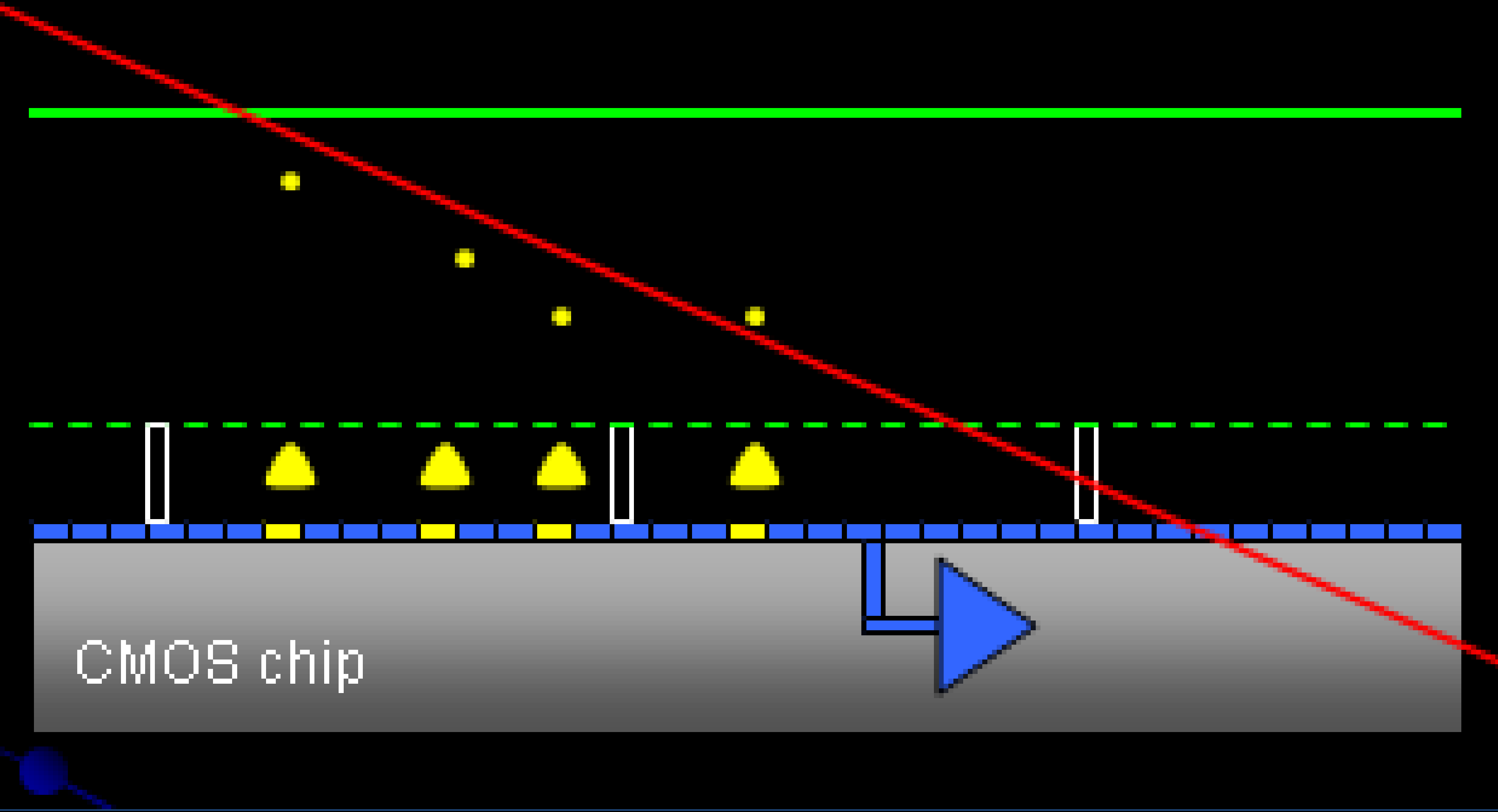


Status of GridPix Developments

Harry van der Graaf (Nikhef, Amsterdam)
6th RD51 Collaboration Meeting
Bari, Oct 7, 2010

NEW

- approval GridPix/Gossip as ATLAS Upgrade R & D project;

- MEMS Technology
  - 18 pcs GridPix made in 2 weeks @ MESA+
  - Univ. Bonn & IZM-Fraunhofer Berlin

- Testbeam Aug 2010 @RD-51 site, CERN
  - discharge proof
  - confirm simulations
  - New Gas system
  - ReLaXd readout system operational

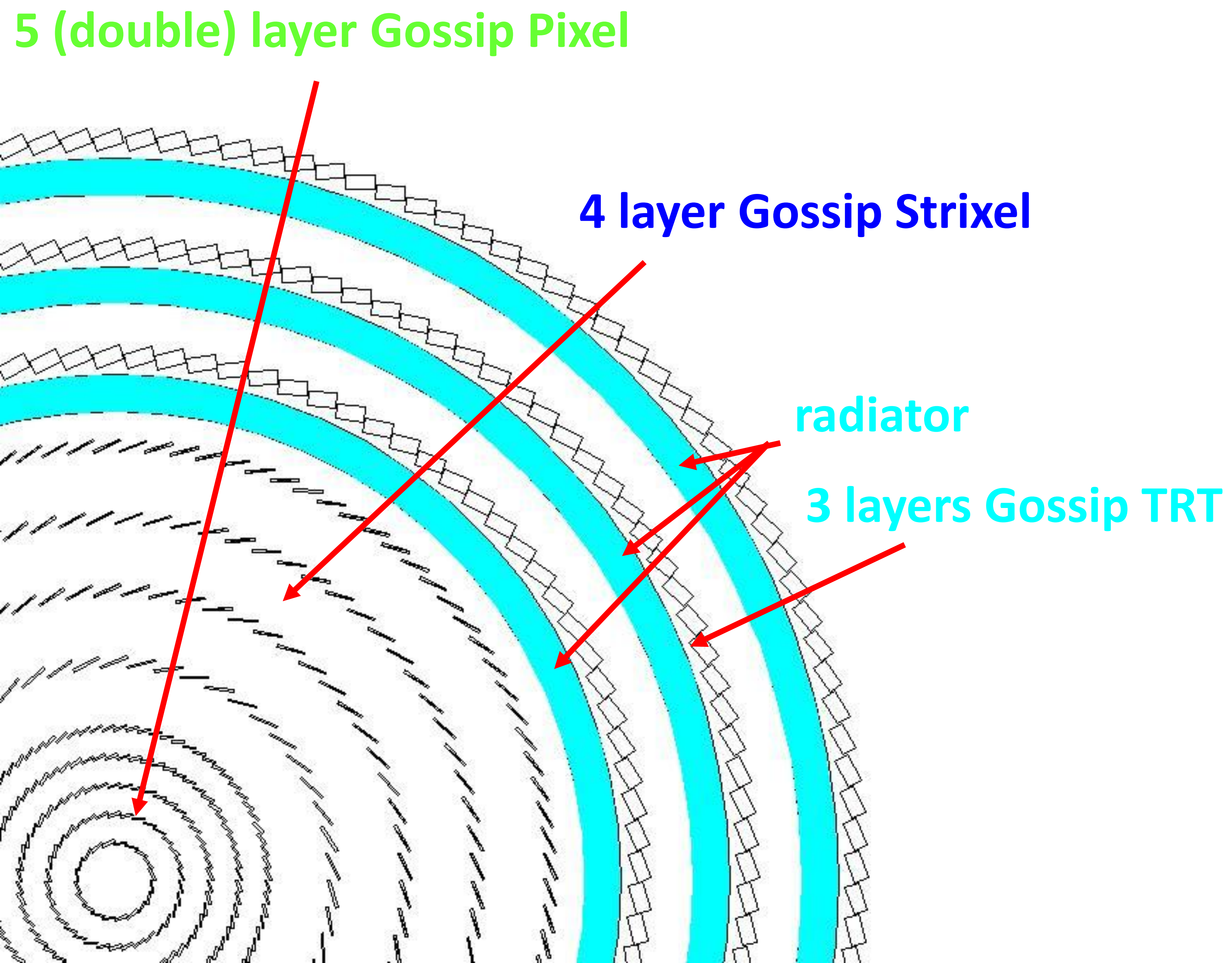
- Saclay/Freiburg: Avalanche statistics and single electron counting with a Timepix-InGrid detector

- Applications:
  - XENON/DARWIN WIMP-search experiments
  - Polarized photon detection PolaPix
  - CAST
  - NA61
  - LHeC

- mini-HV

ATLAS:

“The baseline ATLAS inner tracker upgrade is an all- silicon detector. New technologies such as GridPix and the Gossip version of it could become an alternative sensor technology to pursue for part of the detector. They would only be adopted in case of major performance or cost advantages over silicon technology, or if technical issues are found in the silicon projects in the next 2--3 years. The EB has considered the Gossip R&D proposal, and supports this R&D for a limited duration of 3 years to demonstrate and quantify performance, cost and reliability. In 2013, ATLAS will review the results and consider if there are sufficient elements for further pursuance of this technology for ATLAS”



5 (double) layer Gossip Pixel
4 layer Gossip Strixel
radiator
3 layers Gossip TRT

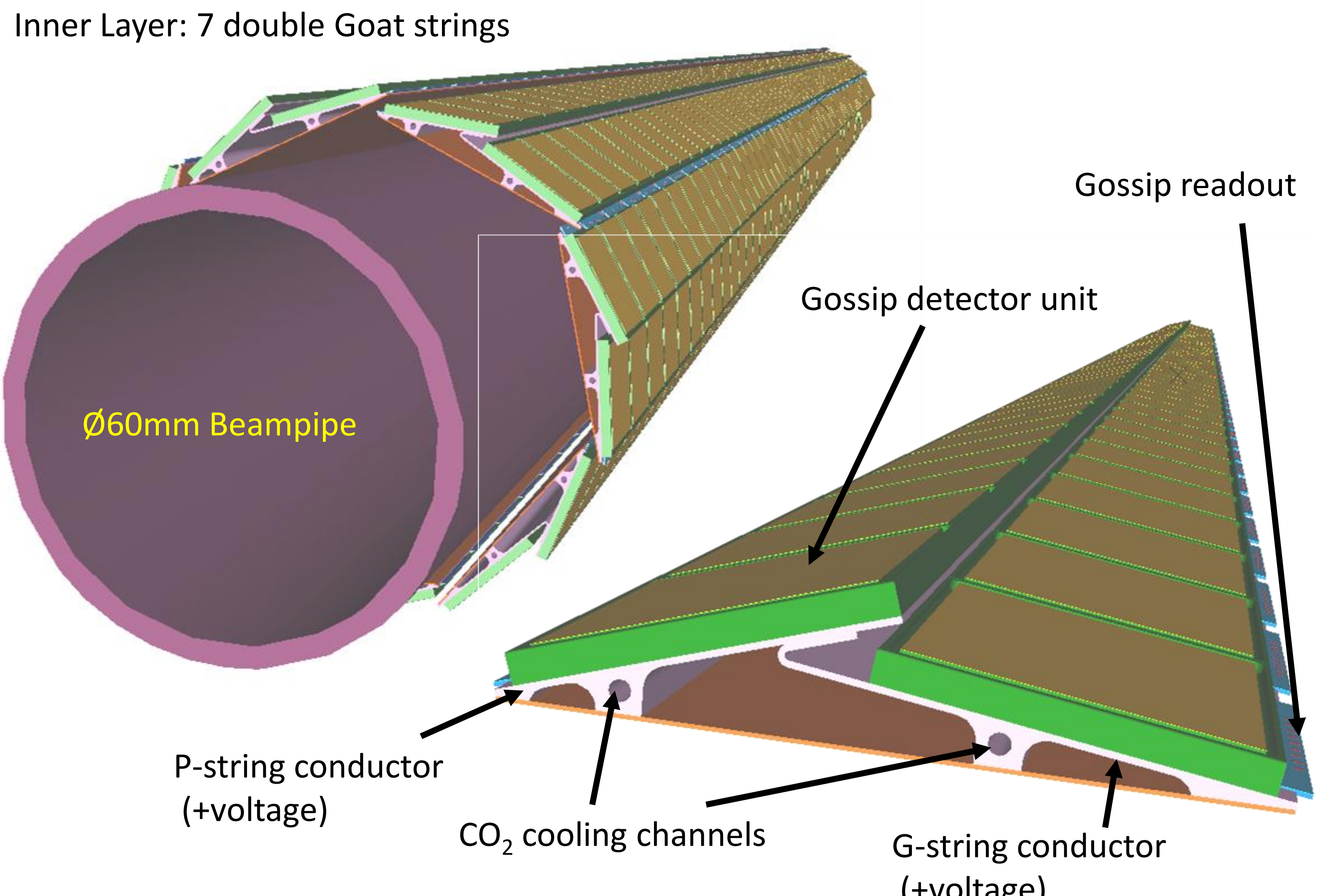
ATLAS: FE-I4 (vertex pixel) chip from foundry:
make proto vertex detector of it.

Alternative for TimePix:

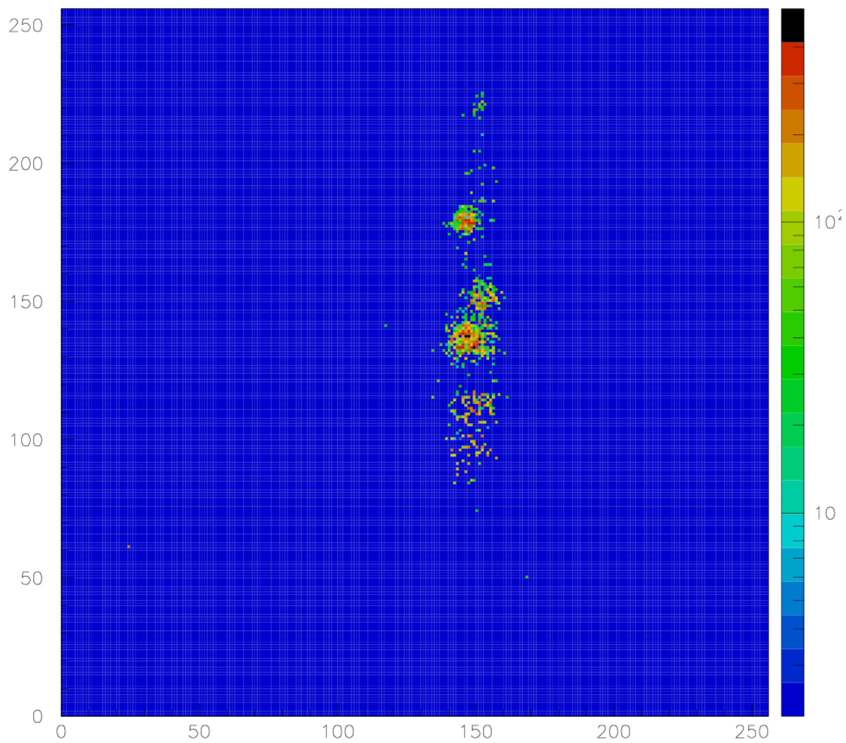
Gossip made with FE-I4 pixel chip:

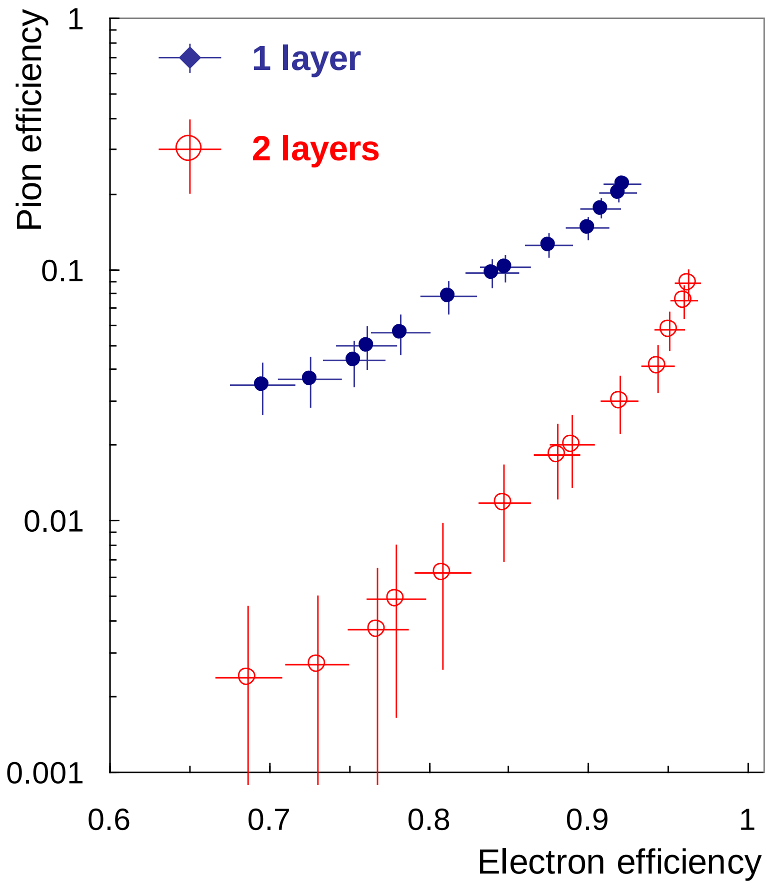
rate effect studies (in testbeam)

GOAT: GOssip in ATlas



Test beam results: Particle Identification





Two method were used

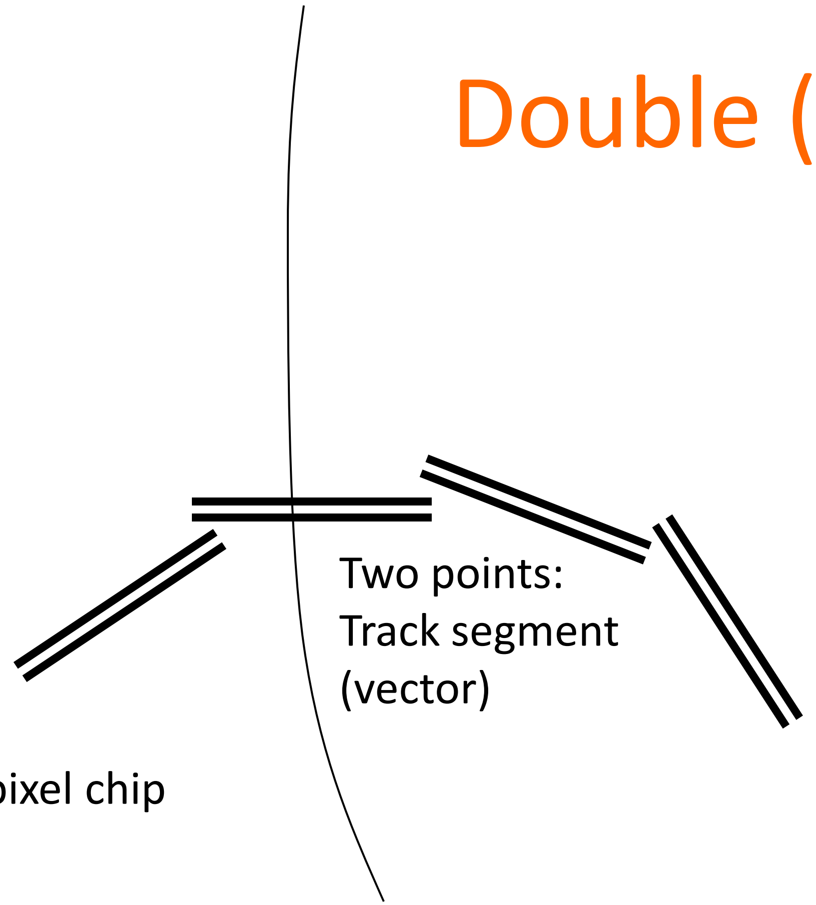
1. Total energy deposition
2. Cluster counting technique

Pion registration efficiency as a function of electron efficiency for 1 and 2 layers of the detector. Cluster counting method.

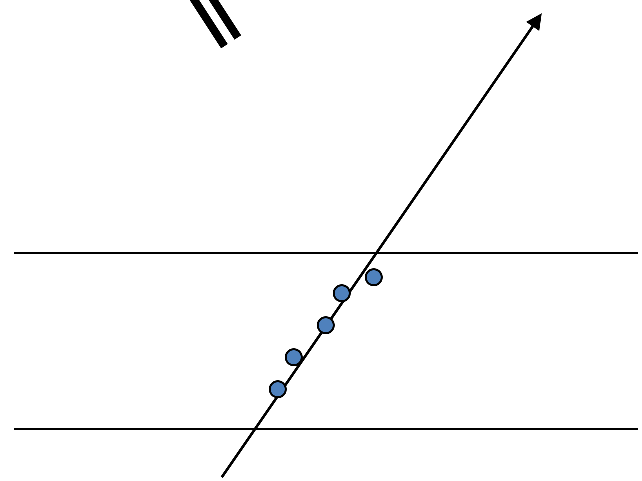
TRD with two detector layers (total thickness ~ 40 cm) allows to achieve rejection factor of **~ 50** for 90% electron efficiency.

Anatoli Romaniouk

Double (Si) layers



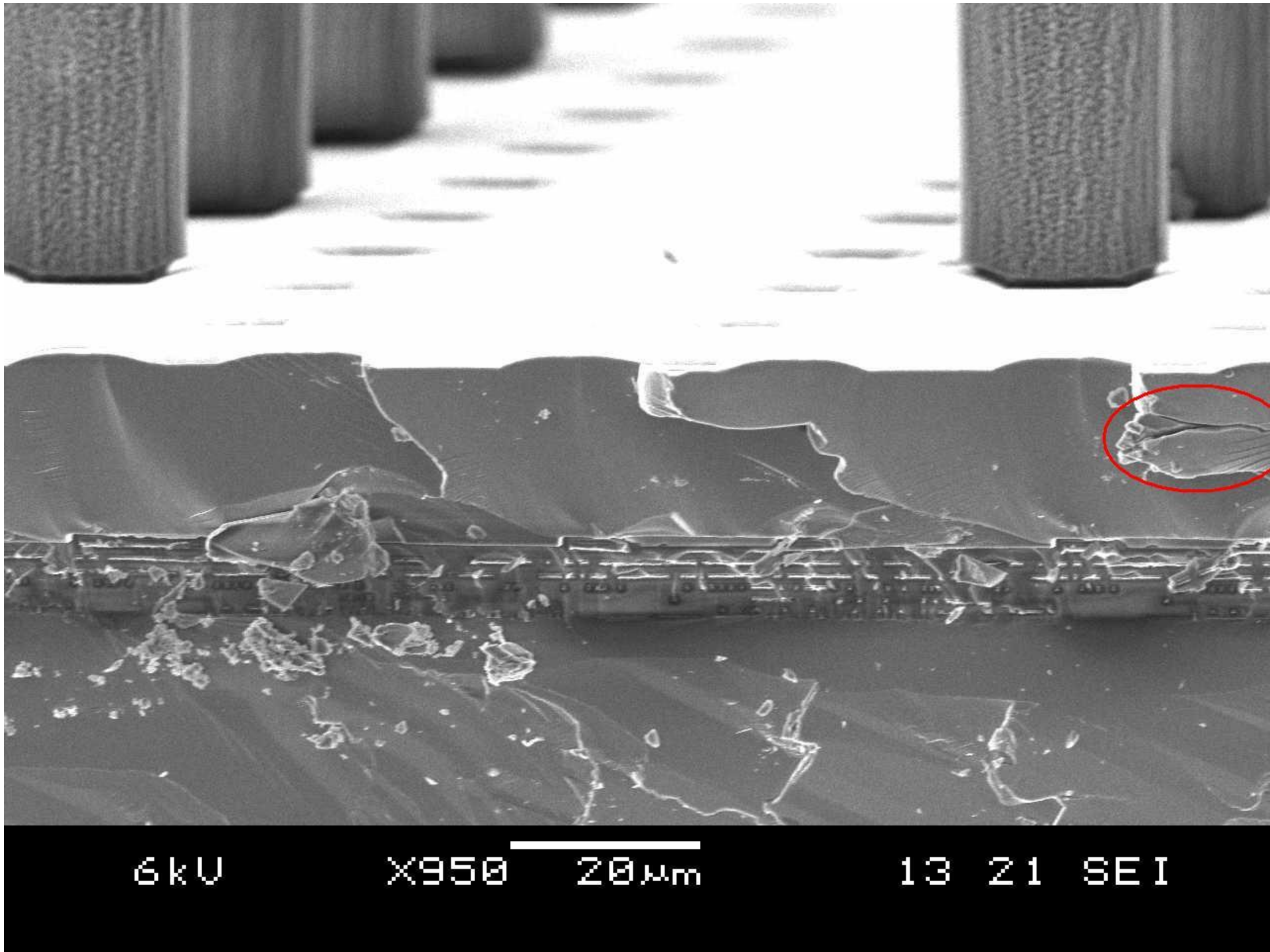
Requires inter-pixel chip communication

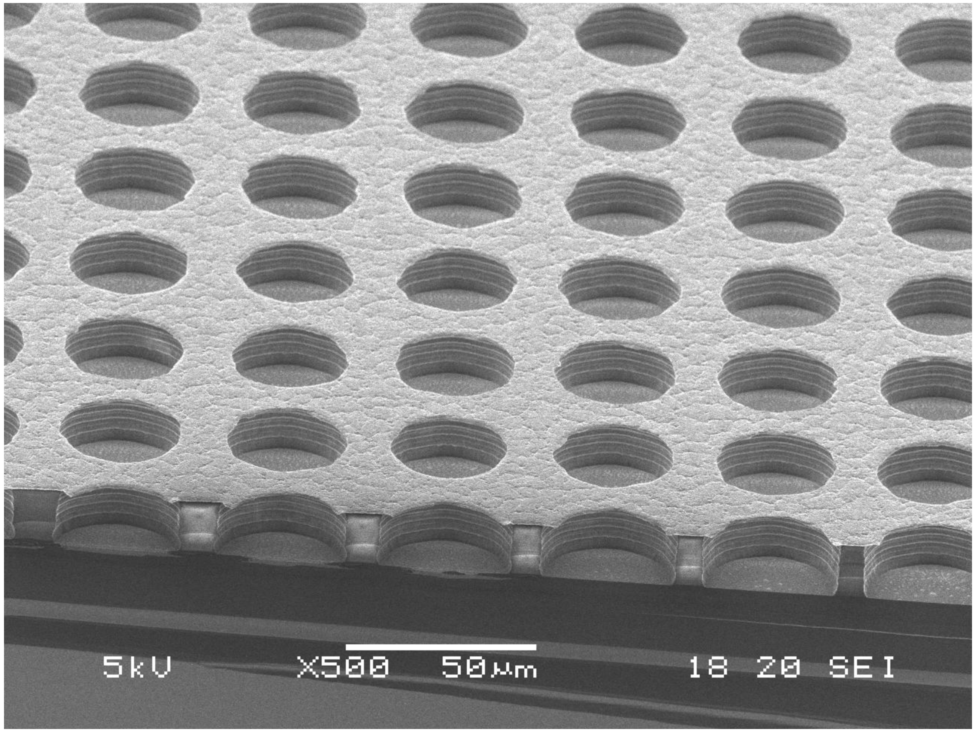


Gossip measures track segment in single layer

MEMS Technology

- May 2010: 18 pcs GridPix (= TimePix + SiNProt + InGrid) made
    - quite good sparkproof!
- weak spots in protection layer found: future: all ceramic InGrid

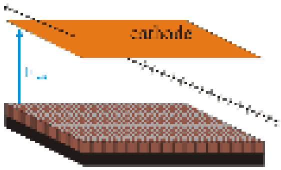




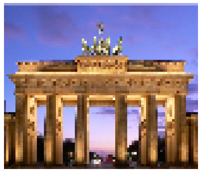
First GEMGrid with SiO_2 as insulating spacer between grid and substrate
Victor Blanco Carballo, MESA+/Nikhef

- Technology transfer to SMC, Edinburgh: failure
- Technology transfer to IZM-Berlin: first working GEMGrids

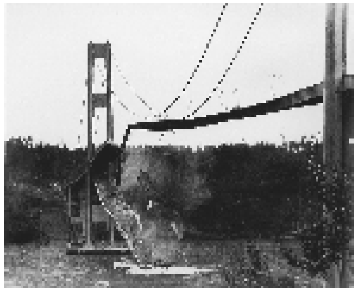
Goal: to make robust, lasting InGrids on 8” wafers, for a low price

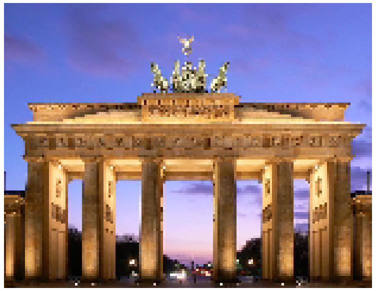


New Wafer-level Process

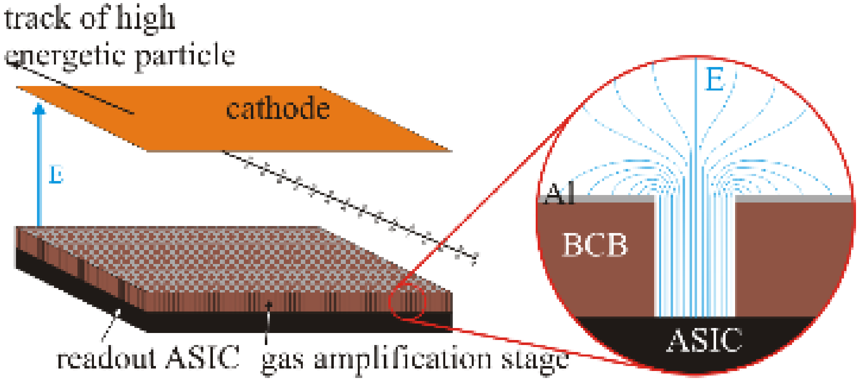


Small number of InGrids produced at Twente satisfy neither the demand of R&D nor for any large experiments.
=> Need to transfer process to wafer-level production
Problem: very delicate structure → need more mechanical stability

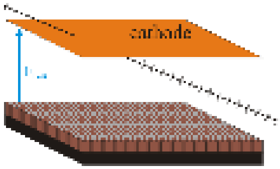




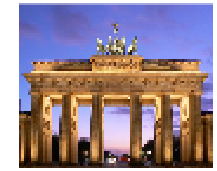
At GEMGrid the grid rests on a solid insulating layer with holes.



