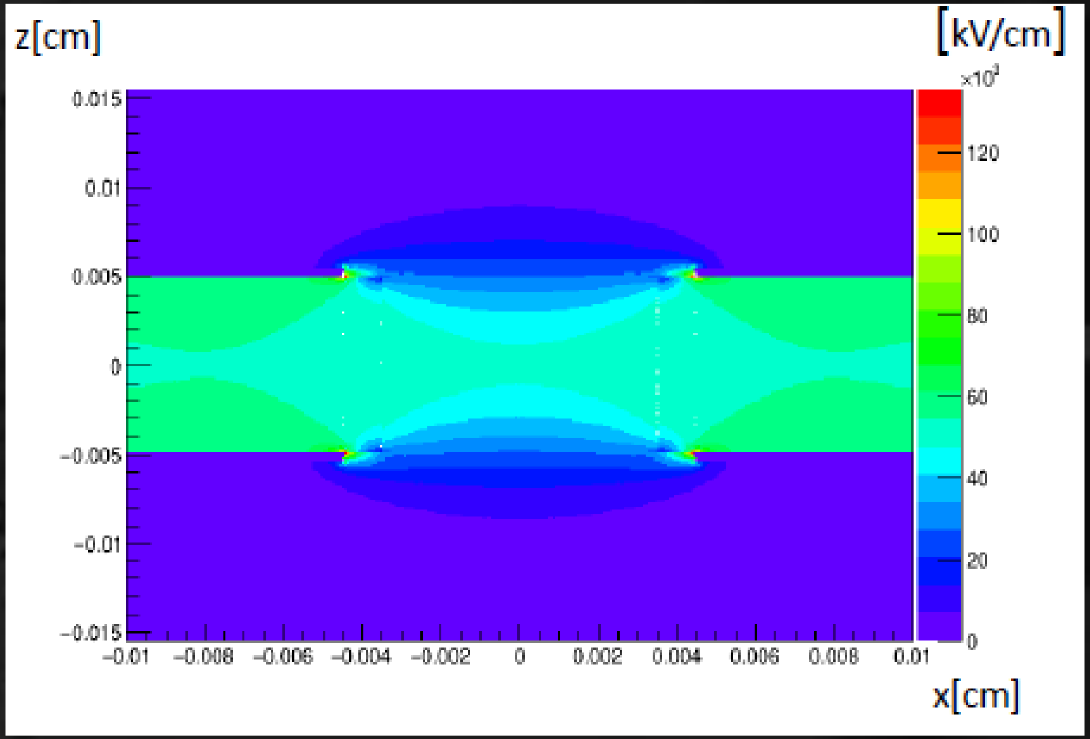


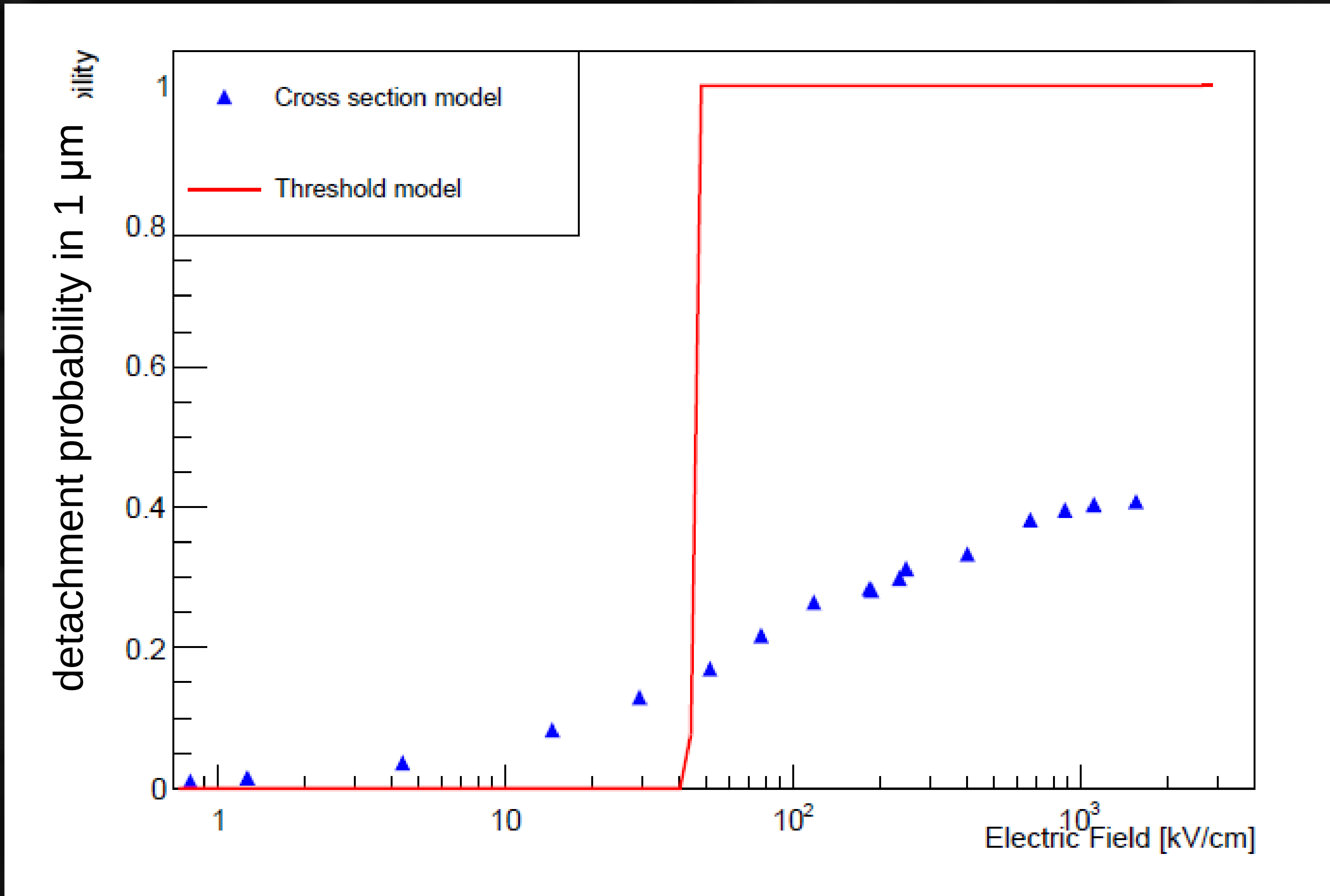
The Journal of Chemical Physics 91 (1989) 2254