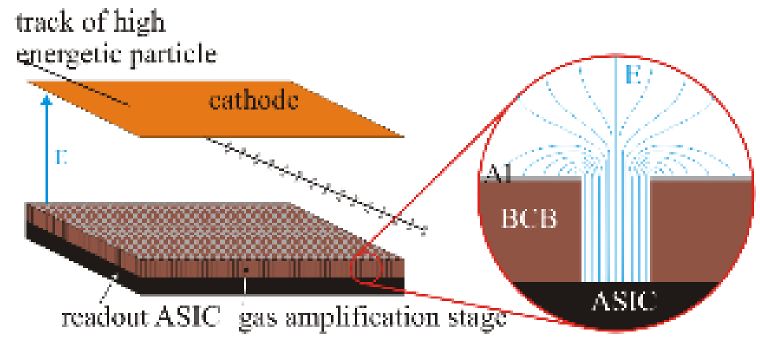
V. Blanco Carballo, et al., Nucl. Instrum. Meth. A 608 (2009) 86

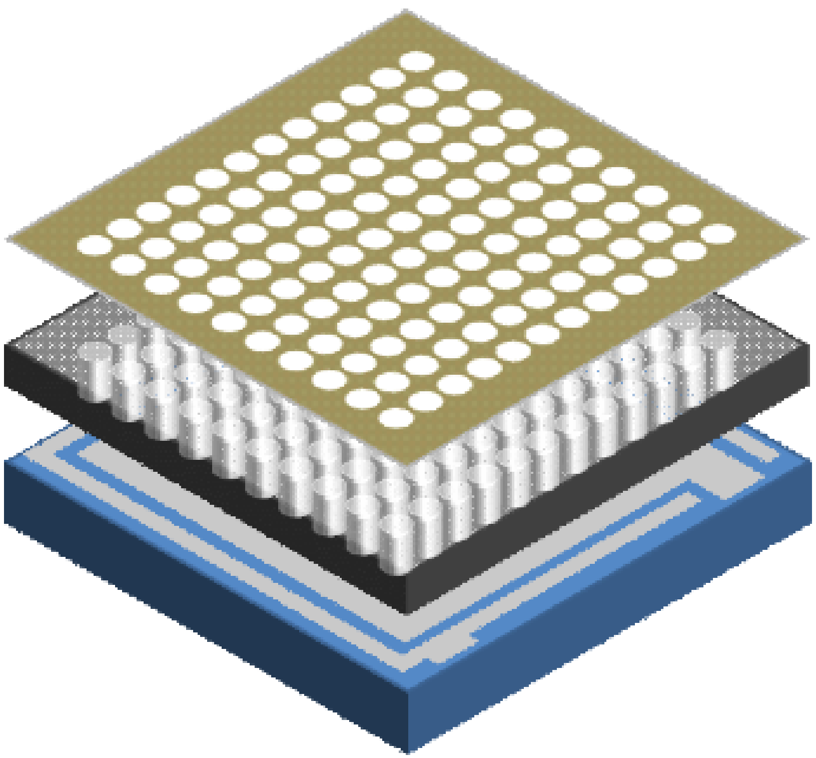


Wafer Level Design of GEMGrid Test Chip (I)



Setup of GEMGrid Test Chip





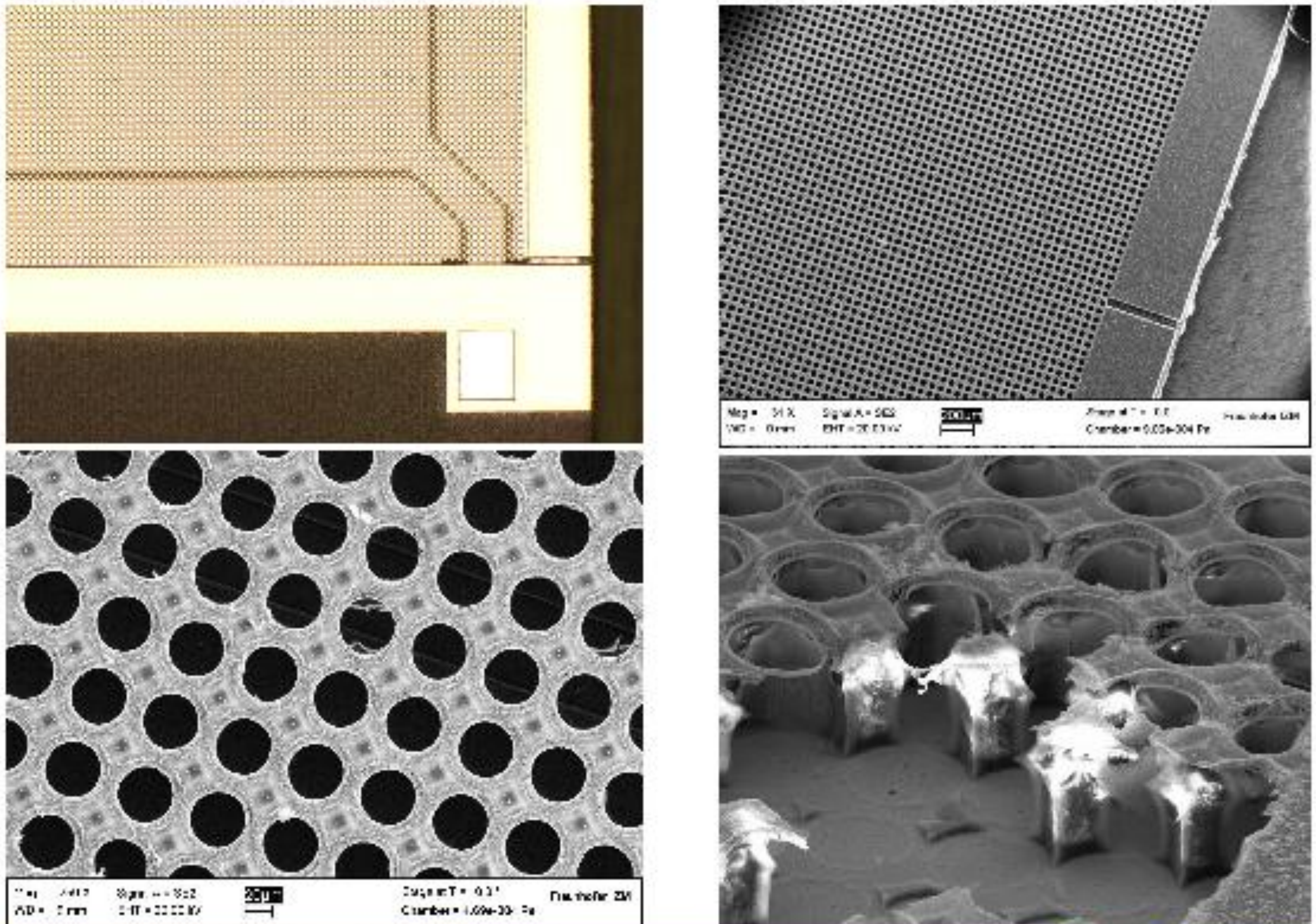
Perforated top electrode – Aluminum

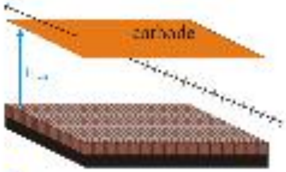
Meshed dielectric layer – BCB

Siliconwafer with bottom electrode
- Aluminum

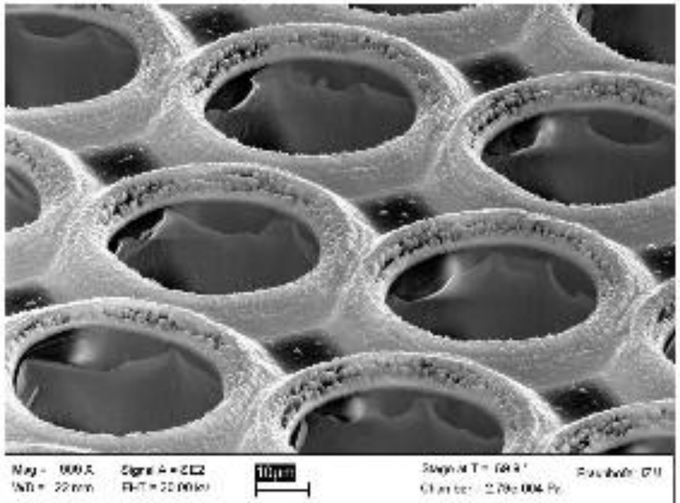
Processing of GEMGrid Test Chip (II)

GEMGrid Test Chip after BCB Dry Etch



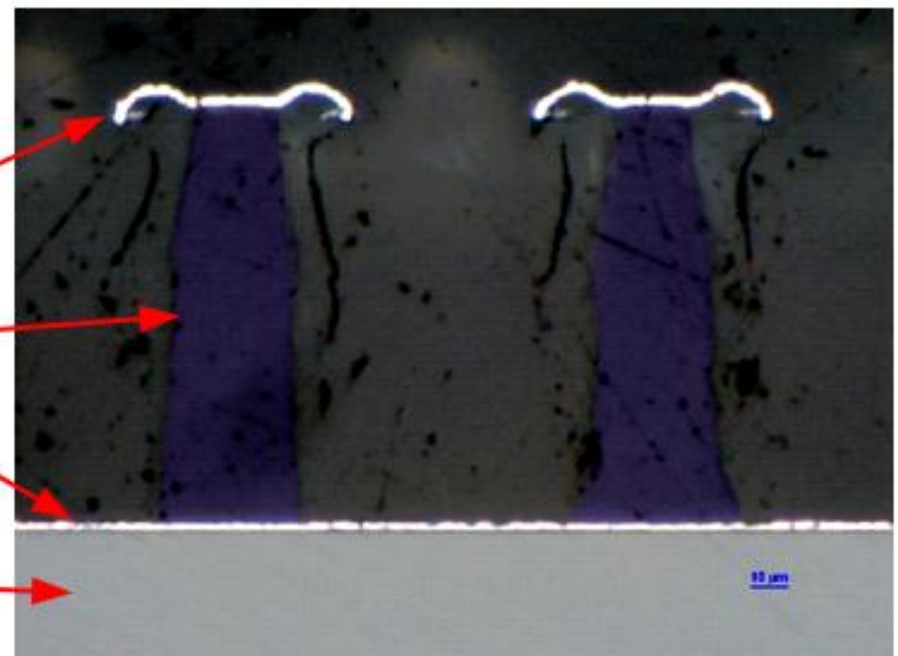


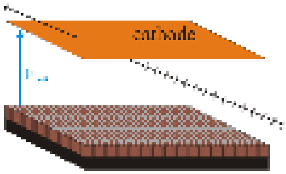
Processing of GEMGrid Test Chip (III)



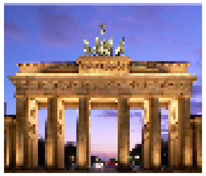
Cross section of GEMGrid test chip embedded in a transparent Epoxy

BCB pillars blue coloured



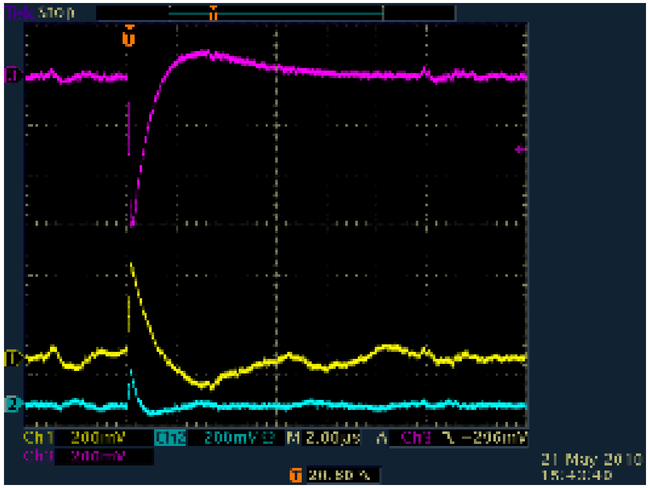


First Signals

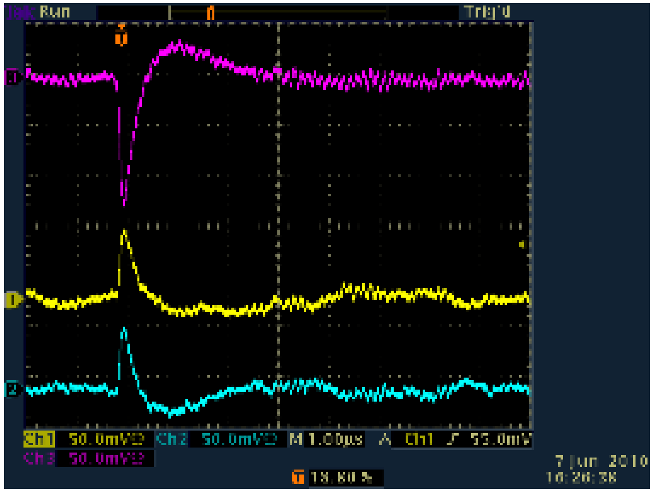


- The detector was flushed with various gas mixtures.
- High voltage was applied to the grid. → low leakage current.
- All 3 signals (pad, ring, decouple from grid) were fed into a slow preamplifier (rise time 180 ns) and visualized with an oscilloscope.
- Occasional signals in agreement with cosmic rays were observed
- Rate was strongly increased by radioactive sources.

signals of ^{90}Sr in Ar:iButan 95:5



signals of ^{55}Fe in He:iButan 95:5



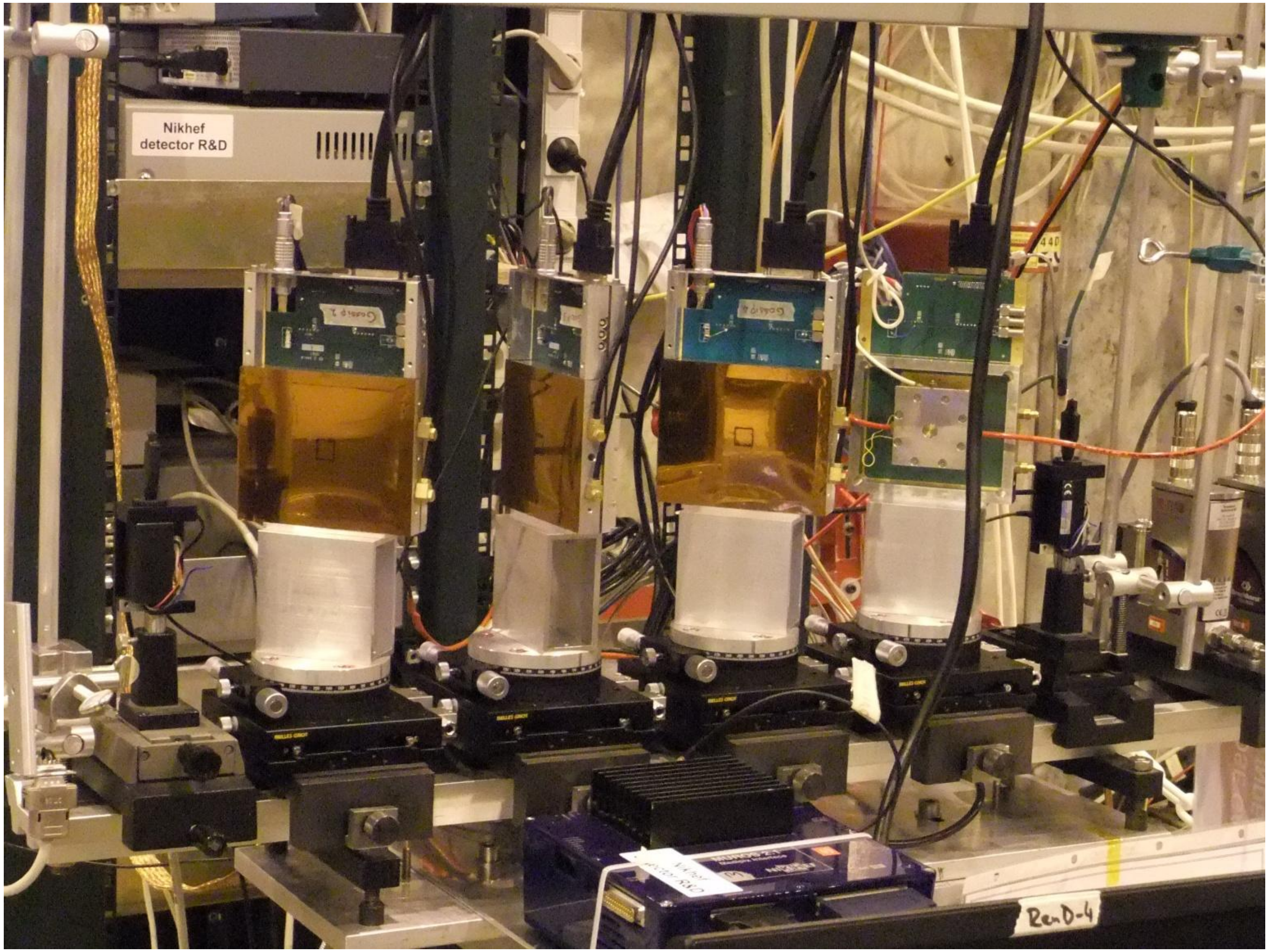
signal of grid

signal of pad

signal of ring

Gossip testbeam August 12 – 22 , 2010

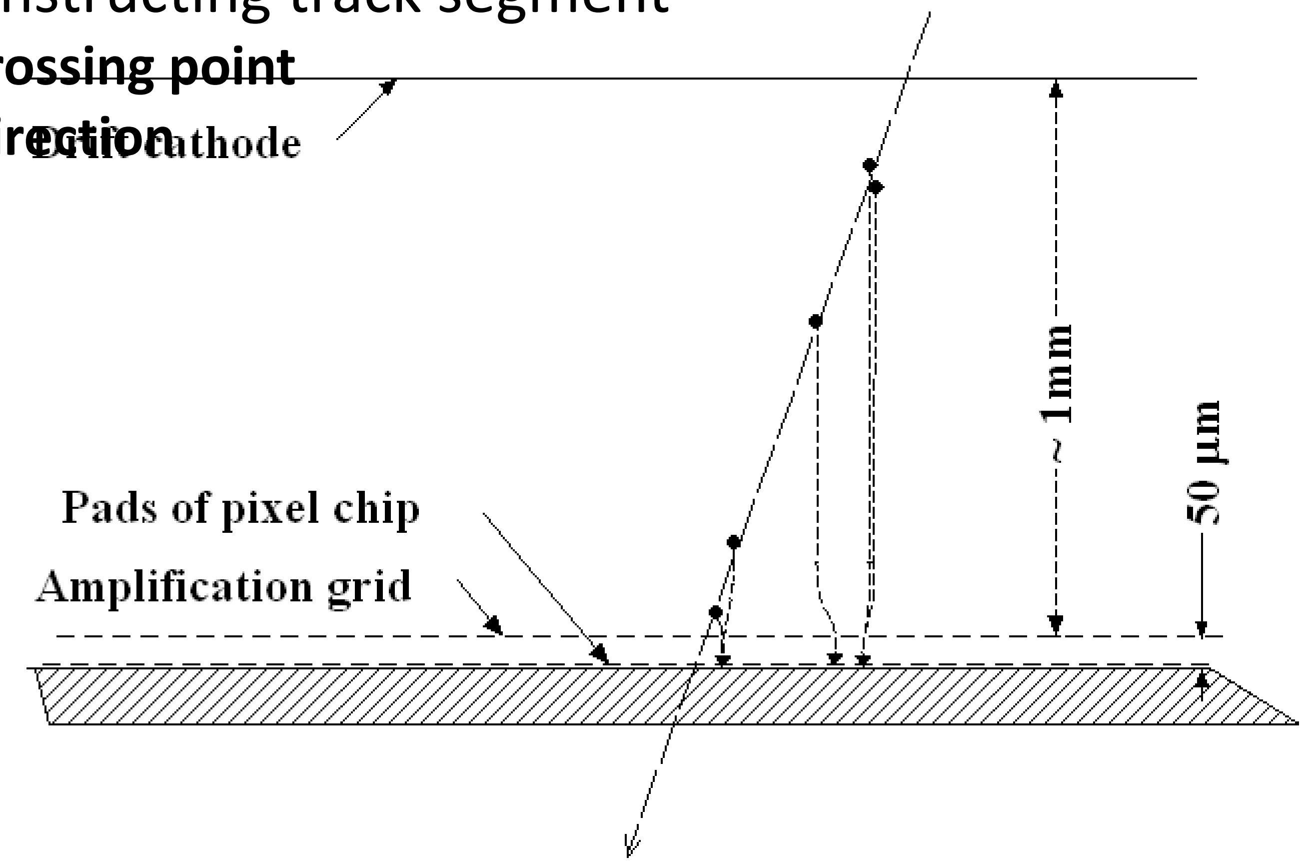
Maarten van Dijk
Martin Fransen
Harry van der Graaf
Fred Hartjes
Wilco Koppert
Sjoerd Nauta
Rolf Schön



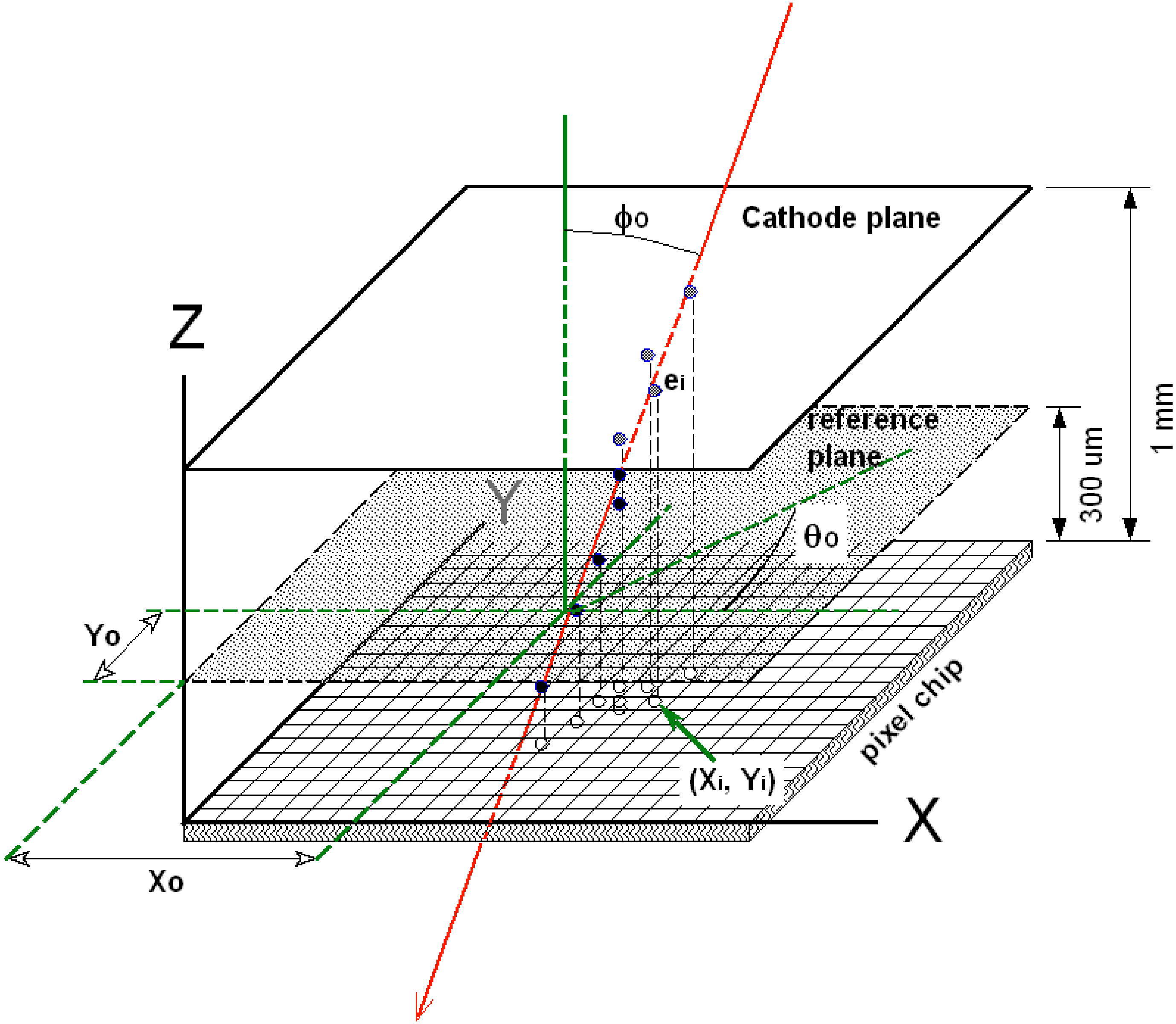
Testbeam Aug 2010, RD51/H4, SPS, CERN

Gossip functioning

- Pixel chip with integrated Micromegas (InGrid)
- Drift gap height 1 mm
  - Getting > 95% track detection efficiency
- Often detecting individual electrons
- Reconstructing track segment
  - **Crossing point**
  - **Direction**



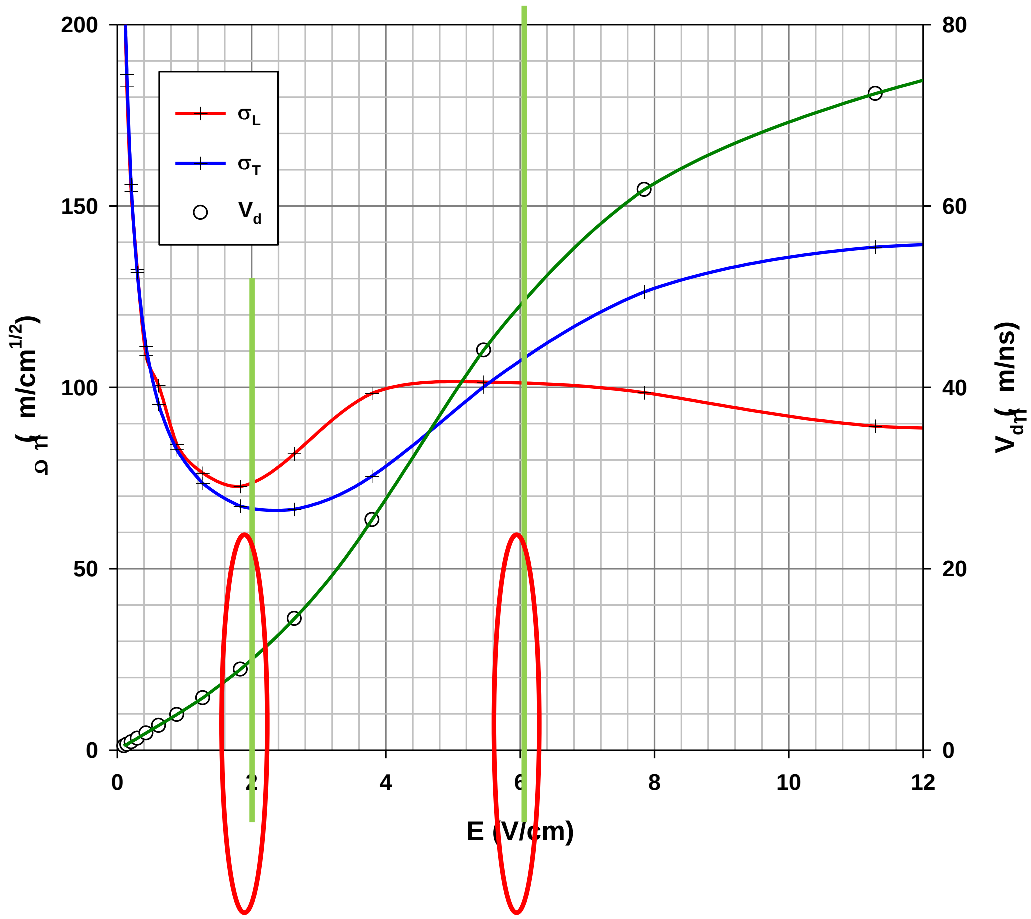
Reconstructing track segment



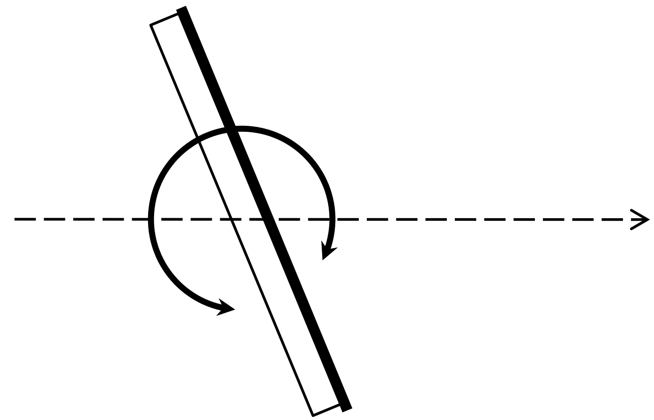
Chamber gas: DME/CO_2 50/50

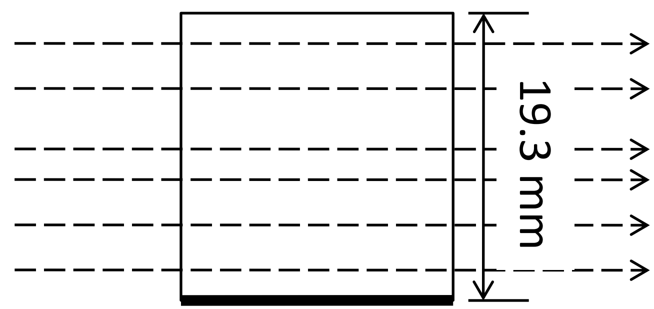
Calculated diffusion (σ) and drift velocity (V_d)of DME/CO_2 50/50 vs electrical field (E)

- DME/CO_2 50/50
  - Very slow and “cool” gas
  - High drift field required
  - Very low diffusion
- Drift fields used in Gossips
  - **2 kV/cm** (lowest diffusion)
  - **6 kV/cm** (Vd = 50 µm/ns)



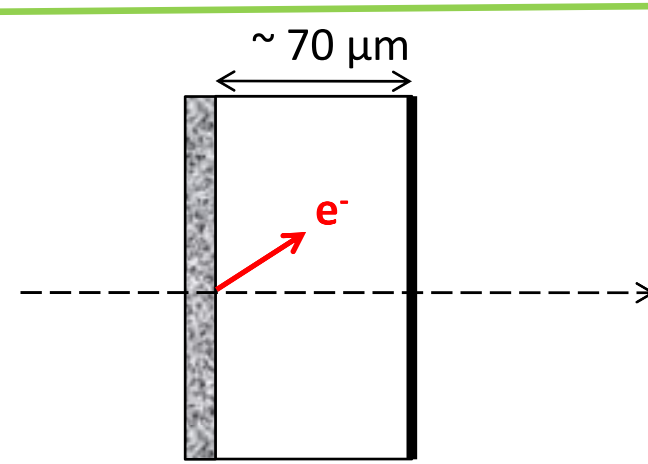
1. **Gossip parameters**
   - Position resolution
   - Angular resolution of track segment
   - Track detection efficiency
   - Dependence on gas gain
   - Double track separation





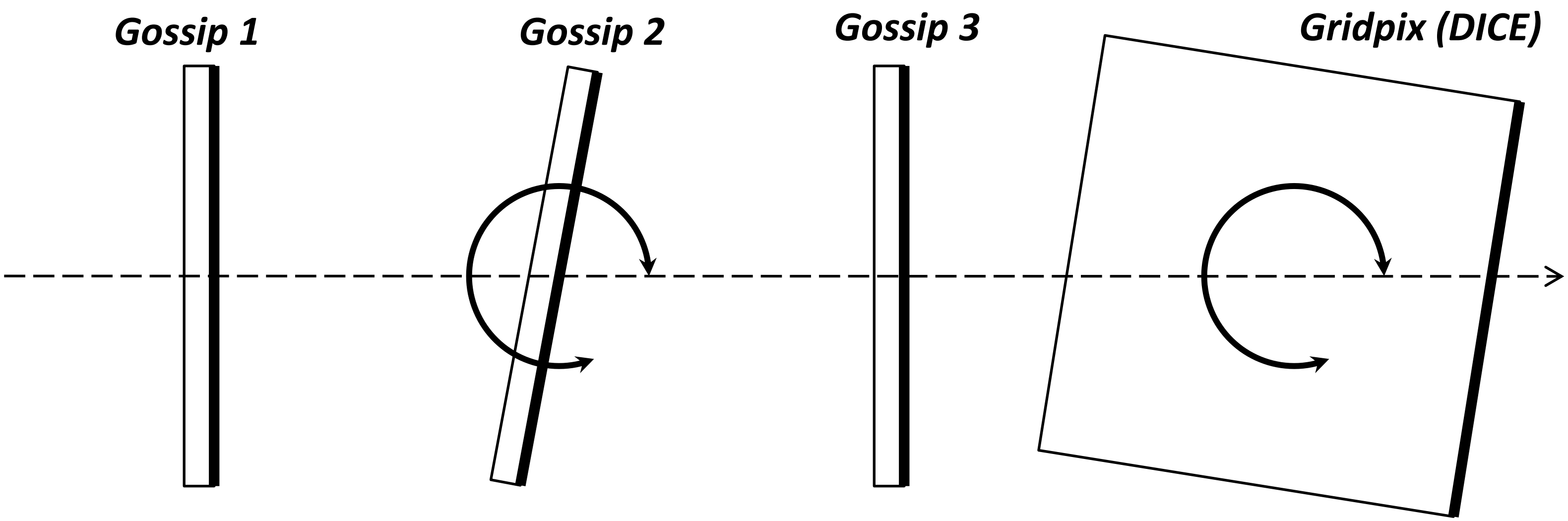
2. **Characterisation** of DME/CO2 50/50 mixture
   - Primary ionisation/cluster density
   - Drift velocity
   - Transverse diffusion

3. **Knock off emission** from cathode
   - **PillarPix** detector, NO drift gap
   - Detecting knock-off electrons from cathode surface
   - Cathode from three different materials: **doped diamond; Cu; Al**



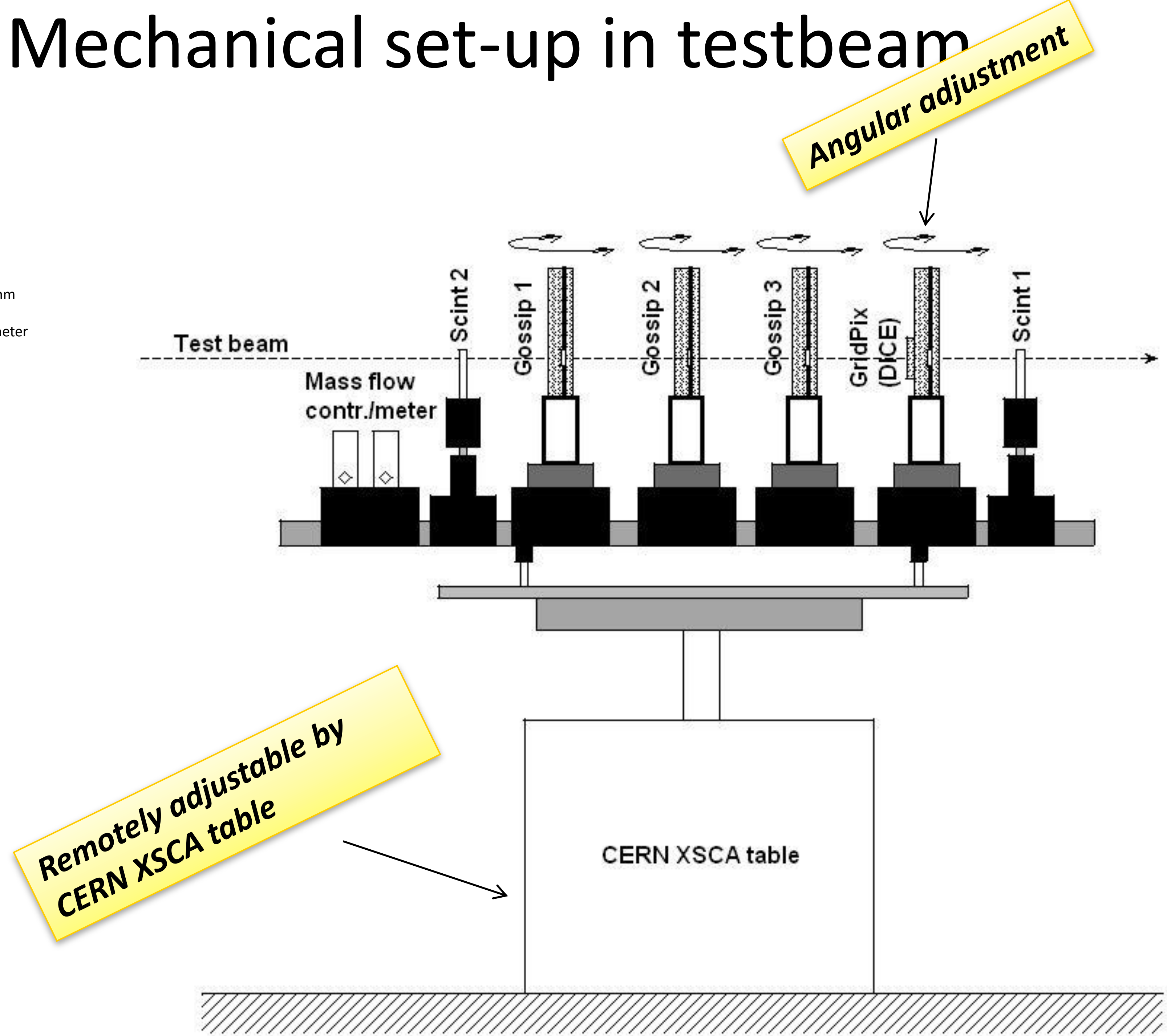
Using Gossip/GridPix telescope as a reference

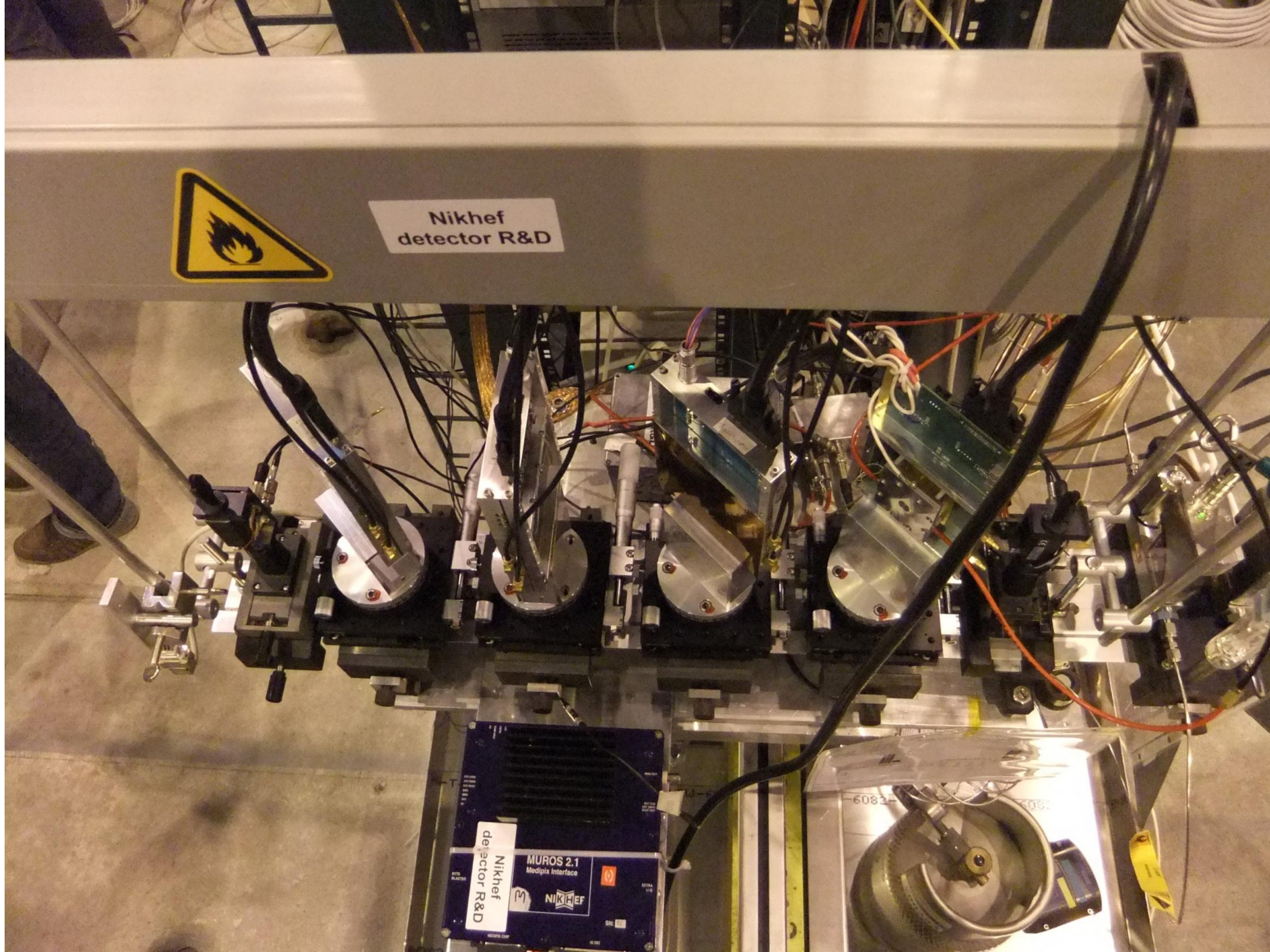
- Measurements done with Gossip 2
- Define track with Gossip 1 and 3
- Reject bad events using the Gridpix detector
  - Wrong angle (background tracks)
  - Outside fiducial volume
  - Multiple tracks (showers)

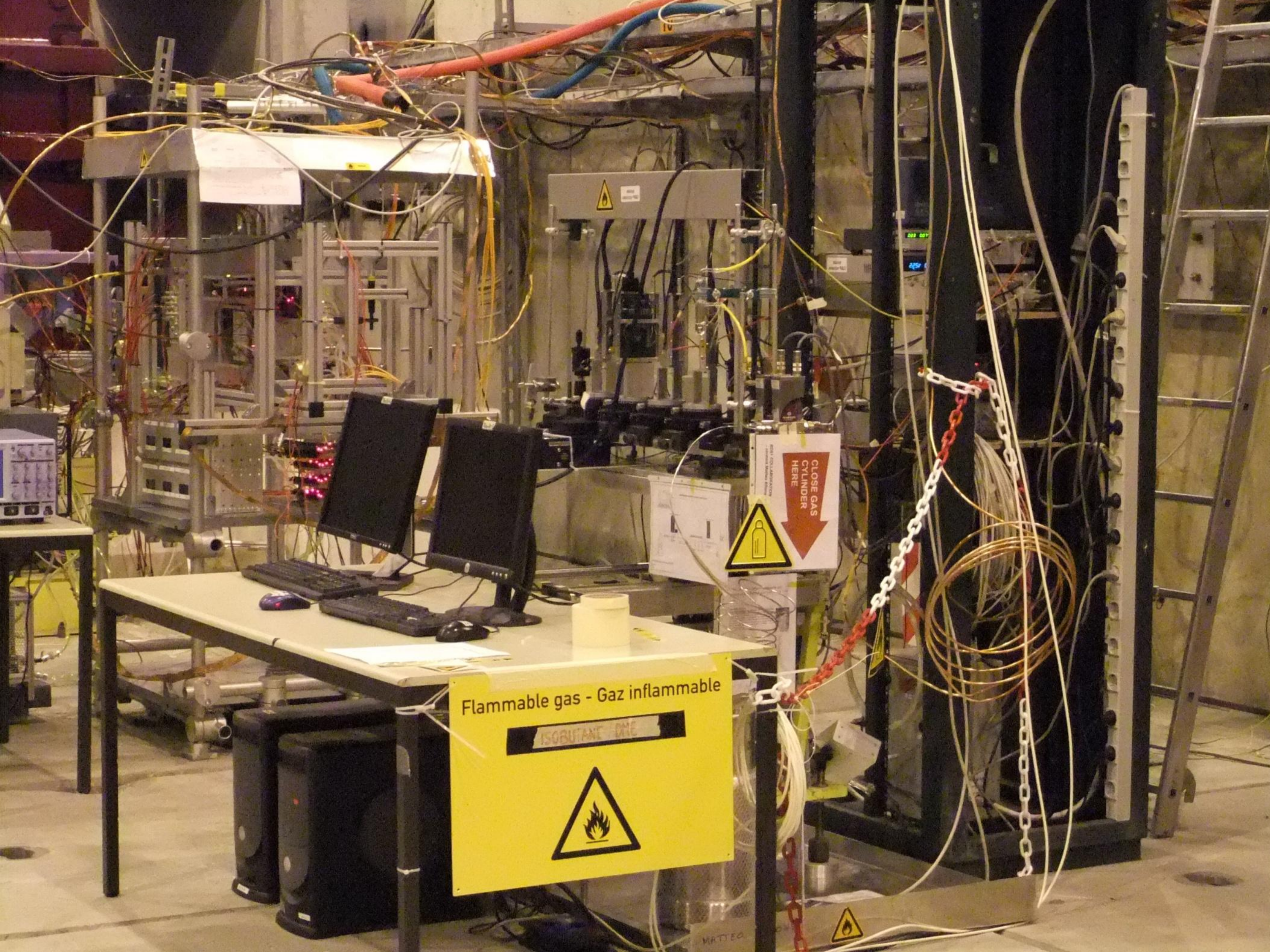


Mechanical set-up in testbeam

- Optical bench
- 4 Gridpix detectors
  - 3 x Gossip
  - GridPix)
- 2 Scintillators 15 x 15 mm
- Mass flow controller/meter