Detachment model ②: threshold model

H. Ishiura @MPGD 2019
proceeding in preparation

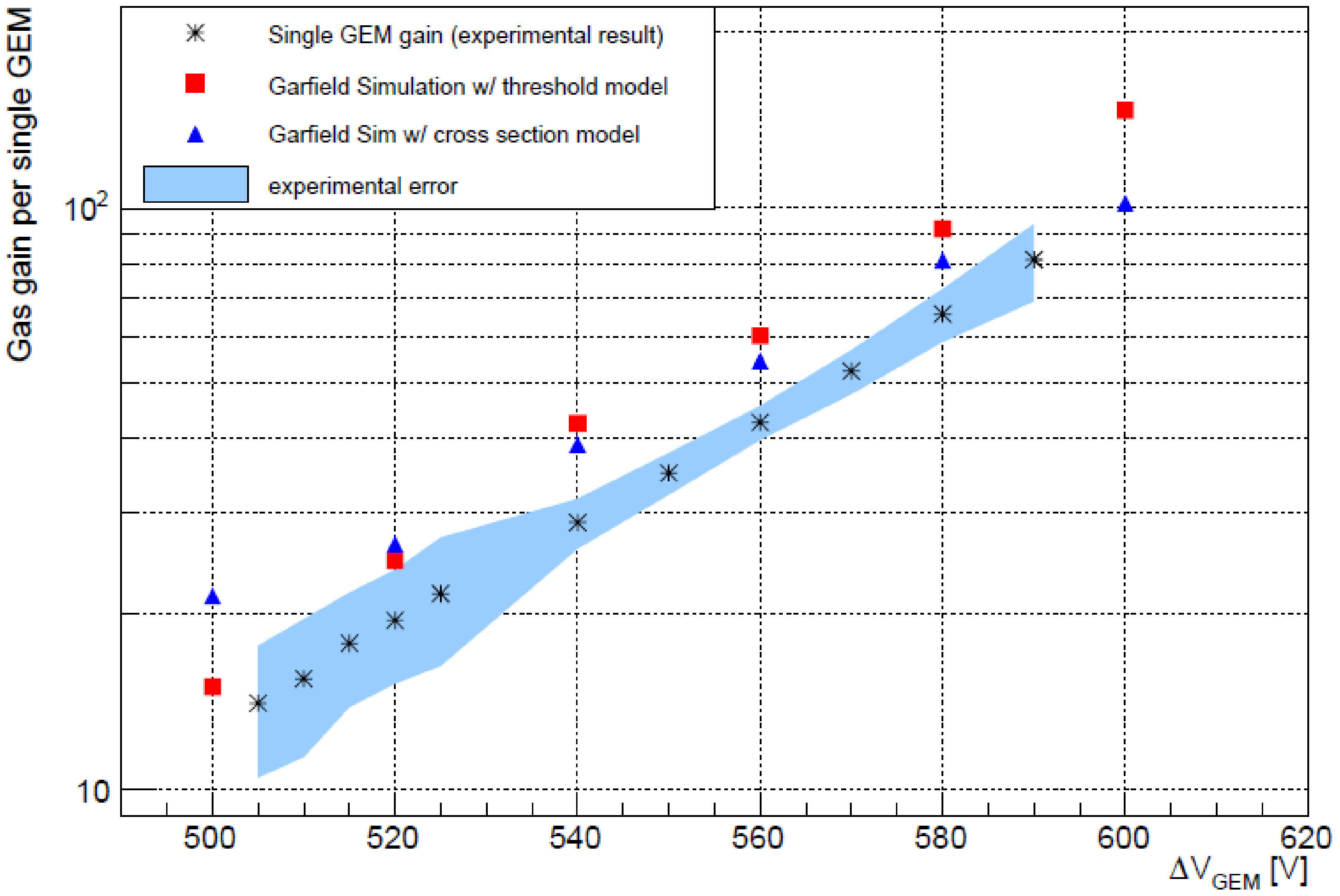
- phenomenological model based on measument
- avalanche starts ~ 50kV/cm





Garfield++ results

H. Ishiura @MPGD 2019
proceeding in preparation



- **gain curve reproduced (without any CORRECTION !)**
- **tuning and application for other MPGDs**

To Do: performance below 10keV

- electron rejection
- fiducialization
- angular resolution

Summary: SF6 Overview (as of 2019-07)

	New Mexico	Italy	Hawai	Kobe	Welleseley	Sheffield
Gain Device	A:1mm GEM B: 400um GEM (CERN)	3x 50um GEM (Kapton, CERN)	Thick GEM	A: u-PIC(DNP) + 100um GEM(LCP, Scienergy) B: 2 x 100um GEM	A 128 um MM B 256 um MM C 512 um MM (CERN)	1mm GEM GEM + wire
Readout	Single ORTEC amp optical	Optical Timepix	Single amp	A: 16+16 strips amp B: Single CREMAT amp	Single ORTEC amp	16ch discrete
Drift , max E	60cm 1kV/cm	5cm 0.6kV/cm		10cm 0.4kV/cm		0.7kV/cm
Pressure(Torr)	20-100	610(mixture) 200-370	20,40	20-152	30-50	30, 40, 50,(100)
Max gain	3000	2200	3000	A: 2000 @ 20torr B: 7000 @ 100torr	500 4000 (SF6+CF4)	1500 @30,40torr
55Fe Eres(σ)	25%	Landau	20%	A: 50% B: 25%	~40%	
Minority peaks	SF5-, SF4-	Hint		SF5-		
Fiducialization	σz=7.3mm			σz=7cm		
tracking				3D with filtersutial, σxy=130um	alpha	alpha
Gamma rejection	down to 15keVee by1D					
others	Water contamination SF6/CF4 mixture	electron drift		Garfield++ work		
Ref	JINST12(2017)P02012 R. Lafler PhD thesis 2019	IDM 2016 JINST13(2018)P04022 1905.04066	T. Thrope PhD 2018	EPJ Web of Conferences 174, 02006 (2018) 2019 J. Inst. 14 T01008	2019 J. Inst. 14 T01008	