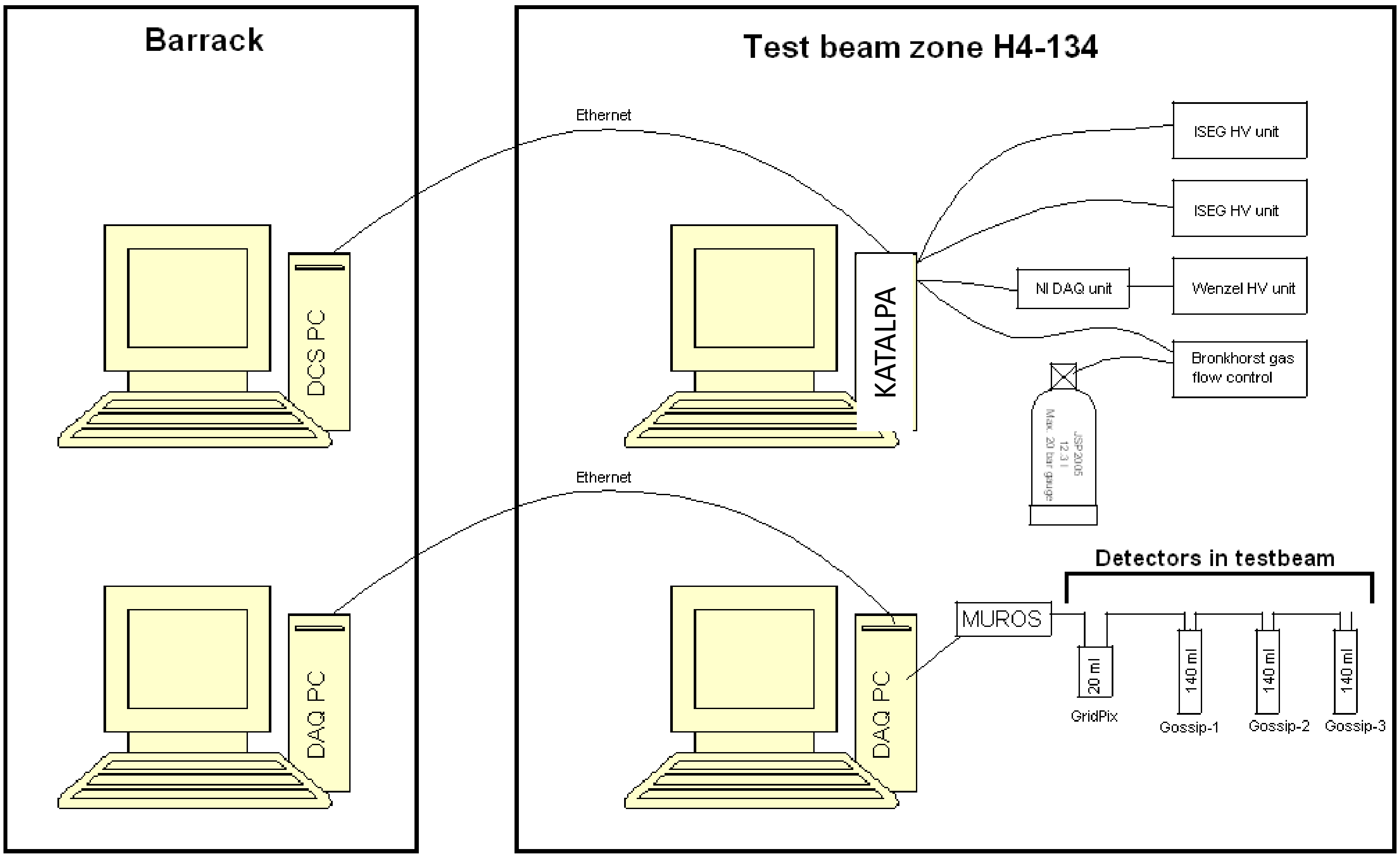



Nikhef
detector R&D
MUROS 2.1
Medipix Interface
NIKHEF
Nikhef
detector R&D

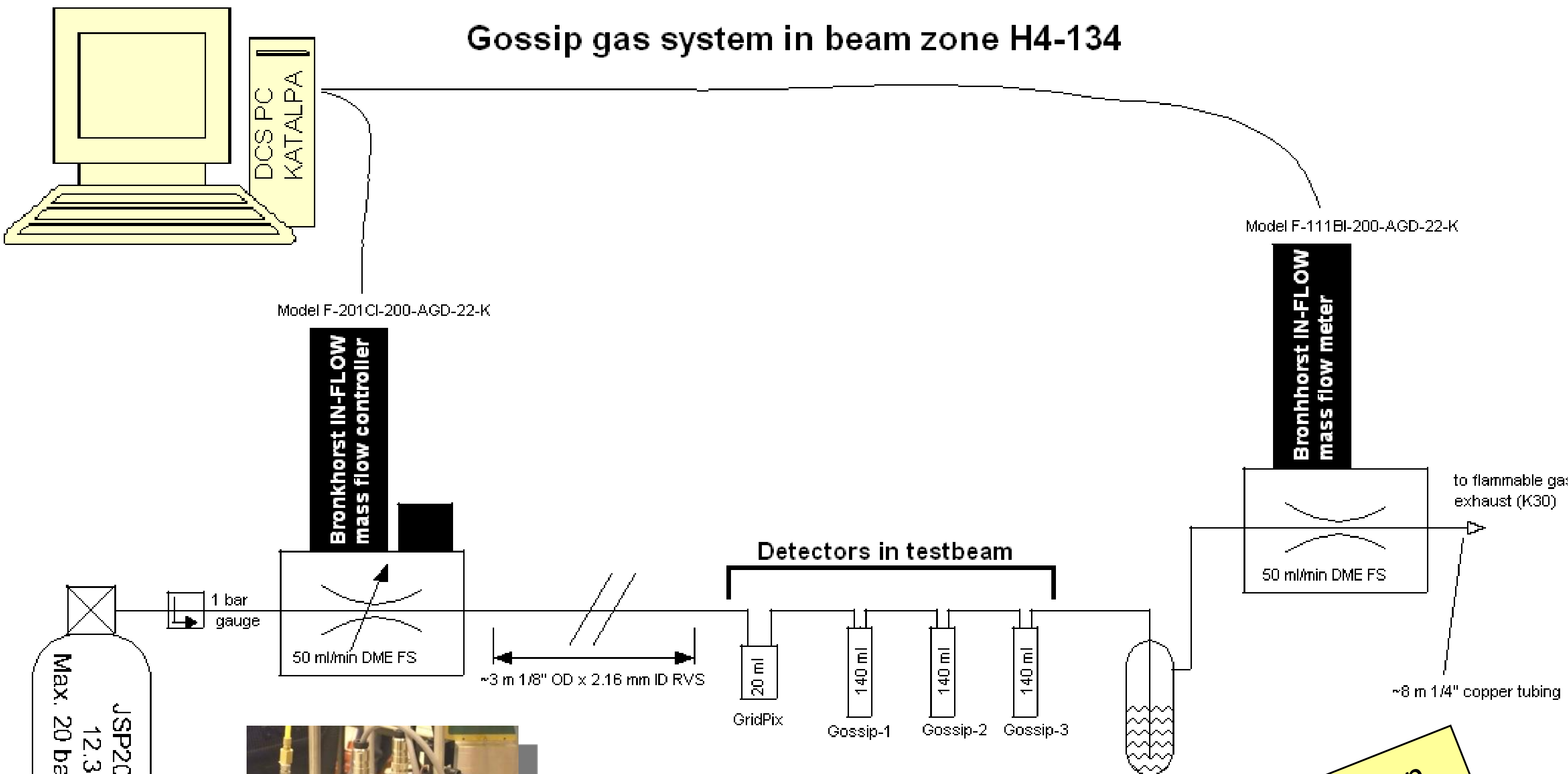

Flammable gas - Gaz inflammable
CLOSE GAS CYLINDER HERE

Completely remotely controlled

- Communication between barrack and experimental area by 2 Ethernet cables
- Using Remote Desktop



Gossip gas system in beam zone H4-134



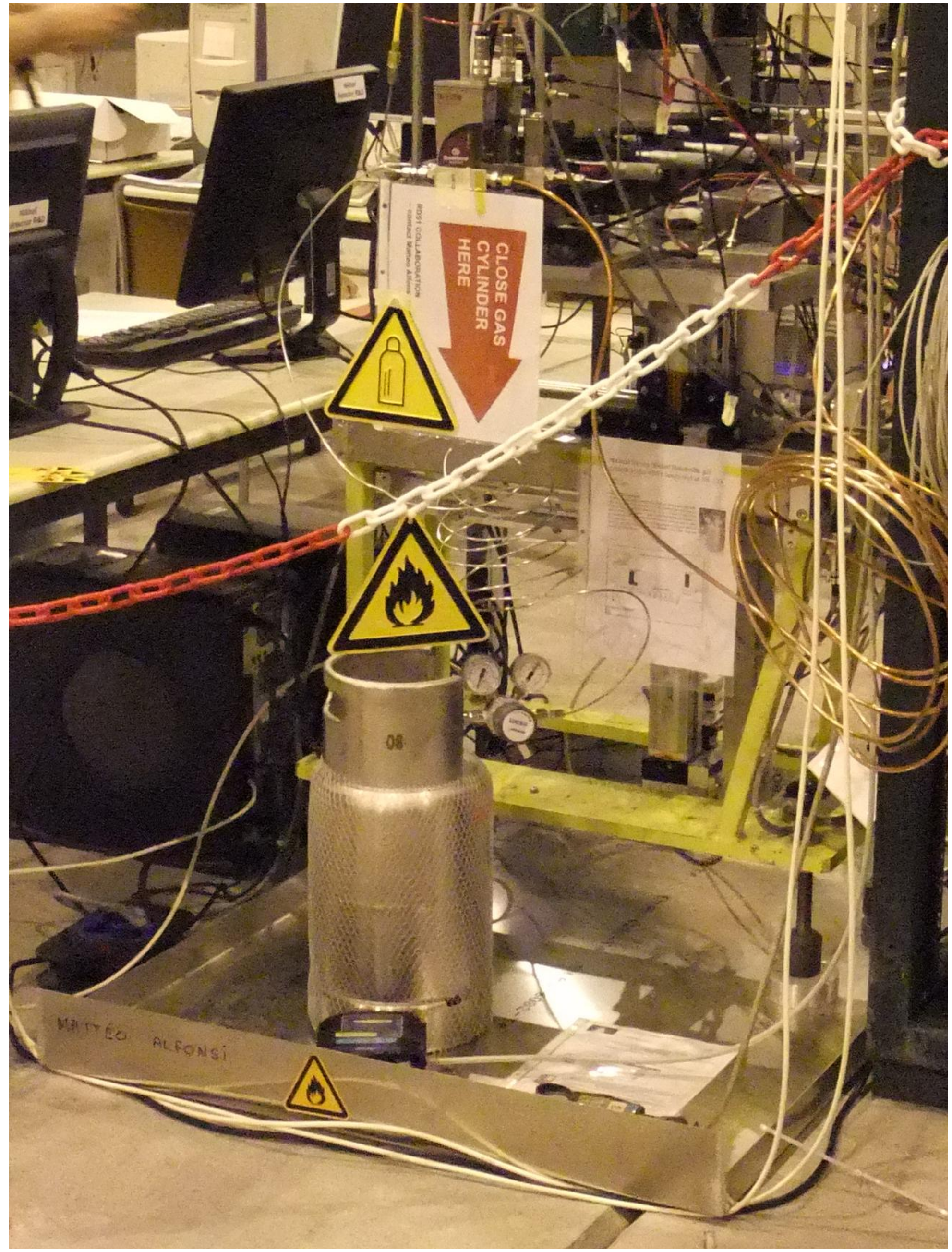
Gas system Gossip test beam in H4-134

Fred Hartjes
Nikhef
2-8-2010

We used a metal tray on the floor, 90 x 130 cm, surrounding the whole gas system

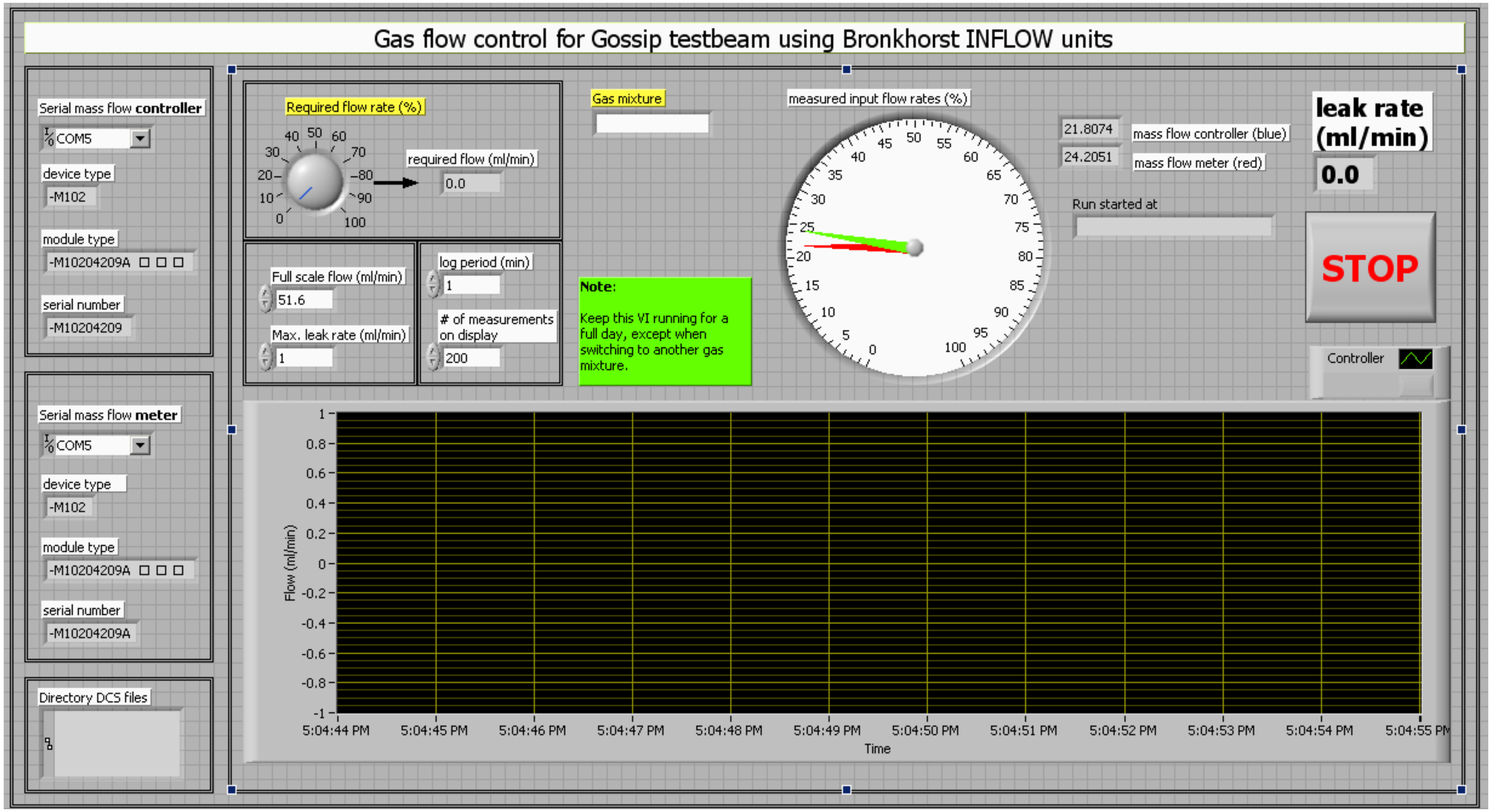
Special requirements for flammable gas

- Gas mixture from 120 l JSP gas bottle
- Whole gas system including bottle contained in leak tray
- Checking gas leaks by measuring deficit between input flow and exhaust flow
- Connected to flammable gas exhaust line



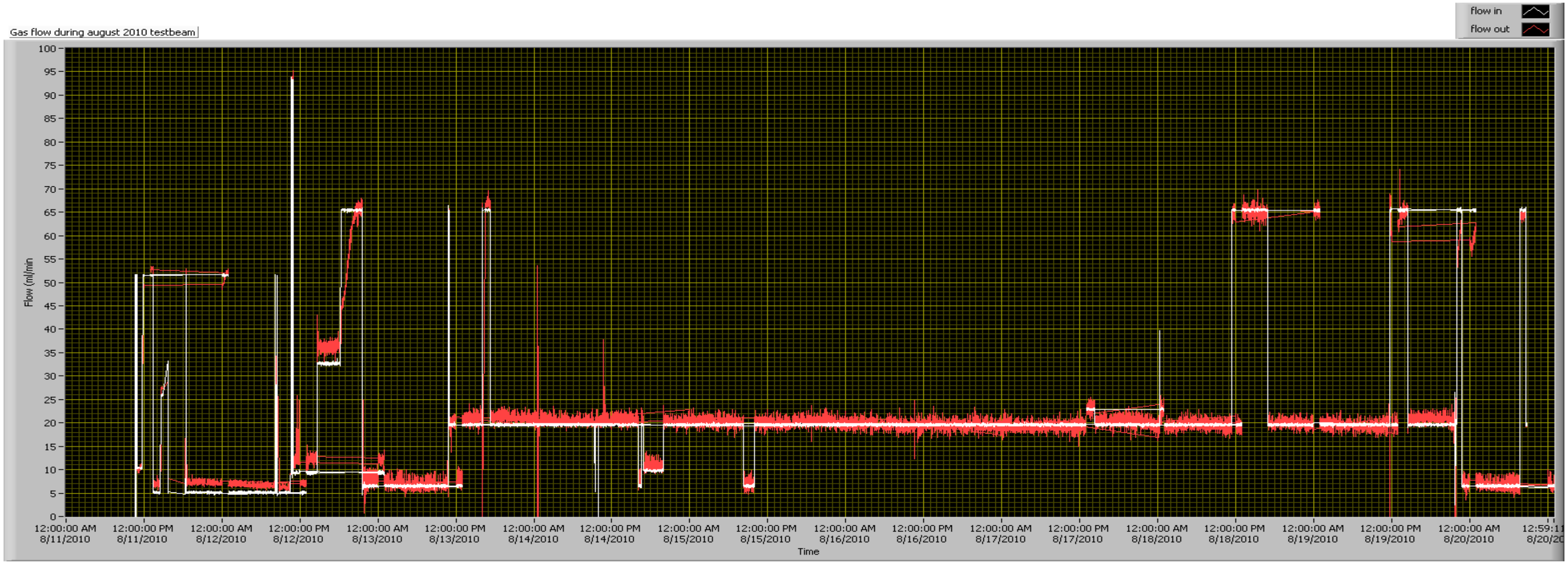
LabView controlled gas system

- Operation
  - Flow logged each minute
  - Alarm at leak rate > 3 ml/min
  - Shut off at integrated leak volume of 30 ml
- Gas flow set between 5 and 50 ml/min
  - Possible calibration error by factory (flow too low)



Gas flow during August testbeam

- White: inlet gas steam
- Red: exhaust gas stream
- Adjusted between 50 ml/min (purge) and 5 ml/min (standby)



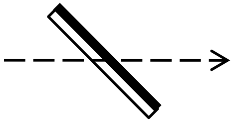
- From August 12 to August 22 in total 60 runs containing ~250k events
- Almost all done with DME/CO_2 50/50 and 150 GeV muons
- Last runs (~ 46k events) with Ar/iC_4H_{10} 80/20
  - ~3k events were hadrons

Run overview Gossip beam test August 2010

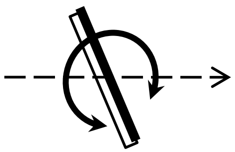
run#	start time	start date	# of event	Vg1	Vg2	Vg3	Vg4	Vf Gossip	Vguard	Vf DICE	α1	α2	α3	α4	gas	Analysed?	
1	19:41	12-8	273	580	580	580	500	780	540	2000	45	0	45	45	DME/CO2		
2		12-8	1696	580	580	580	500	780	540	2000	45	0	45	45	DME/CO2		
3		12-8	654	580	580	580	500	780	540	2000	0	0	0	0	DME/CO2		
4		13-8	1463	580	580	580	500	780	540	2000	0	0	0	0	DME/CO2		
5		13-8	1023	580	580	580	500	780	540	2000	0	0	0	0	DME/CO2		from ev 322 tests beam tuning
6		13-8	1024	600	600	600	530	800	630	4390	0	0	0	0	DME/CO2	X	
7		13-8	788	450	450	450	450	650	600	4310	45	45	45	45	DME/CO2		run in TOT mode
8		13-8	1340	450	450	450	450	650	600	4310	45	45	45	45	DME/CO2	X	
9		13-8	773	450	450	450	450	650	600	4310	45	45	45	45	DME/CO2		
10		13-8	714	470	470	470	470	670	620	4330	45	45	45	45	DME/CO2		run in TOT mode
11		13-8	1026	470	470	470	470	670	620	4330	45	45	45	45	DME/CO2	X	
12		13-8	4026	470	470	470	470	670	620	4330	45	45	45	45	DME/CO2		
13		14-8	770	490	490	490	490	690	640	4350	45	45	45	45	DME/CO2		repair timing + rot. DICE, TOT
14		14-8	1022	490	490	490	490	690	640	4350	45	45	45	45	DME/CO2	X	
15		14-8	1017	490	490	490	490	690	640	4350	45	45	45	45	DME/CO2		
16		14-8	741	510	510	510	510	710	660	4370	45	45	45	45	DME/CO2		run in TOT mode
17		14-8	1612	510	510	510	510	710	660	4370	45	45	45	45	DME/CO2	X	
18	14:19	14-8	1388	510	510	510	510	710	660	4370	45	45	45	45	DME/CO2		peak at 90 ns hopefully cured
19		14-8		530	530	530	520	730	670	4380	45	45	45	45	DME/CO2		run in TOT mode
20	17:40	14-8	4362	530	530	530	520	730	670	4380	45	45	45	45	DME/CO2	X	
21		14-8		550	550	550	530	750	680	4390	45	45	45	45	DME/CO2		run in TOT mode
22	20:28	14-8	2188	550	550	550	530	750	680	4390	45	45	45	45	DME/CO2	X	
23		14-8		570	570	570	530	770	680	4390	45	45	45	45	DME/CO2		run in TOT mode
24	22:12	14-8	2059	570	570	570	530	770	680	4390	45	45	45	45	DME/CO2	X	
25	23:27	14-8	17728	590	590	590	530	790	680	4390	45	45	45	45	DME/CO2	X	Run overnight until 8:06
26	10:32	15-8	339	590	590	590	530	790	680	4390	45	45	45	45	DME/CO2		run in TOT mode
27	10:55	15-8	348	600	600	600	540	800	690	4440	45	45	45	45	DME/CO2		run in TOT mode
28	12:19	15-8	2275	600	600	600	540	800	690	4440	45	45	45	45	DME/CO2	X	
29	14:52	15-8	2192	610	610	610	550	810	700	4450	45	45	45	45	DME/CO2	X	
30		15-8	824	610	610	610	550	810	700	4450	45	45	45	45	DME/CO2		run in TOT mode
31		15-8	694	620	620	620	560	820	710	4420	45	45	45	45	DME/CO2		run in TOT mode
32	19:40	15-8	2251	620	620	620	560	820	710	4420	45	45	45	45	DME/CO2	X	
33		15-8	2898	620	620	620	560	1220	710	4420	45	45	45	45	DME/CO2	X	
34		15-8	4270	620	620	620	560	1220	710	4420	10	45	10	10	DME/CO2		
35		16-8	5839	620	620	620	560	820	710	4420	10	45	10	10	DME/CO2		DICE trip
36		16-8	4015	620	620	620	560	820	710	4420	10	0	10	10	DME/CO2	X	
37		16-8	4596	620	620	620	560	1220	710	4420	10	0	10	10	DME/CO2	X	
38		16-8	4569	620	620	620	560	1220	710	4420	10	5.75	10	10	DME/CO2	X	
39		16-8	17919	620	620	620	560=> 550	820	710	4420	10	5.75	10	10	DME/CO2		DICE trip problems
40		16-8?	4084	620	620	620	520	1220	670	4380	10	11.5	10	10	DME/CO2		DICE reduced after trips
41		17-8	4306	620	620	620	530	820	680	4390	10	11.5	10	10	DME/CO2		broad beam, low intensity
42		17-8	5001	620	620	620	540	820	690	4390?	10	23	10	10	DME/CO2		~ 10x more particles
43		17-8	5307	620	620	620	540	1220	690	4440	10	23	10	10	DME/CO2		
44		17-8	30855	620	620	620	540	820	690	4440	0	0	0	90	DME/CO2	X	
45		18-8	6442	620	620	620	540	820	690	4440	0	0	0	90	DME/CO2	X	gasflow to 65 ml/min
46		18-8	7097	620	620	620	540	820	690	4440	0	0	0	90	DME/CO2	X	lower thresh. DICE
47		18-8	1940	620	620	620	540	820	690	4440	0	0	0	10	DME/CO2		Vf of pos2 at 0V
48		19-8	9854	620	620	620	540	820	690	4440	0	45	0	10	DME/CO2		Vf of pos2 at 0V
49		19-8	8358	620	620	620	540	820	690	4440	0	45	45	10	DME/CO2		Vf of pos2 at 0V
50	11:44	20-8	4440	620	620	620	540	820	690	4440	45	45	45	0	DME/CO2		Vf of pos2 at 0V
51	14:50	20-8	2410	620	0	620	540	820	690	4440	45	45	45	0	DME/CO2		PillarPix dead, P3 sparky
52	16:26	20-8	292	620	0	620	540	820	690	4440	45	45	45	0	DME/CO2		Hadr.;SCXA:106;306=>092;366
53	16:38	20-8	3832	620	0	620	540	820	690	4440	45	45	45	0	DME/CO2		Hadrons, no field on P3 and P2
54	18:07	20-8	2744	620	0	620	540	820	690	4440	45	45	45	0	DME/CO2		sheet missing
55	11:27	21-8	3381	620	620	620	540	820	690	4440	0	0	0	10	DME/CO2		
56	12:48	21-8	5314	620	620	620	540	570	450	3245	0	90	0	10	DME/CO2		SC2 5.5 to PC, SC1 2.5 oppos.
57	18:19	21-8	634	420	420	420	350	570	450	3245	0	0	0	10	Ar/iC4H10		150 GeV hadrons
58	18:32	21-8	4314	420	420	420	350	570	450	3245	0	0	0	10	Ar/iC4H10		Hadrons => muons
59	19:50	21-8	34348	420	420	420	350	570	450	3245	0	0	0	10	Ar/iC4H10		
60	9:30	22-8	11804	420	420	420	350	570	450	3245	0	11.5	0	10	Ar/iC4H10		

What has been measured?

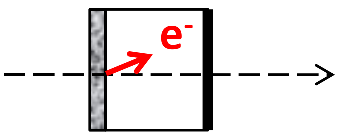
- Much data for Gossip under 45°
  - 50k events
  - Grid voltage scan from -510 to -620 V
  - Mostly at field 2 kV/cm
  - 2.8 k ev at 6 kV/cm



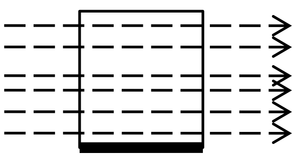
- Also 10k events under 4 other angles
  - 0; 5.75; 11.5 and 23°
  - Both at drift field of 2 and 6 kV/cm



- 25k events with secondary emission detector

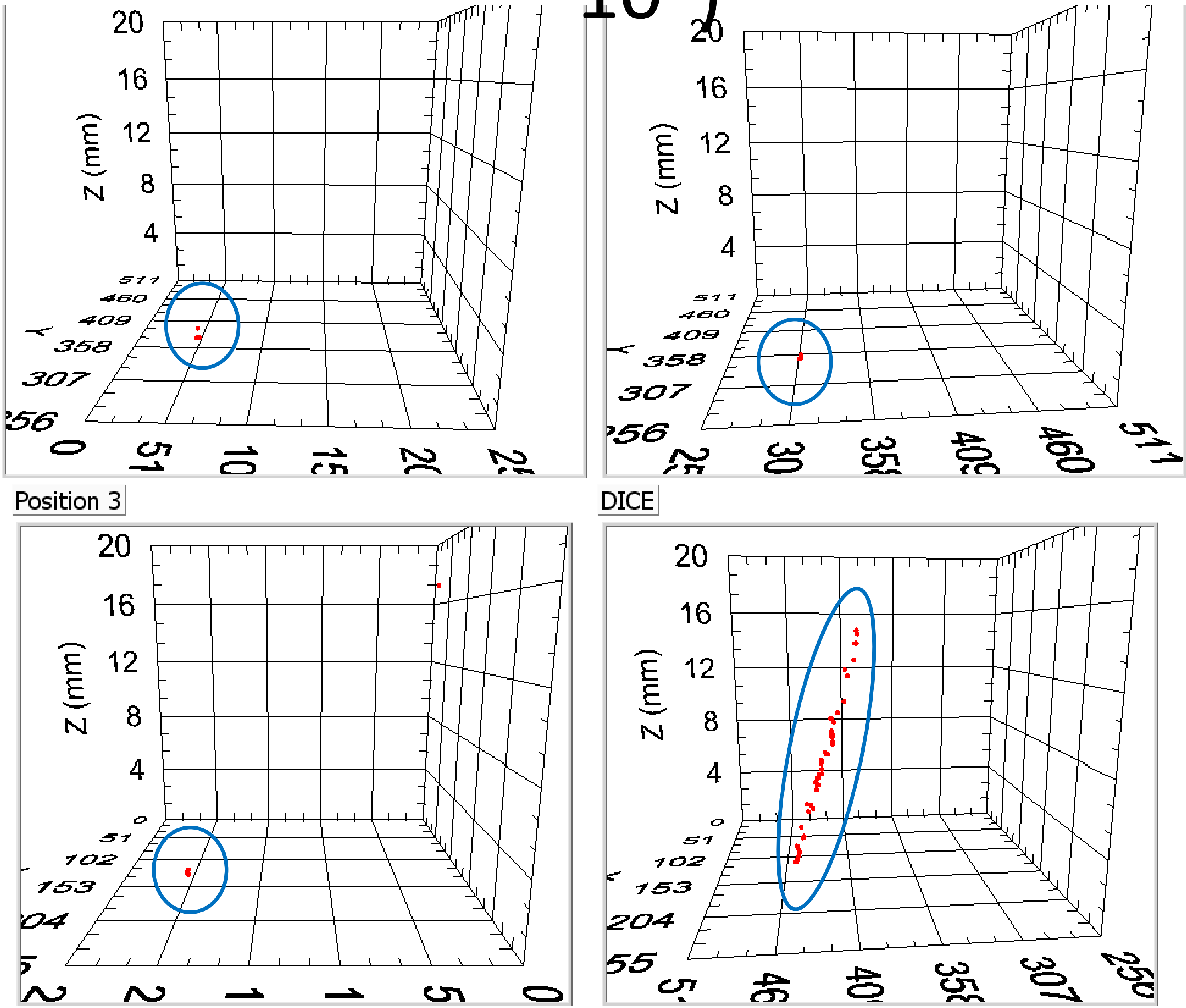


- 44k events with tracks in GridPix under 90°



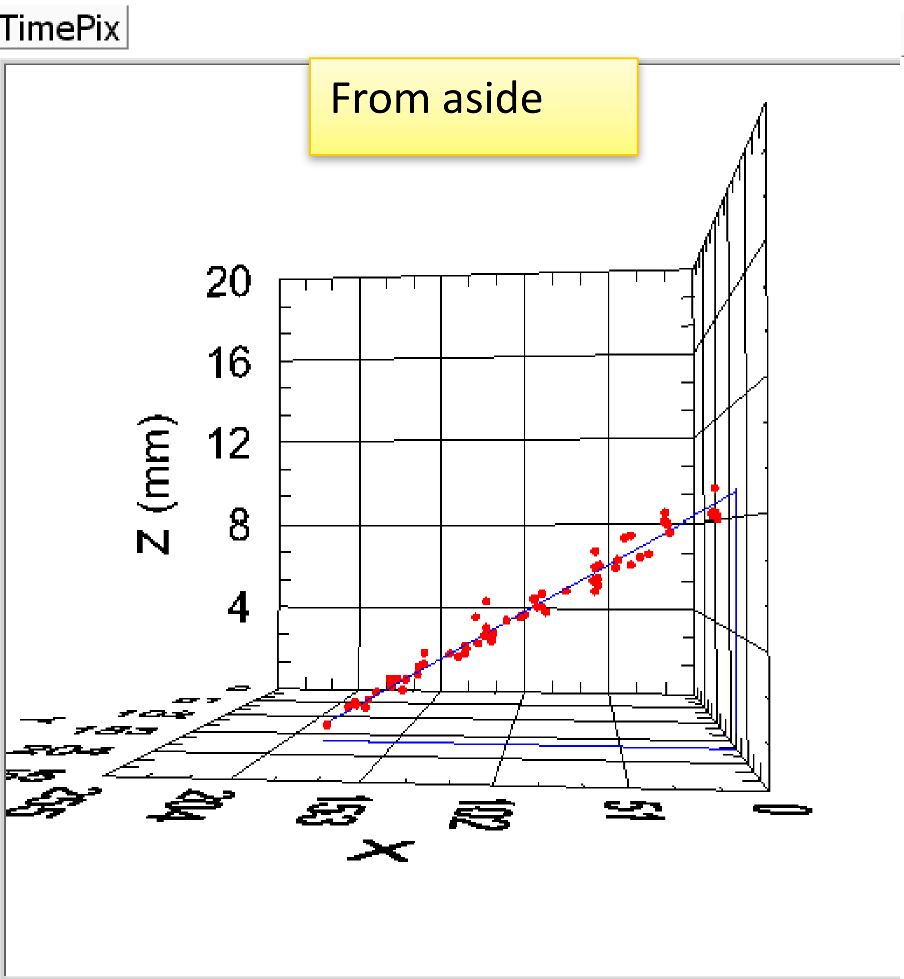
- 5k events with parallel tracks in Gossip

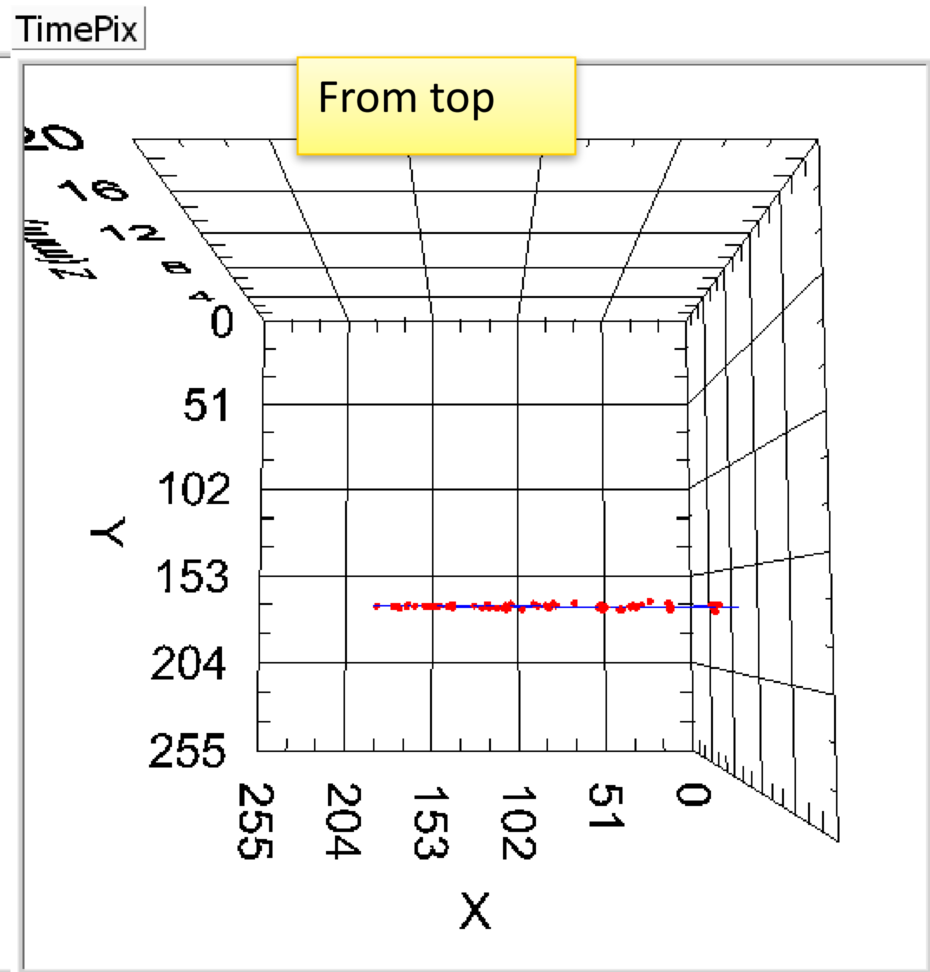
Typical event in all 4 detectors (angle 10°)



Typical event in GridPix under 45°

- Very small diffusion but big time slewing





Data analysis

- Just started, only preliminary results are given here
- **Cuts** on each detector individually

- Fitted tracks
  - Slope
  - Intercept Z=0
  - Fit residue

- Pixel hits
  - Fiducial area
  - Maximum drift time

Fit Cut Matrix

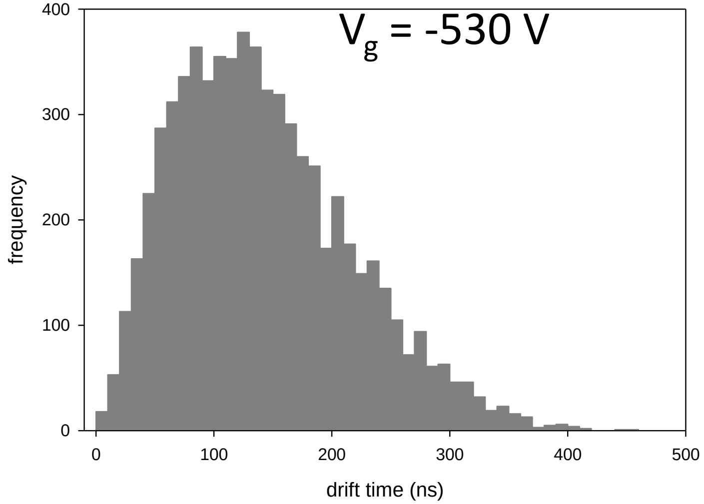
	Position 1	Position 2	Position 3	DICE	
0	1	1	1	-0.15	Max Z-X slope
1	-1	-1	-1	-0.25	Min Z-X slope
2	1	1	1	1	**Z-X slope enable**
3	0	0	0	0.04	Max Z-Y slope
4	0	0	0	-0.02	Min Z-Y slope
5	0	0	0	1	**Z-Y slope enable**
6	0	0	0	13	Max X intercept (Z=0, mm)
7	0	0	0	5	Min X intercept (Z=0, mm)
8	0	0	0	1	**X intercept enable**
9	0	0	0	10	Max Y intercept (Z=0, mm)
10	0	0	0	2	Min Y intercept (Z=0, mm)
11	0	0	0	1	**Y intercept enable**
12	0	0	0	1	Max X-slope residue
13	0	0	0	1	**X slope residue enable**
14	0	0	0	0.01	Max Y-slope residue
15	0	0	0	1	**Y slope residue enable**

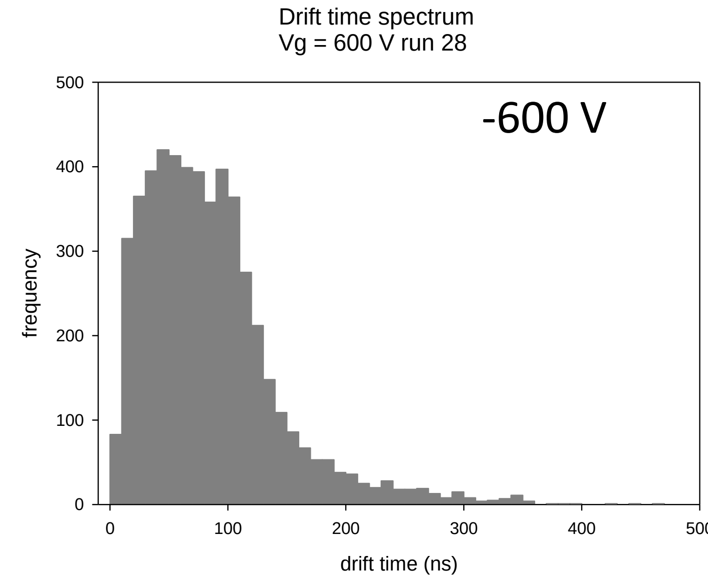
Pixel Cut Matrix

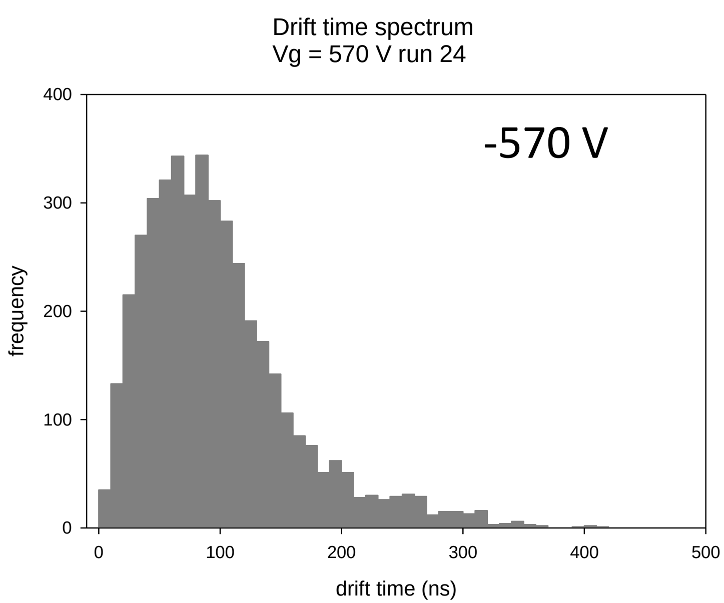
	Position 1	Position 2	Position 3	DICE	
0	245	245	245	245	X upper limit (pix)
1	10	10	10	10	X lower limit (pix)
2	1	1	1	1	**X fid enable**
3	245	245	245	245	Y upper limit (pix)
4	10	10	10	10	Y lower limit (pix)
5	1	1	1	1	**Y fid enable**
6	2	2	2	10	# of hits
7	0	0	0	0	**# of hits enable**
8	150	150	130	0	Max drift time (ns)
9	1	1	1	0	**Max drift time enable** (1: cut; 2: coerce)

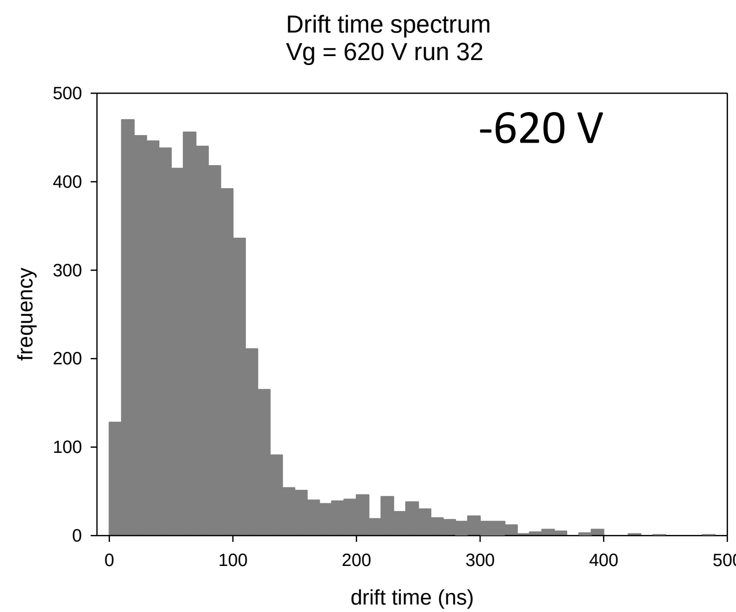
Drift time spectrum

- TimePix suffering from time slewing
- Less dominant at high gain



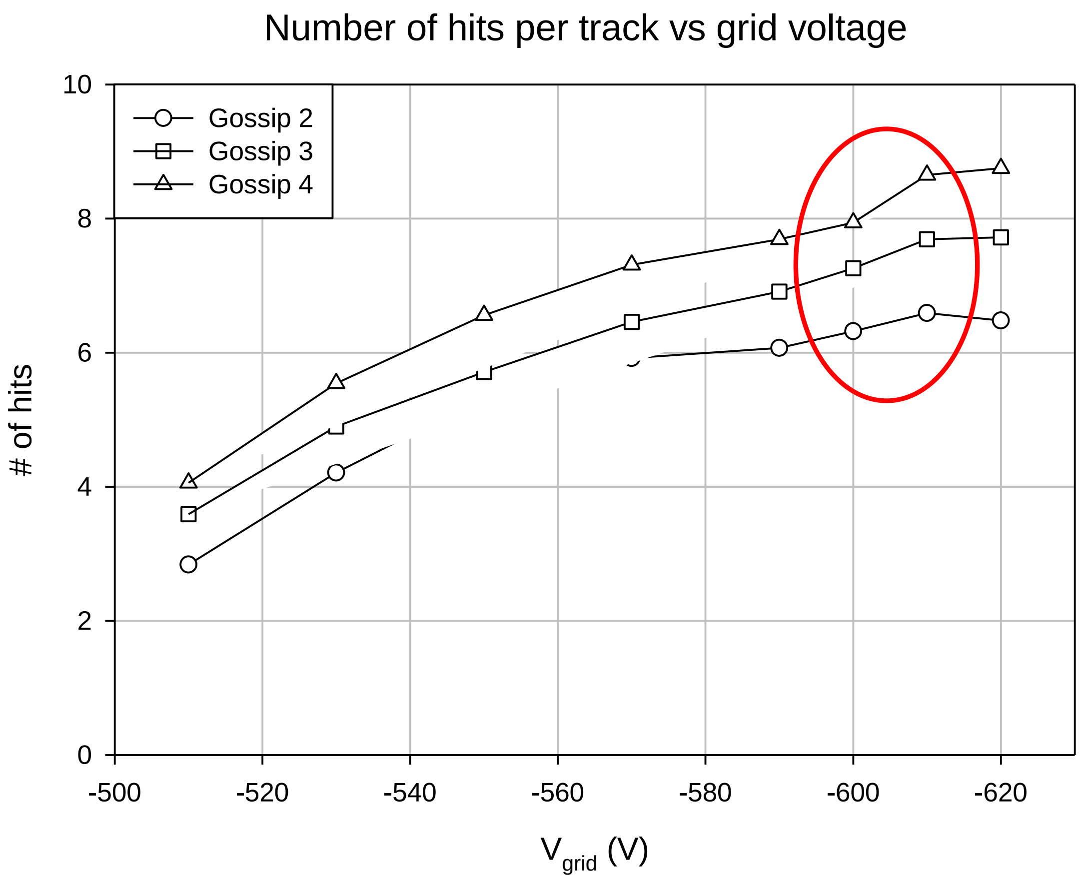


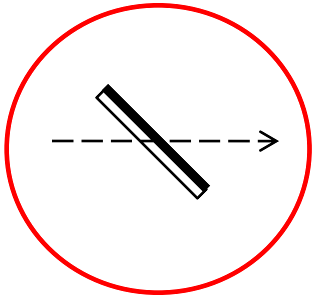




Number of hits per track in Gossip vs grid voltage

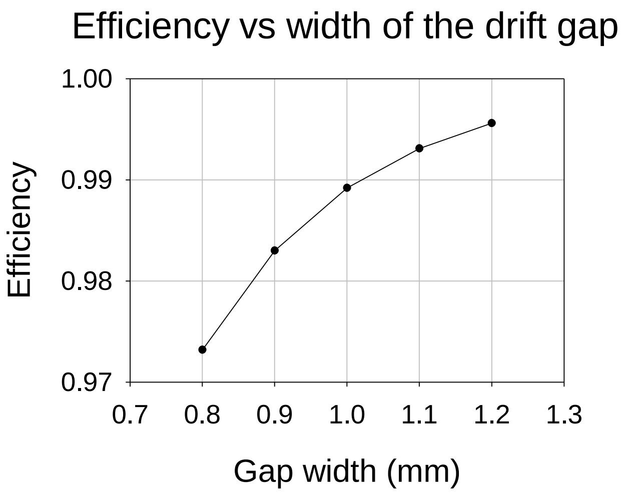
- Angle 45°
- Unexpected difference between the three Gossips
  - If Gas gap of Gossip 2 were 1.0 mm, then the gap of Gossip 4 should be 1.3 mm
- Jump in number of hits from -600 to -610

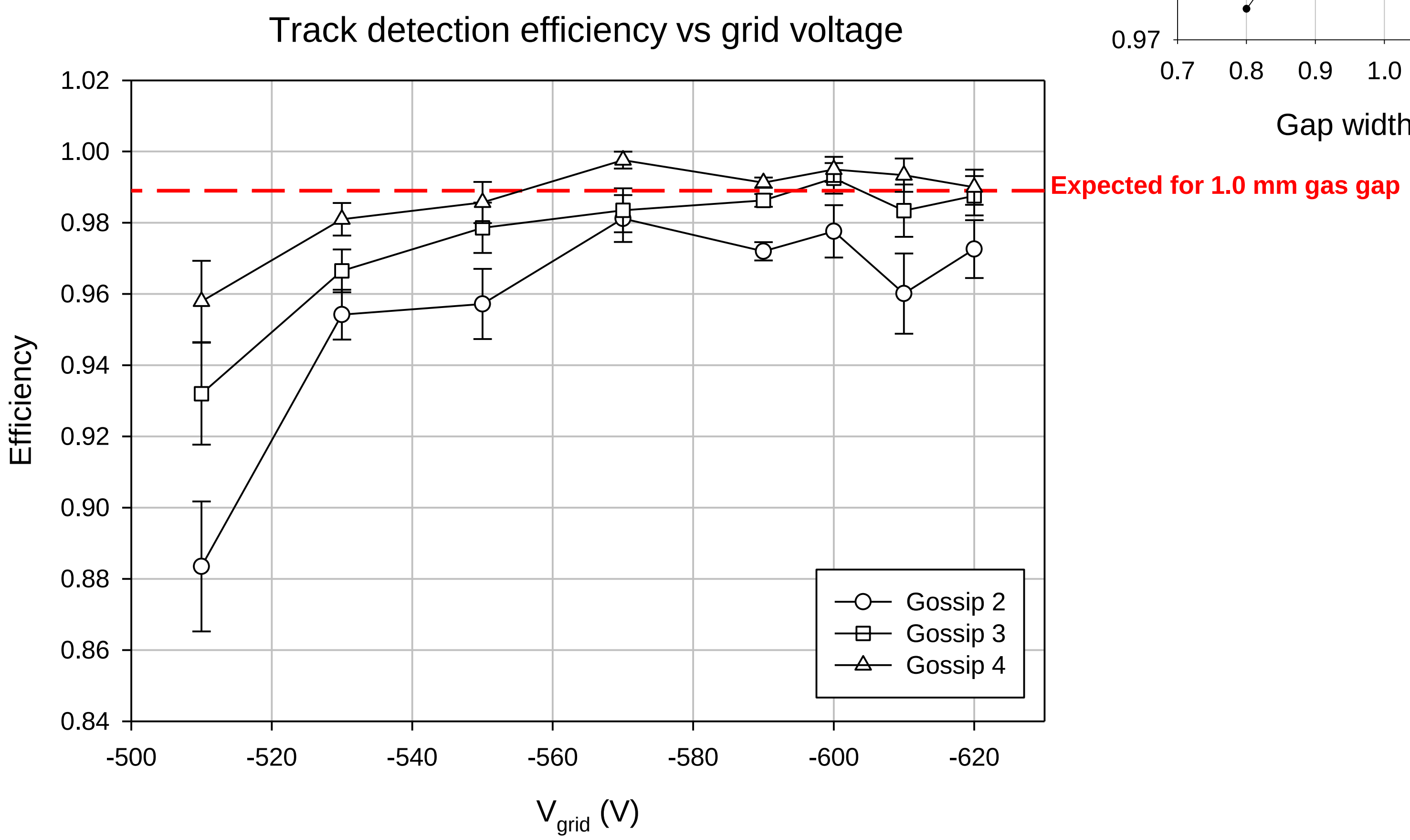




Track detection efficiency

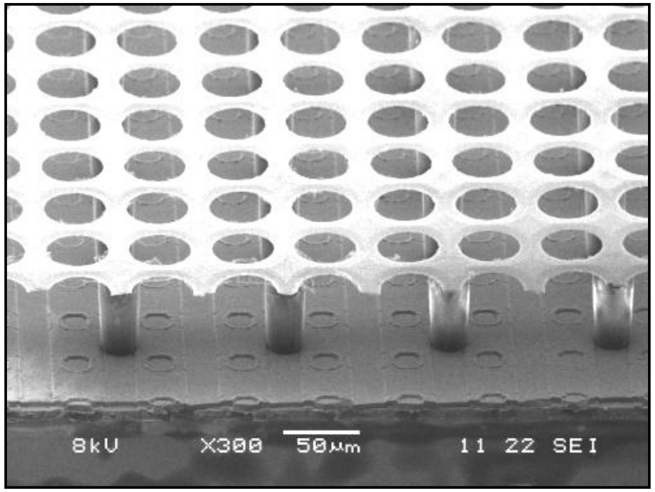
- Tracks selected by GridPix detector
- Completely flat plateau from ~ -570 V on
- Expected for 1.0 mm DME/CO2: 98.9%

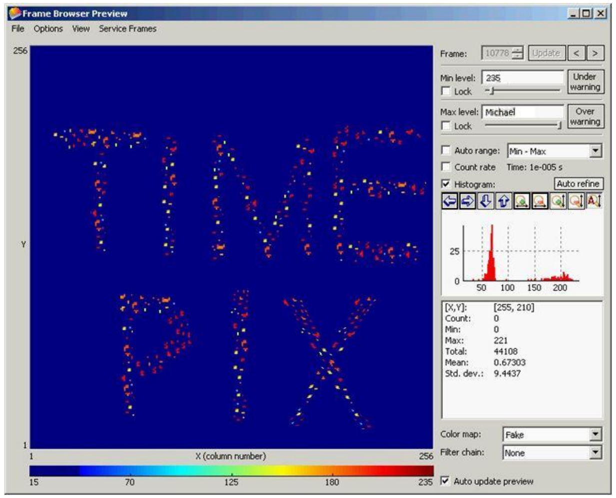




Concluding:
Detectors operating well, but some results not yet understood

- All three Gossips were operating reliably without any HV problem at high gain
- GridPix (mostly running at -560 V has less good gain, but probably still good single electron efficiency
- Infrastructure of remote control of HV and gas advantageous
  - May be modified when beam is on
  - Values permanently logged
- Data to determine position resolution and angular resolution for 5 difference angles of incidence
- Gossips have excellent track detection efficiency from -570 V on
- Jump in number of hits for V_{grid} going from -600 V to -610 V not yet understood
- Difference in number of hits between Gossip 2, 3 and 4 not understood
  - Difference confirmed by drift time spectrum
  - Metrology before testbeam showed difference in drift gap height of only 4%





Avalanche statistics and single electron counting with a Timepix-InGrid detector

Michael Lupberger

EUDET Annual Meeting

29.09-01.10.2010 DESY, Hamburg, Germany

Hardware
Setup

Gas box, volume: 1,5 l

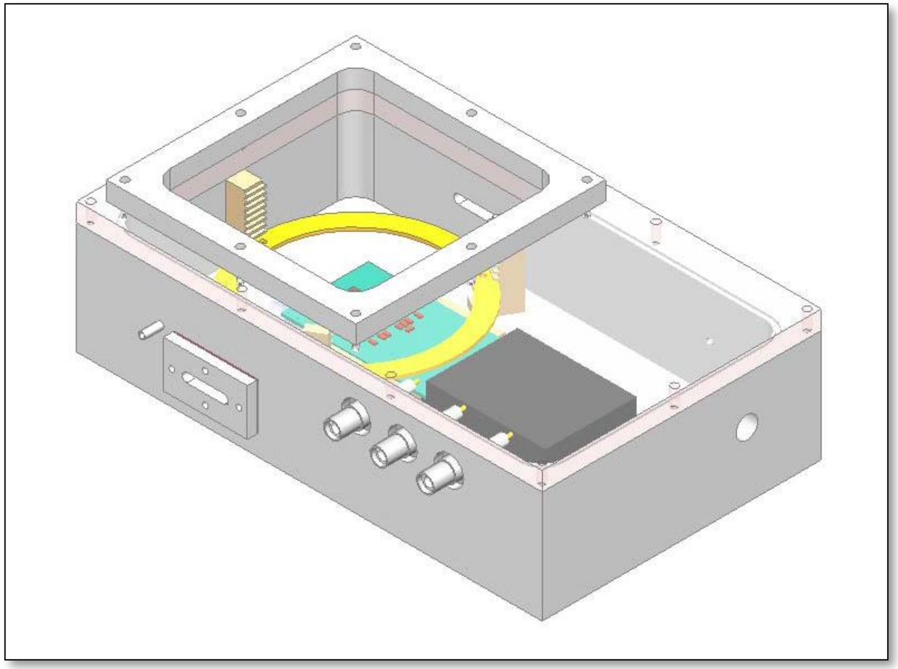
Source: Fe55, directly on cathode

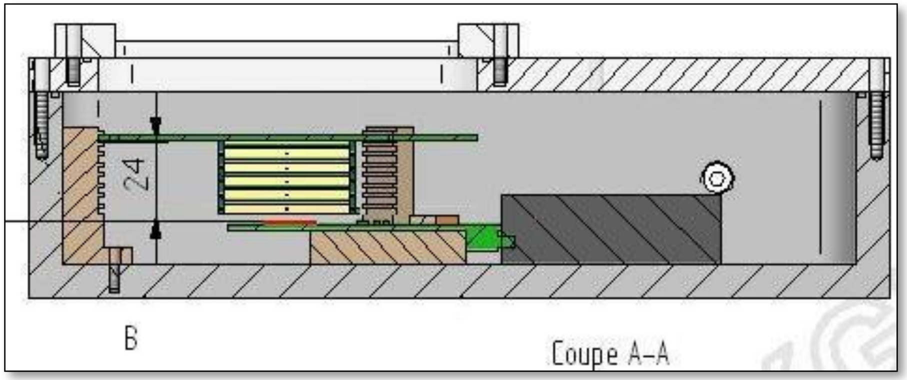
Gas: ArIso 95/5 (ArIso 80/20, P10, CF4)

Readout: MUROS, 36MHz, Pixelman
Filter: > 10 Pixel per Frame

Drift distance: max. 2,4 cm
Amplification gap: 50µm
SiProt: 7µm

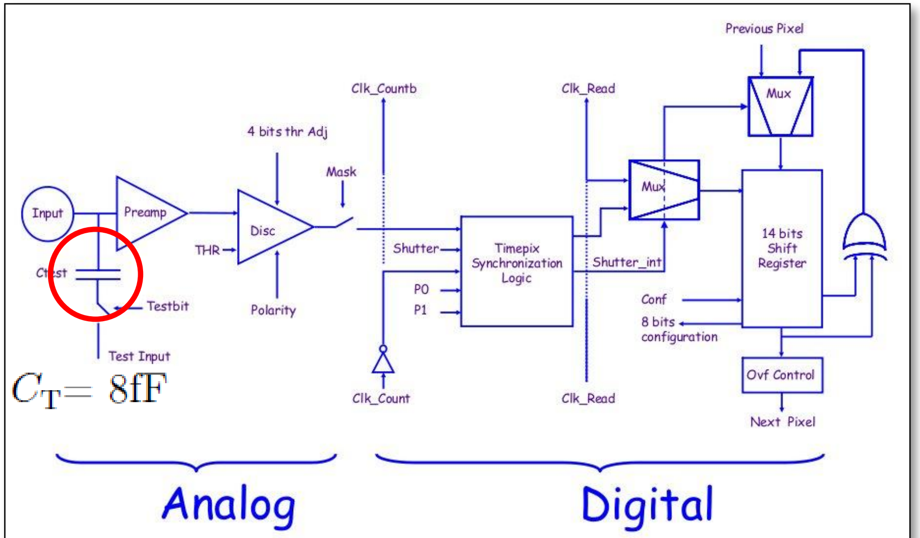
Field degrader
No anode plate around InGrid





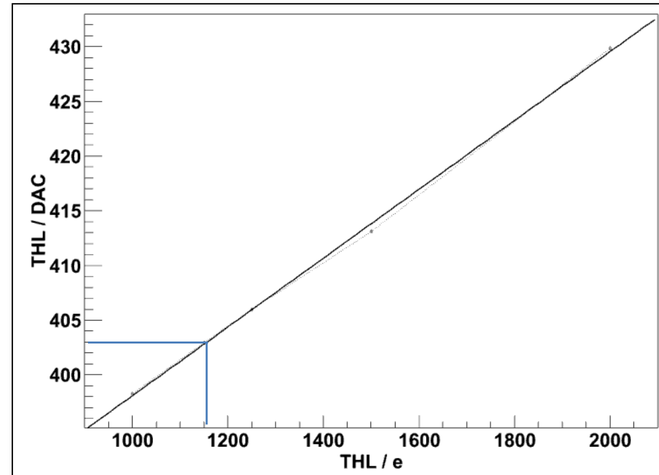
Hardware

Calibration

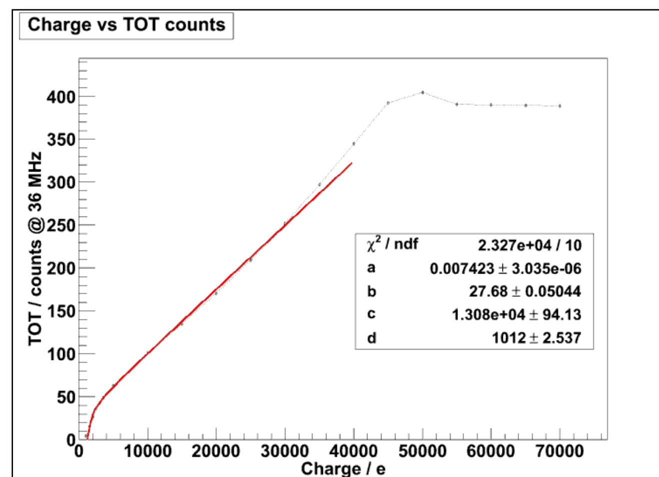


$Q_{inj}\,[e^-] = 50 \cdot \Delta U_{inj}[\mathrm{mV}]$ $\quad Q_{inj} = C_T \cdot \Delta U_{inj}$

Threshold DAC $\rightarrow$ #e- calibration



TOT $\rightarrow$ #e- calibration



Internal test pulses applied to each pixel via MUROS

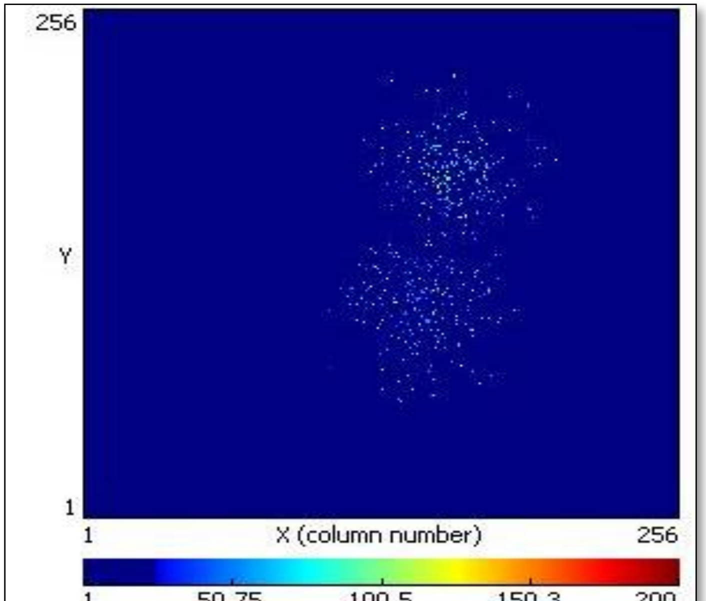
→ Known input charge into electronics

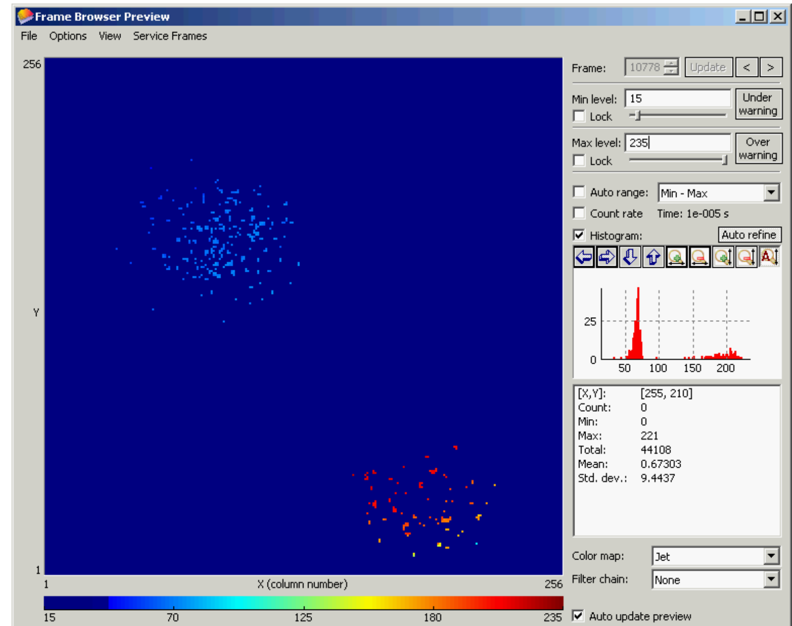
→ Threshold calibration

→ TOT calibration !Non linear for low charge

Software

Analysis code





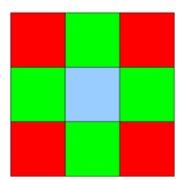
TOT Mode: 1. Check circularity of clouds

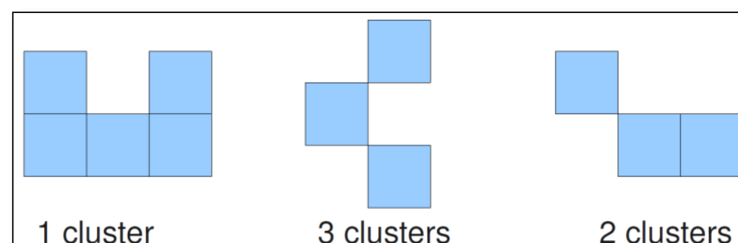
TIME Mode: 1. Separate clouds with time information

2. Check if cloud near centre
3. Check cloud size RMS

Find clusters (group attached pixels)

→ Histograms, Fits, TOT to electrons …

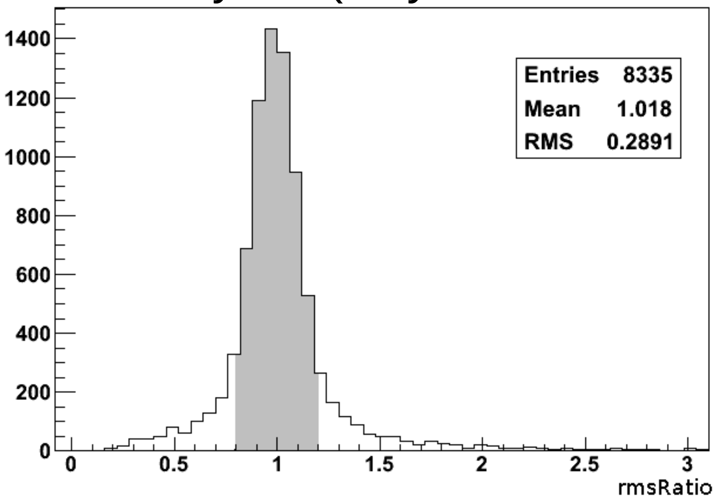




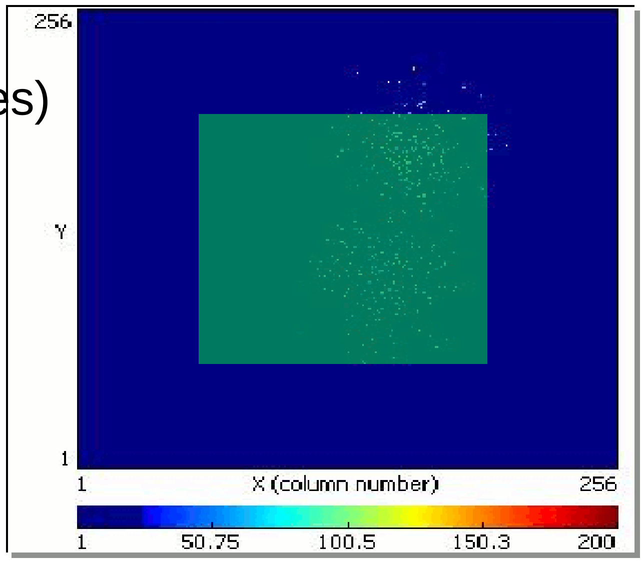
Software

Analysis code

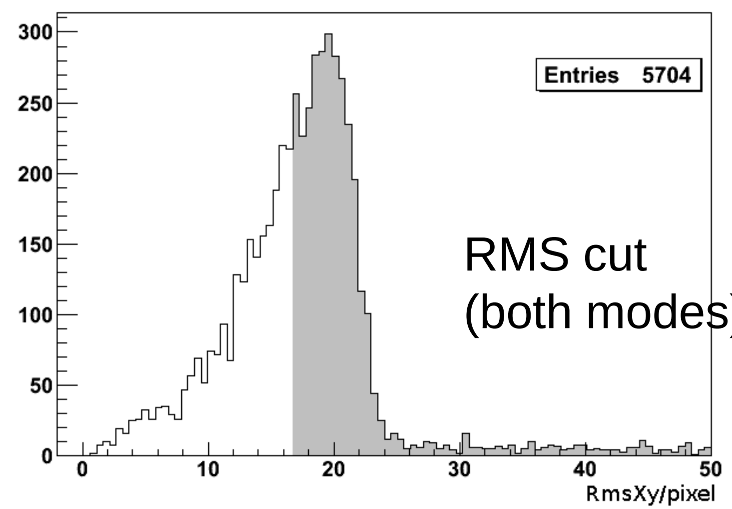
Circularity cut (only in TOT mode)



Centre cut
(both modes)



Physical interpretation of RMS cut:
Only take electron clouds, that have drifted a long distance:
⇒Primary electrons separated by diffusion
Cut: RMS of 16.4 pixels on chip



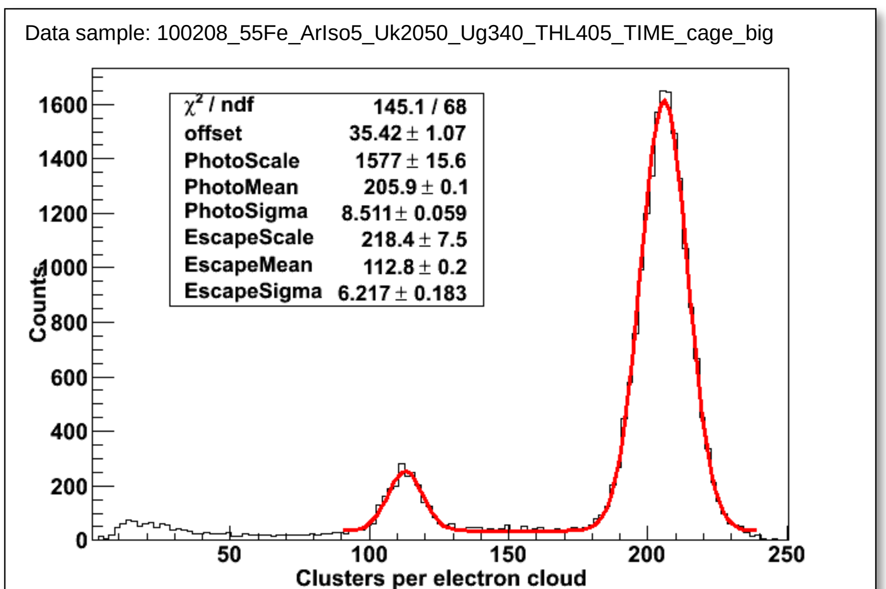
RMS cut
(both modes)

Fe55 Spectra

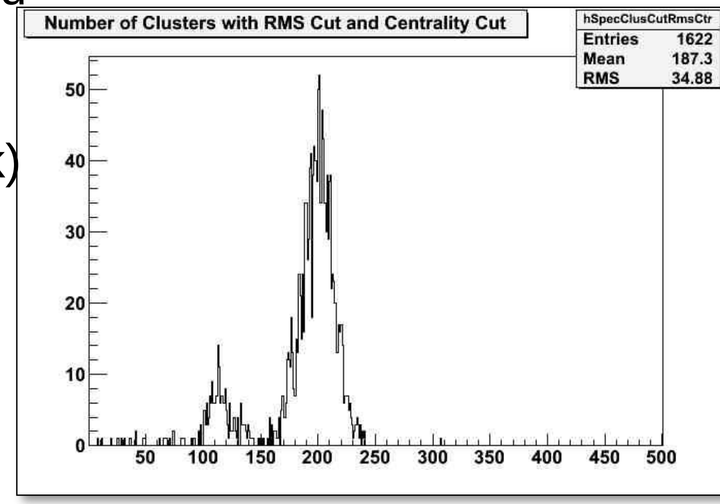
Resolution

- Count number of hit pixels/clusters per electron cloud
- Chromium foil to absorb K_β photons
- long term measurement and hard cut on cloud size
- best resolution achieved: 9,73% FWHM (photo peak)

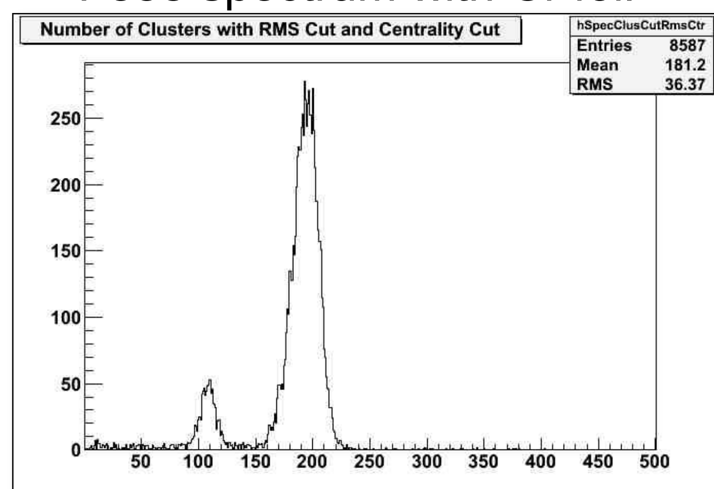
$$\left(\frac{\sigma_{N_d}}{N_d}\right)^2 = \frac{1}{N_p}\left(F + \frac{1-\frac{N_d}{N_p}}{\frac{N_d}{N_p}}\right)$$ [1] $\Rightarrow F = 0.26$ (upper limit)



Fe55 spectrum without Cr foil



Fe55 spectrum with Cr foil



[1] Max Chefdeville, Development of Micromegas-like gaseous detectors using a pixel readout chip as collecting anode

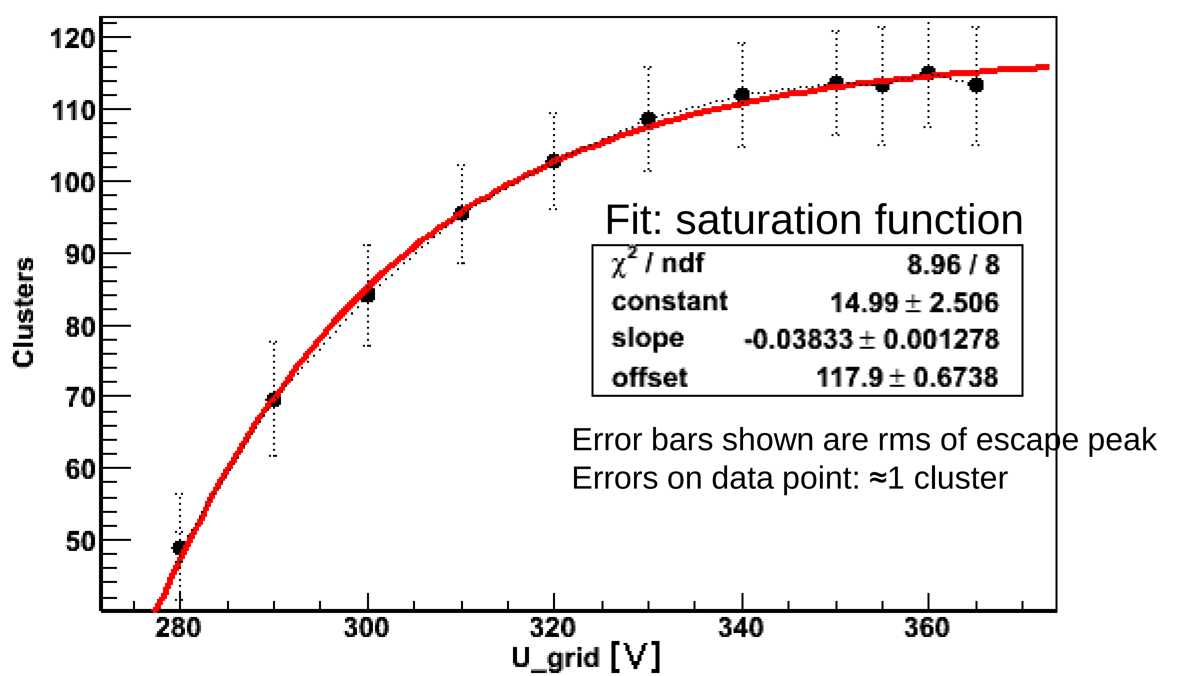
Fe55 Spectra
Clusters in escape peak

In ArIso 95/5:
- have a look on escape peak: less electrons, better separated by diffusion
- enough diffusion to arrive at plateau for escape peak: 117.9±0.7 cluster
- most clusters include just one pixel (also some charge sharing)
  ⇒ 1 cluster ≅ 1 primary electron at plateau
- applying harder cuts on RMS of electron cloud does not effect number of clusters

- escape peak at: 2,9 keV
- photo peak at: 5,899 keV

- ⇒ 236±1 electrons expected in photo peak (max counted: 215 cluster)

Simulations (H.Schindler):
233 electrons in photo peak
(MAGBOLTZ)

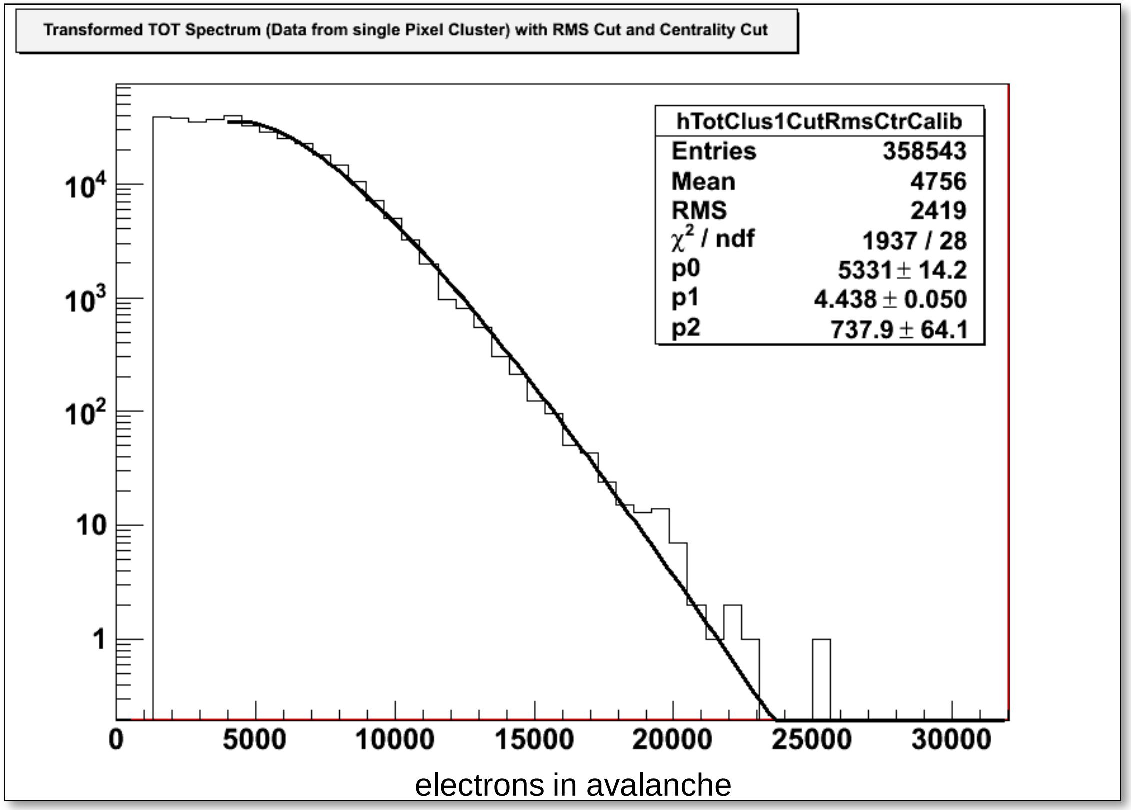


TimeOverThreshold

TOT Spectra

Data sample:
U_{grid}=330 V

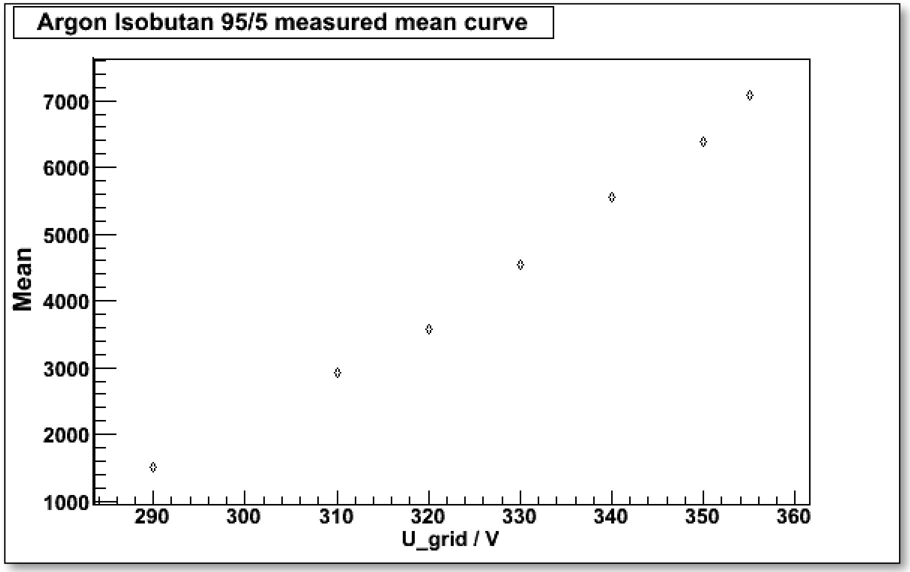
Polya fit forced starting from 4000
Advantages:
•TOT → #e- calibration reliable
Disadvantages:
•few data points for low voltages
•just tail fit



TimeOverThreshold

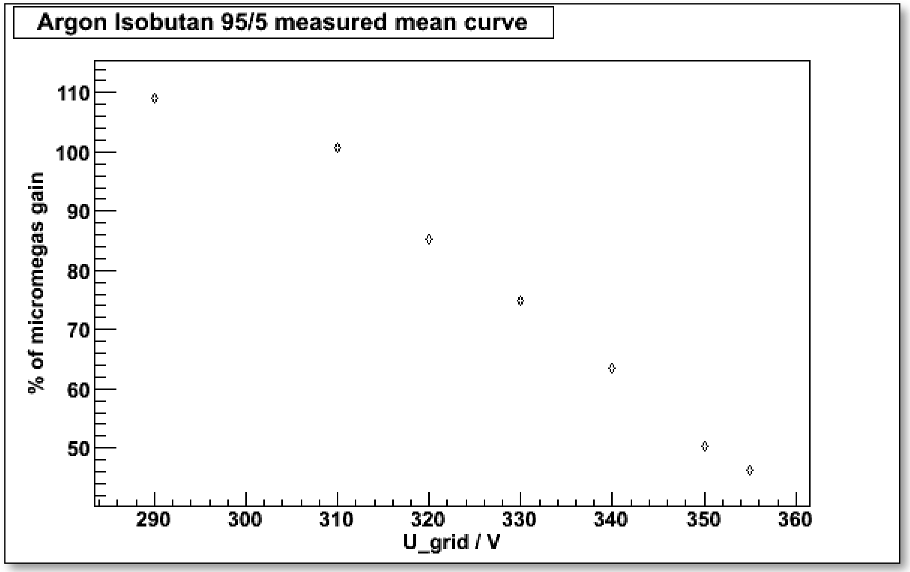
Gain Curve

Mean of Polya fit curve



Use TOT → #e- calibration ⇒ gain curve
→ Not exponential at all
→ Very low gain at high voltages

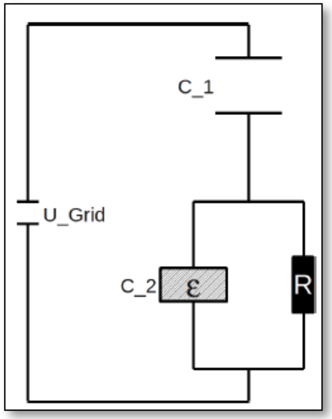
Comparison to Micromegas results



→Higher gain at lower voltages?
  → lowest gain ≈ threshold
  → inaccurate calibration for low gains
→ Gain drop with voltage
  → difference to Micromegas: SiProt

TimeOverThreshold
Influence of SiProt

Reason for lower gain: SiProt layer over anode. Look on single Pixel:
SiProt acts as capacitor that charges with avalanches and discharges over high resistance



$$\frac{dQ}{dt} = G\,f - \frac{Q}{RC}$$

$$G[C](U_{\mathrm{Si}}) = e\exp(A + B \times \Delta U)$$

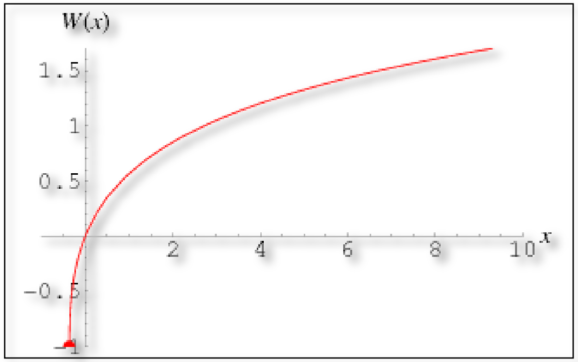
$$\Delta U = U_{\mathrm{grid}} - U_{\mathrm{Si}}$$

$$\frac{U_{\mathrm{Si}}(t\to\infty)}{R} = G(U_{\mathrm{Si}}(t\to\infty))\,f \Rightarrow \frac{U_{\mathrm{Si}}(t\to\infty)}{R\,f\,e} = \exp(A + B \times (U_{\mathrm{grid}} - U_{\mathrm{Si}}(t\to\infty)))$$

f = avalanche frequency, Q=C·U
G = number of electrons per avalanche
R = resistance of SiProt
C = capacitance of SiProt

$$U_{\mathrm{Si}}(t\to\infty) = \frac{W(B\,R\,f\,e\,\exp(A + B \times U_{\mathrm{grid}}))}{B}$$

W: Lambert W-function



$$\tau = RC = \varepsilon_0\,\rho\,\varepsilon$$

	a-Si:H	Si_3N_4
$\rho/[\Omega\,\mathrm{cm}]$	10^{11} [2]	10^{14} [3]
ε	11.8 [1]	7.5 [3]

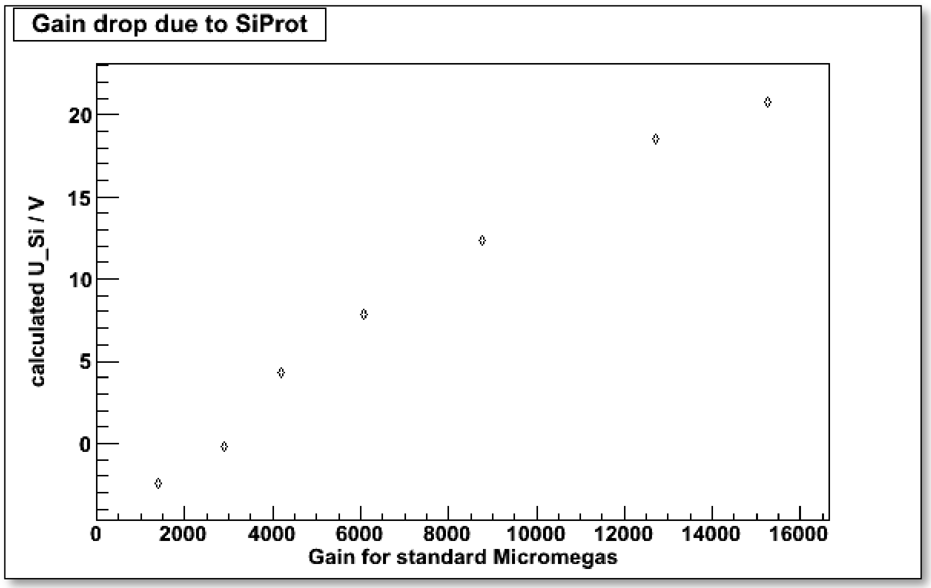
$\Rightarrow \tau \approx 1$ min

[1] S. C. Deane and M. J. Powell, Field-effect conductance in amorphous silicon thin-film transistors with a defect pool density of states, Journal of applied physics 1993, vol. 74, no11, pp. 6655-6666
[2] M.A. Chefdeville, Development of micromegas-like gaseous detectors using a pixel readout chip as collecting anode, Univ. of Twente, January 2009
[3] http://www.siliconfareast.com/sio2si3n4.htm

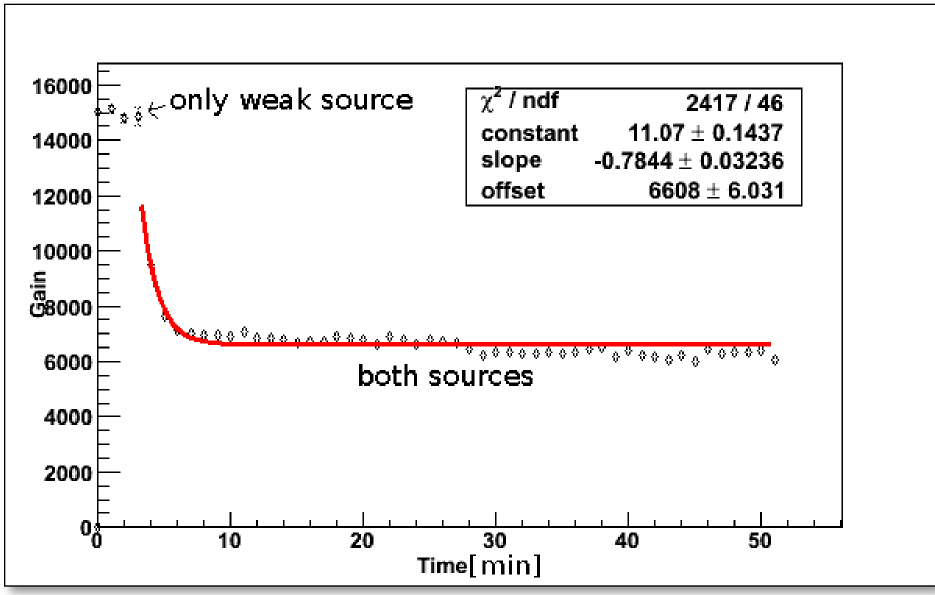
TimeOverThreshold

Influence of SiProt

Calculation of voltage on SiProt surface



Example for gain drop (charging of SiProt)



$$G = \exp\left(A + B \cdot U\right)$$

$$mean = G_{measured} = \exp\left(A + B \cdot \Delta U\right)$$

$$\Rightarrow \Delta U = \frac{\ln(mean) - A}{B}$$

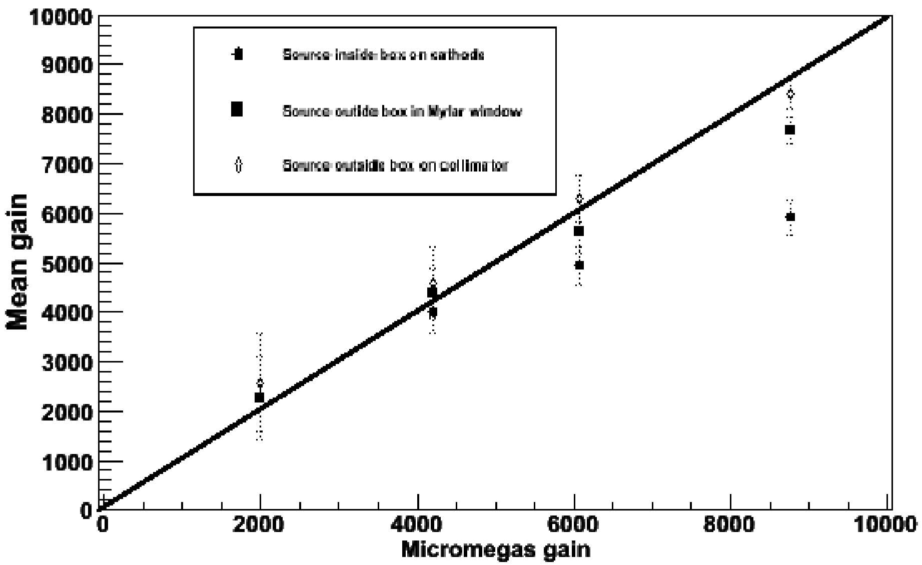
$$U_{Si} = U - \Delta U$$

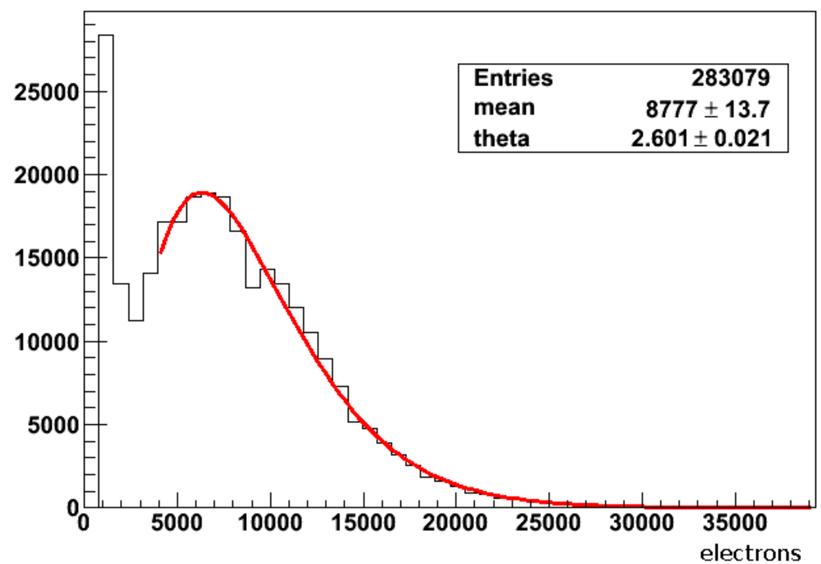
$$U_{Si} = \frac{W\left(B \cdot f \cdot R \cdot G\right)}{B}$$

Put on second, stronger source during measurements:
Gain drop from 15000 to 6600 with τ = 1.27±0.05 min

TimeOverThreshold

Low rate measurements





Place source further away from detector
-> inside detector (high rate)
-> outside detector box (low rate)
-> outside detector box + collimator (highest rate)

InGrid gain approaches Micromegas gain

Measurement at lowest rate
→ high gain
→ noise visible, as acq. time needs to be longer
→ $\Theta = 2.6$

Combined Measurement

Detection Efficiency

Comparison of theory and measurements assuming Polya distribution
Combine gain and primary electron measurements

From gain (TOT) measurements: Polya mean = gain

From primary electron (TIME) meas.:
number of prim. electrons,
117,9 electrons = 100 % det. Eff.

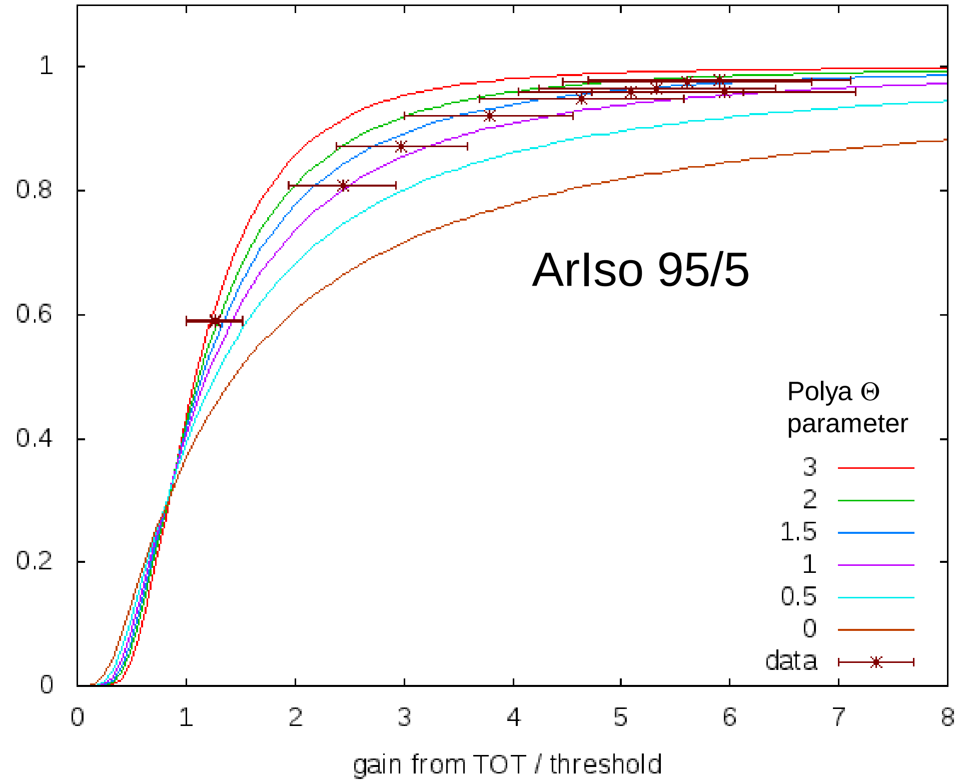
Detection efficiency:

$$\kappa(m, G, t) = \int_t^{\infty} \frac{m^m}{\Gamma(m)} \frac{1}{G} \left(\frac{g}{G}\right)^{m-1} \exp\left(-m\frac{g}{G}\right) dg$$

$m = \Theta + 1$
Threshold: t=1150 electrons

$\Rightarrow$ $0.5 < \Theta < 2$

[1]



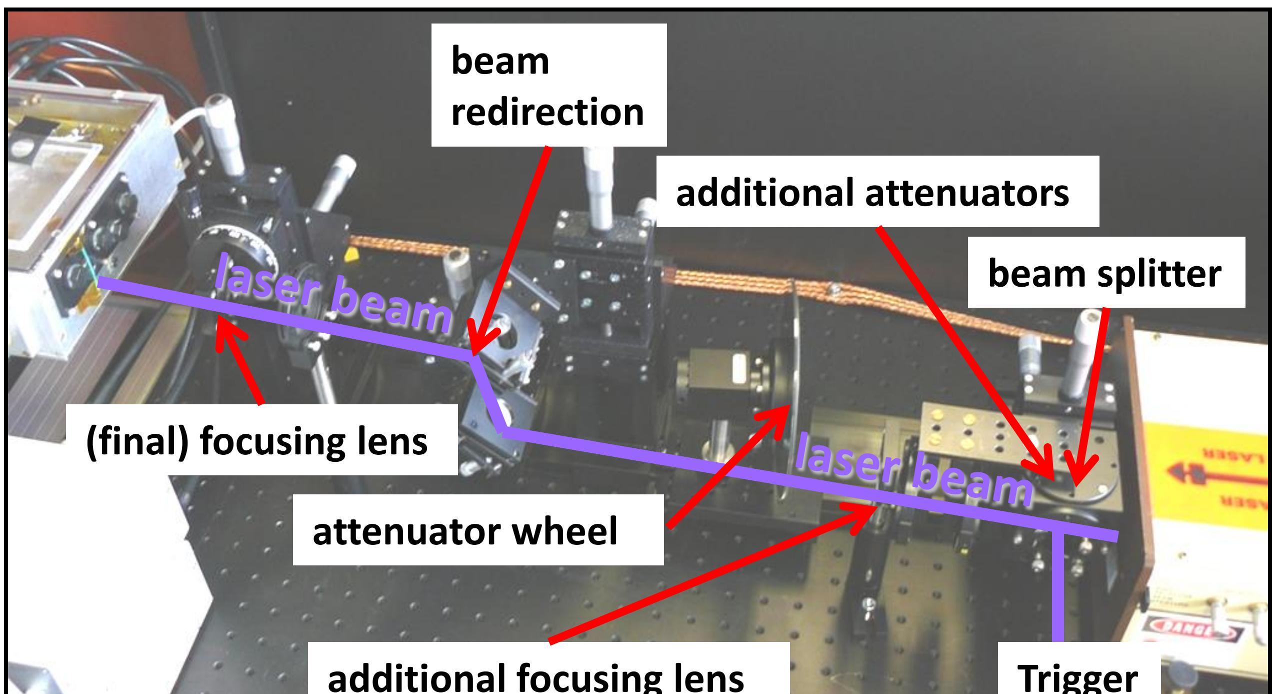
[1] Max Chefdeville, Development of Micromegas-like gaseous detectors using a pixel readout chip as collecting anode

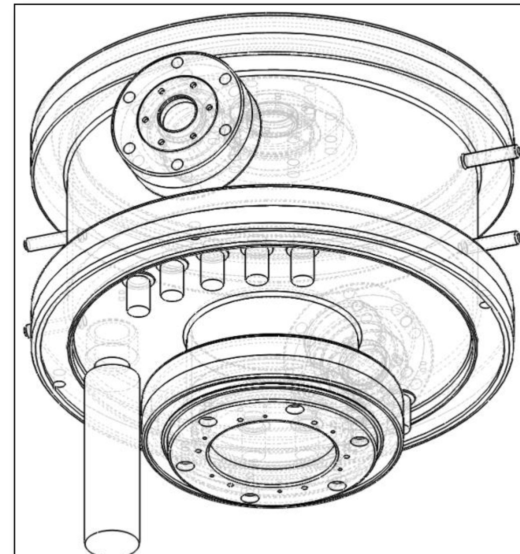
TimeOverThreshold

Laser measurements

Quantitative measurements of gain – rate dependence

- Use (pulsed) LASER test bench and gas box in Freiburg
  → photo effect on cathode, few electrons
  → defined frequency and position of primary electrons
  → temperature und pressure registration



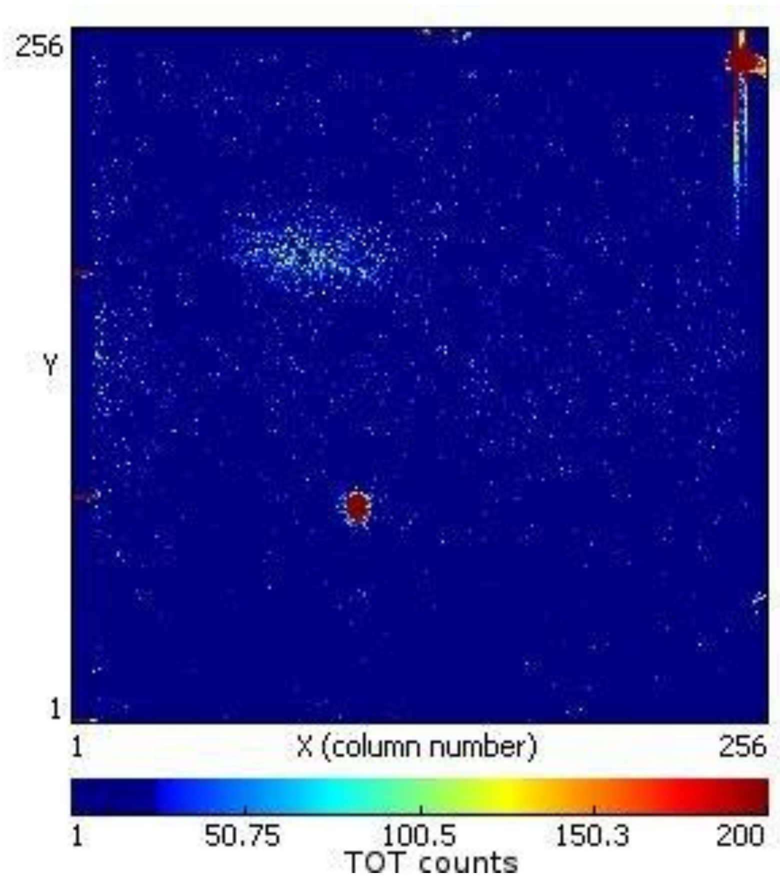


Measurement program:

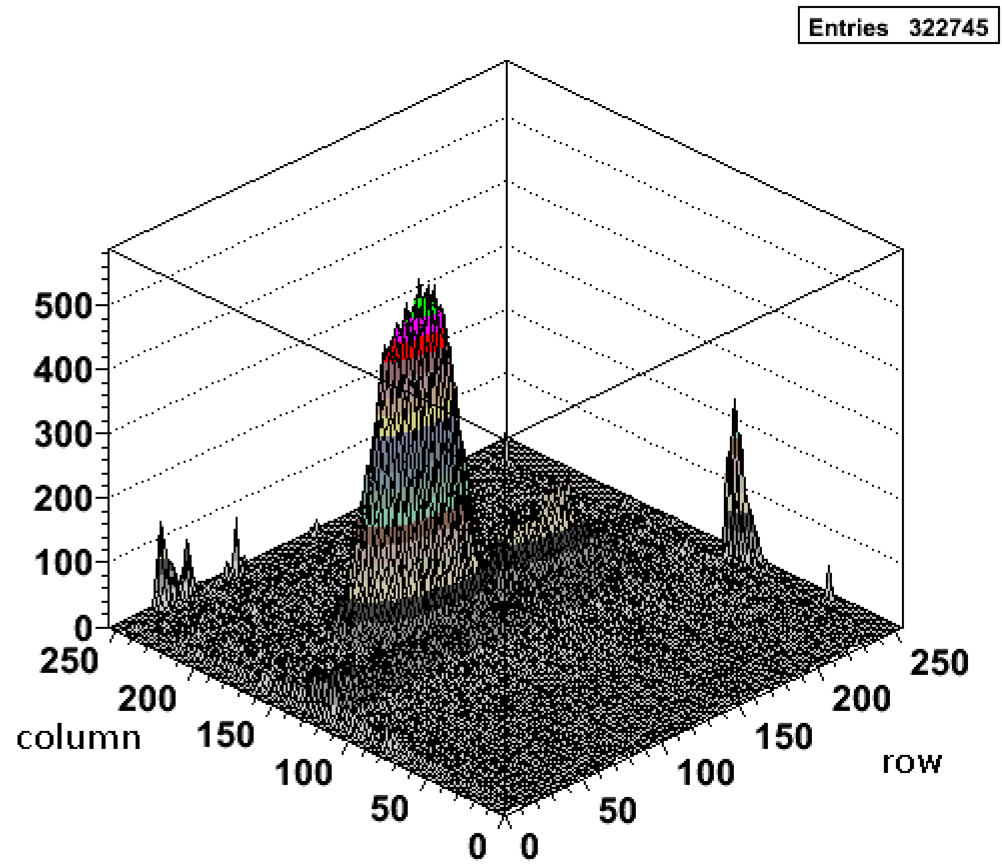
- TIME mode:
  → drift velocity
  → electron counting
- TOT mode:
  → charging effect of SiProt
  → surface scan

TimeOverThreshold

Laser measurements



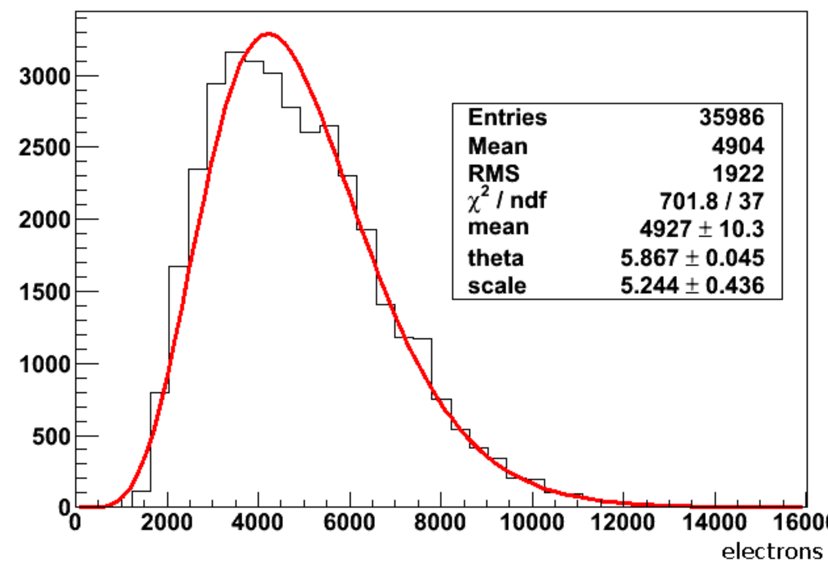
Problem: leakage current from grid to chip charges SiProt, reduces gain
⇒Quantitative G(f) measurements not possible, hot spots masked

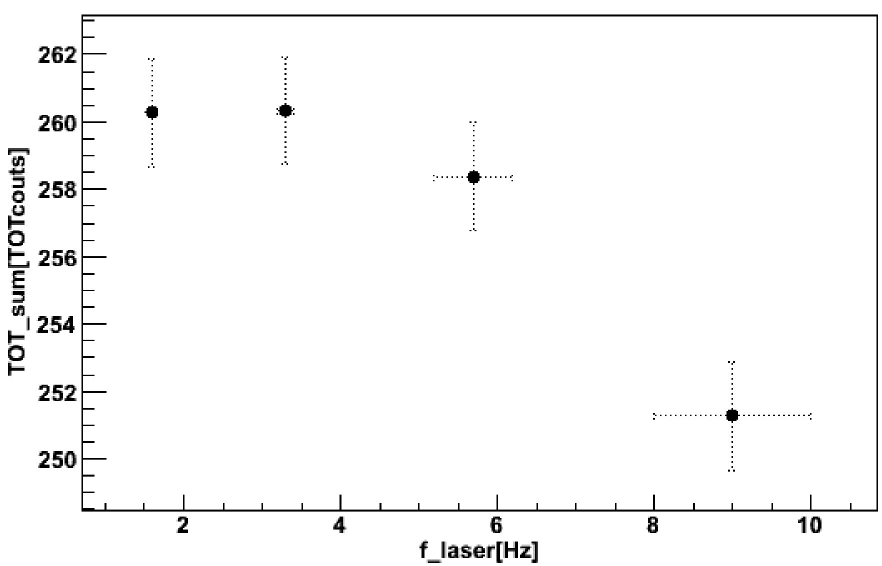


Hit pixels in one run: LASER focus on chip, discharges at grid border

TimeOverThreshold
Laser measurements

Photo electrons per LASER pulse:
Poisson distributed: mean ≈ 4





Gain spectrum:
→Mean ≈ 56 % of Micromegas gain
→Narrow distribution (high Θ)
Could be due to problems with recent TOT calibration (under study)

Data indicates gain drop for higher LASER repetition rates (not as clear as for 55Fe sources)

Conclusion

<u>Fe55 spectra (primary electron counting):</u>

- 97.8% single electron detection efficiency was reached in ArIso 95/5 with 117.9 ± 0.7 electrons in escape peak.
- A resolution of 9,73% FWHM was reached for the photo peak leading to a upper limit for the Fano factor of 0.26.

<u>TOT mode (gain measurements):</u>

- TOT mode can be used to measure the gain of a TimePix InGrid detector.
- Effects of the SiProt layer have to be taken into account:
  - reduces gain
  - SiProt layer can be modeled by a not perfect capacitor
  - measured time constant of capacitor $\approx$1 minute as predicted by model.
- Θ value between 0.5 and 2. for gains from 2000 to 5000.
- Pulsed LASER used to produce primary electrons by photo effect. Problems with Ingrid prevented gain measurement. Avalanche rate dependence of gain could not be analysed quantitatively.

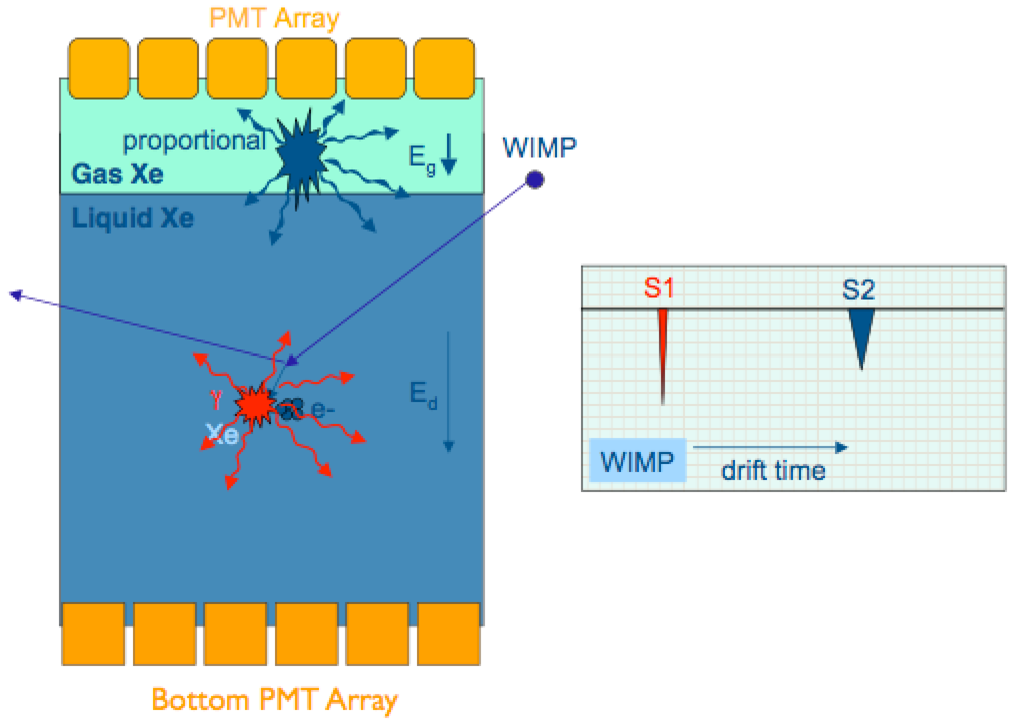
WIMP search, bi-phase Xenon

- GridPix TPC

as

WIMP / DBD

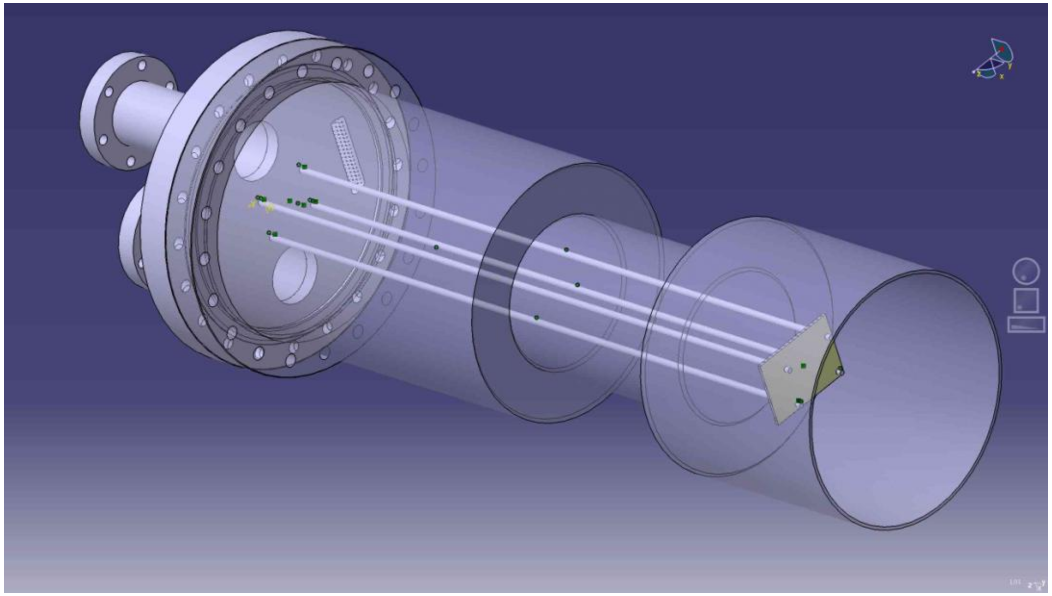
detector



Source: Direct Searches for Dark Matter, Elena Aprile, EPS - HEP, July 21 2009, Krakow, Poland

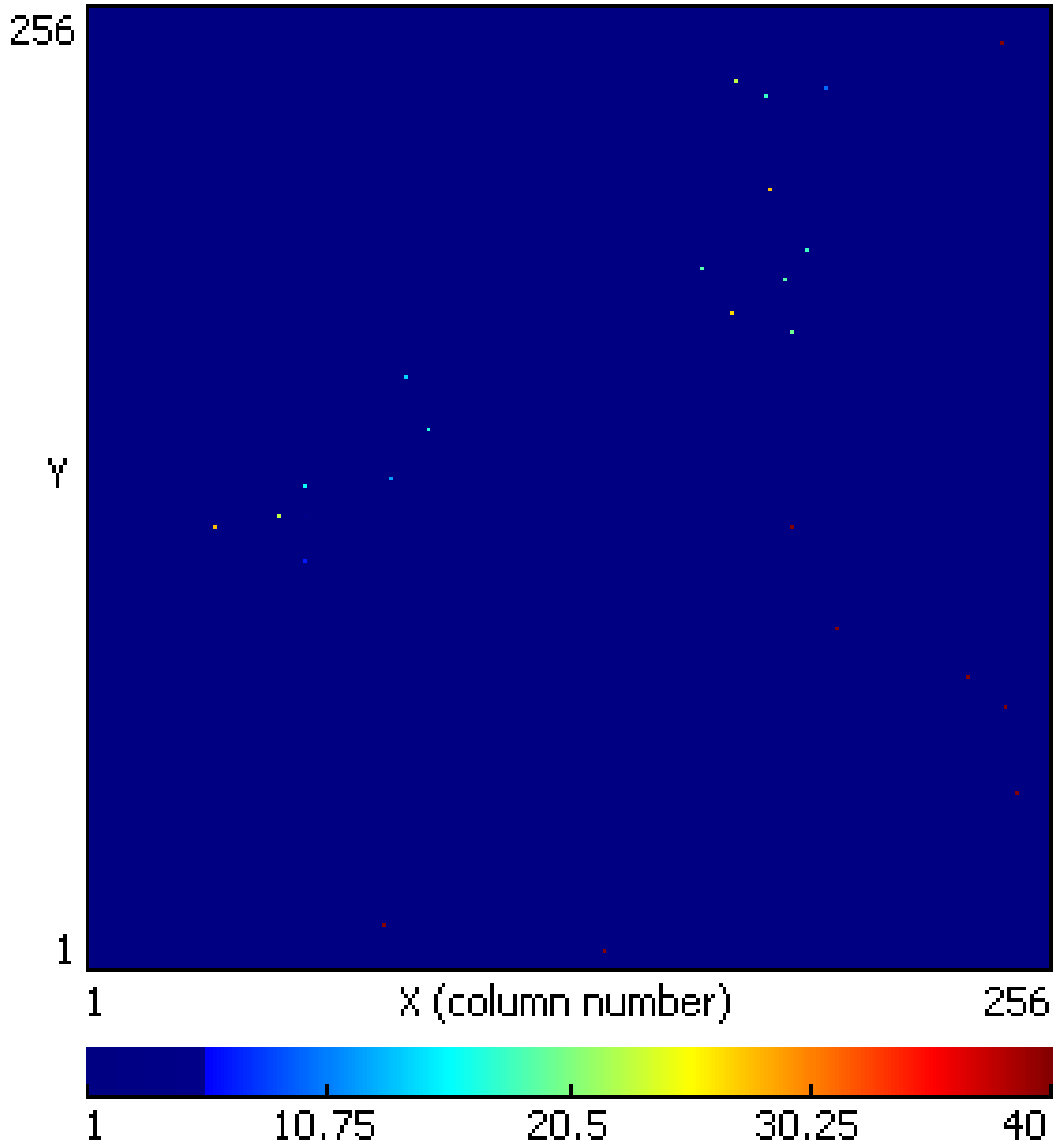
Gridpix in Xenon: Test setup

- Collaboration DARWIN/XENON
  Columbia Univ., N.Y.



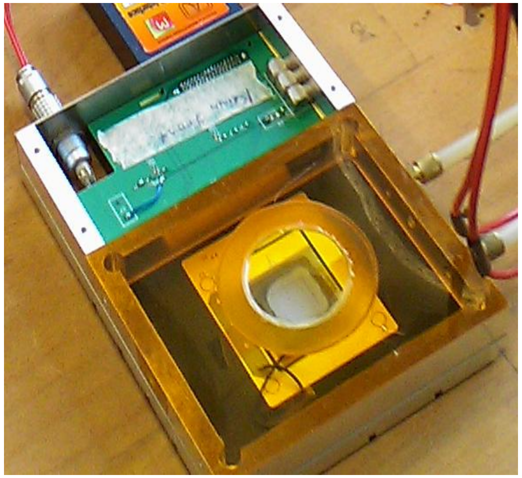
55Fe in pure argon,
HVgrid = 340 V
P = 1 bar
T = -70 C
at NLR cryostat

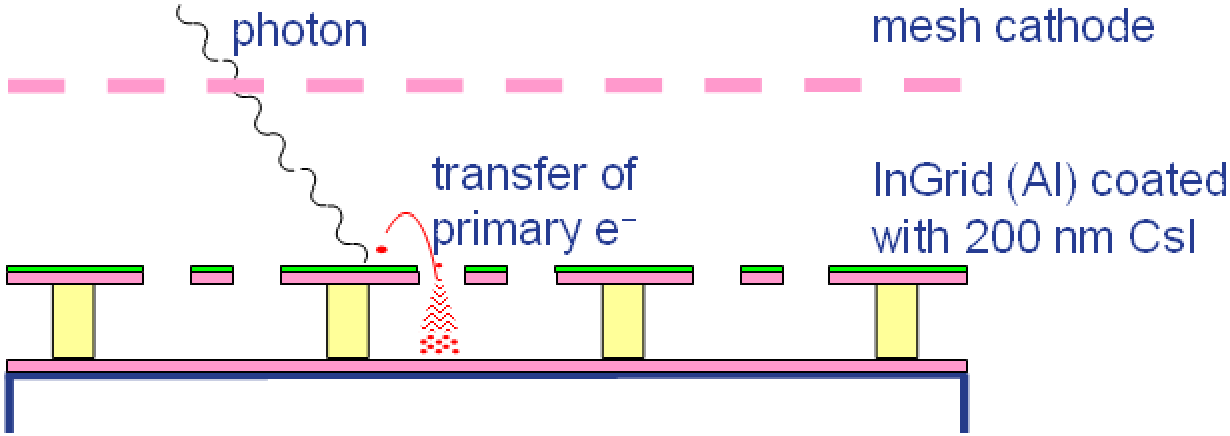
gain: ~ 200 !

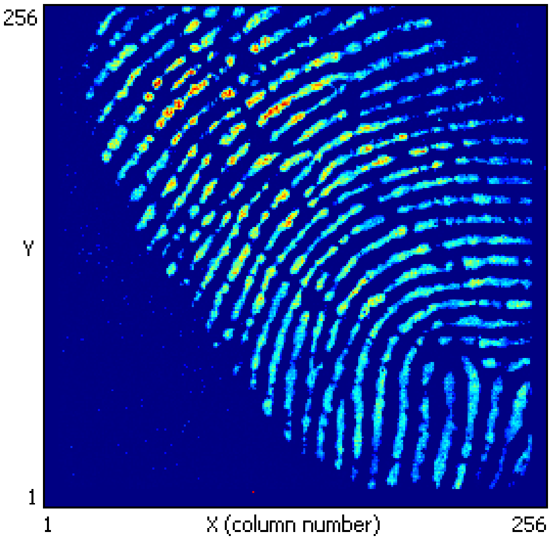


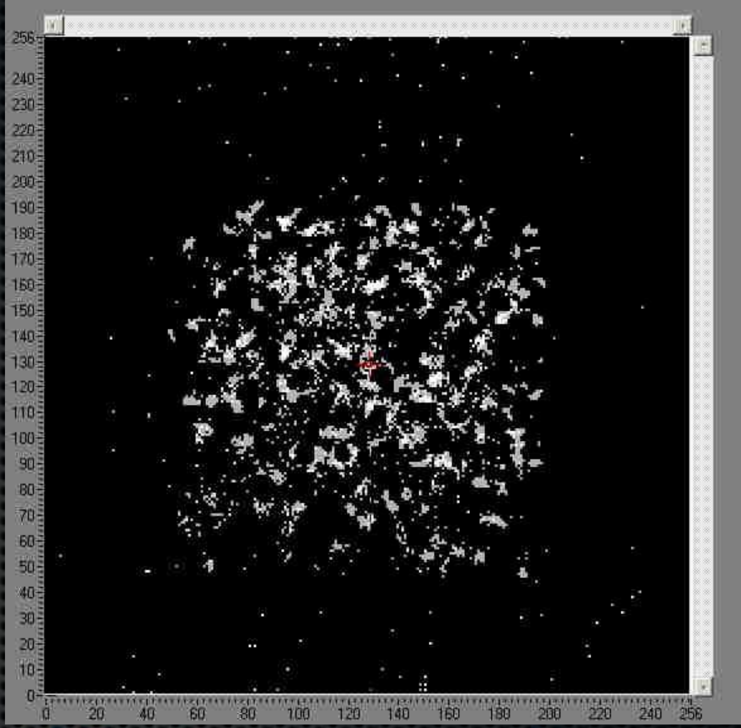
Expanding GridPix?

- Photoelectric effect
- Future possibility:
  CsI layer on grid









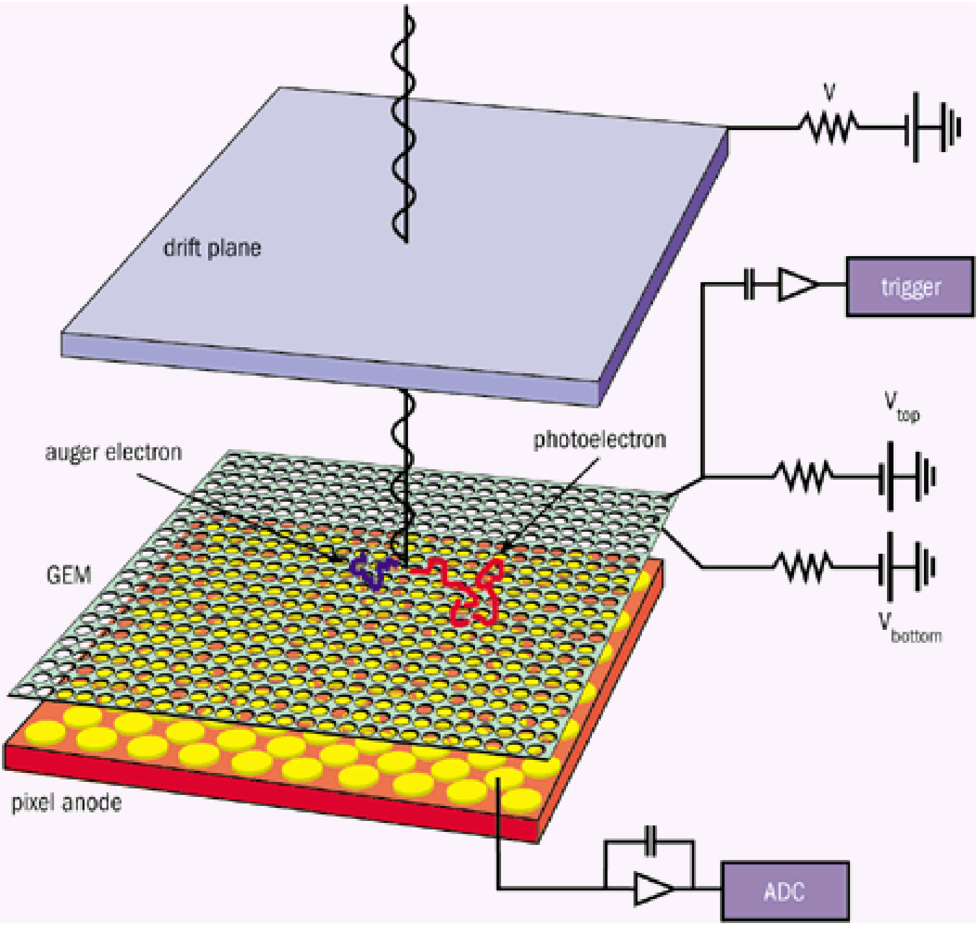
PolaPix

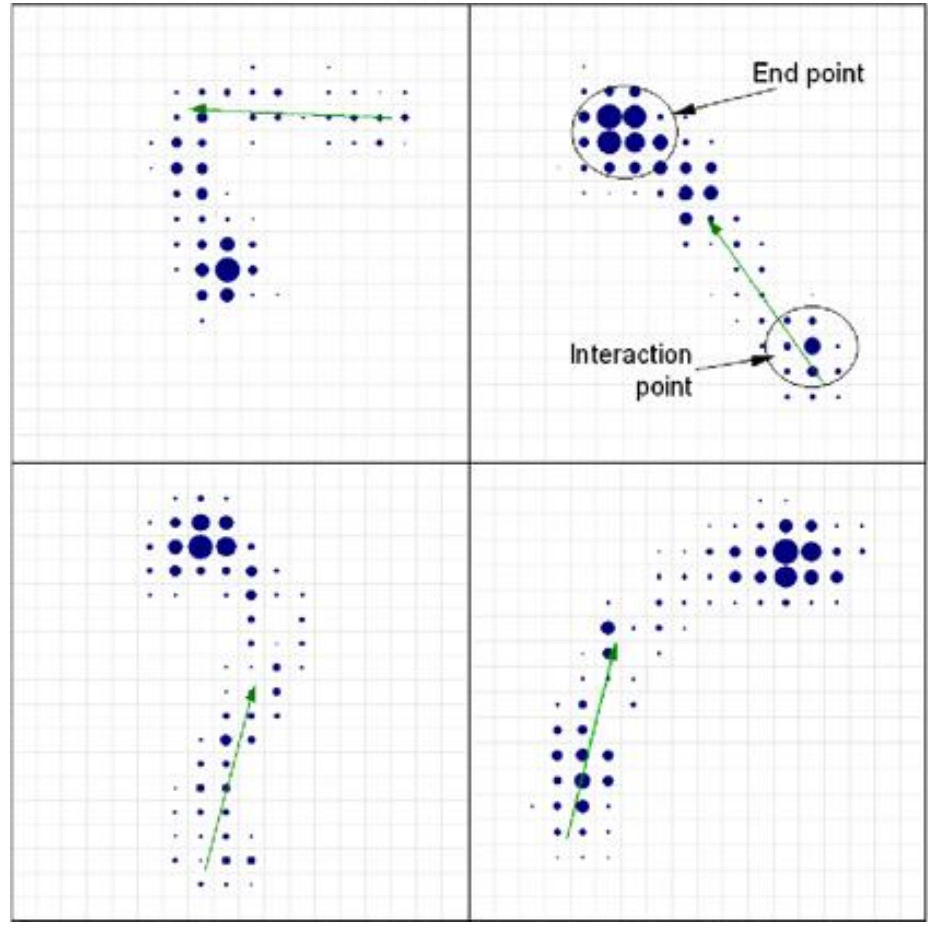
Using a GridPix detector for the 3D detection of polarized X-ray photons

Sjoerd Nauta - Nikhef

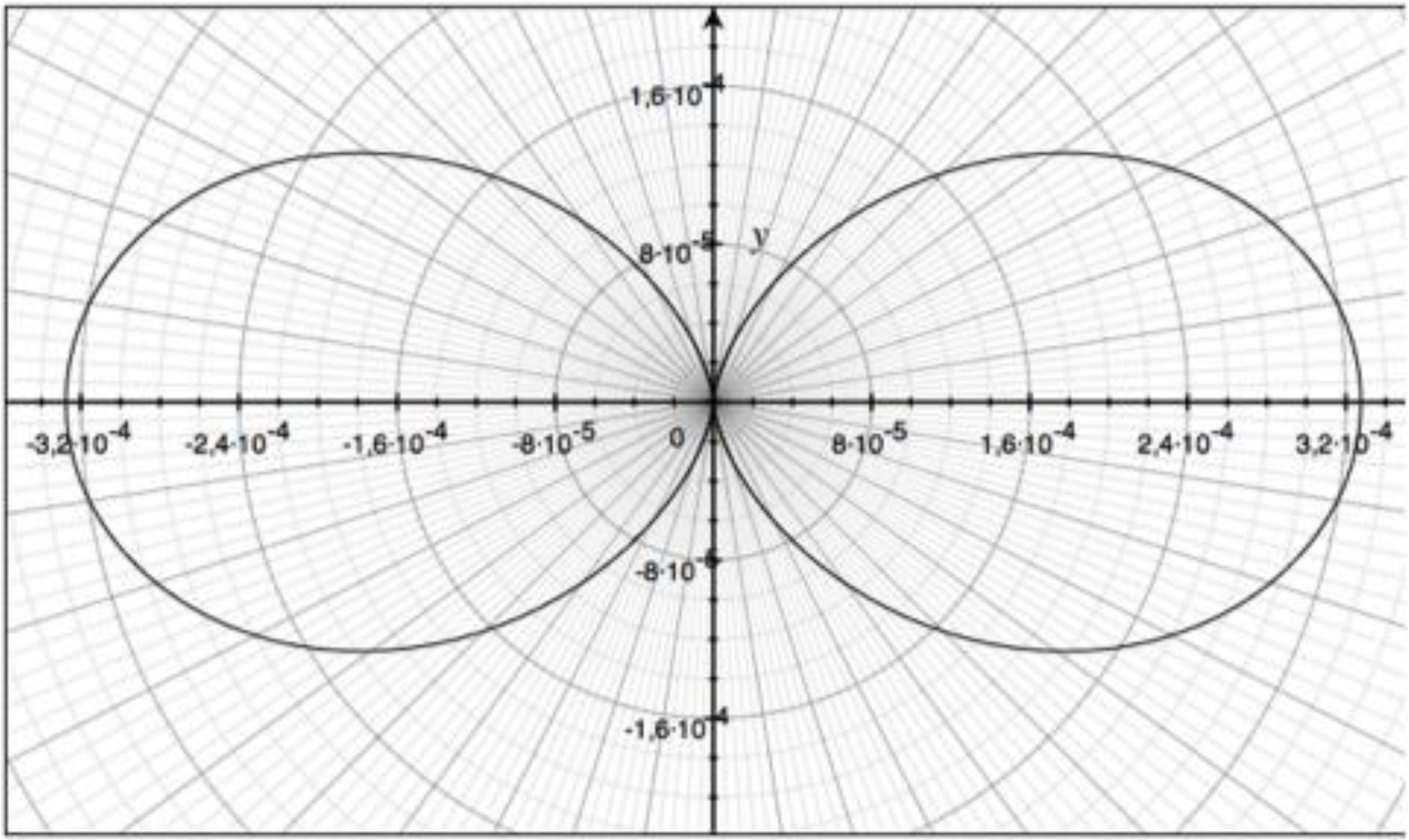
NIKHEF

TUDelft





X-ray Polarimeter proposed by R. Bellazzini



Distribution of direction of photo-electron of (fully) polarised X-rays

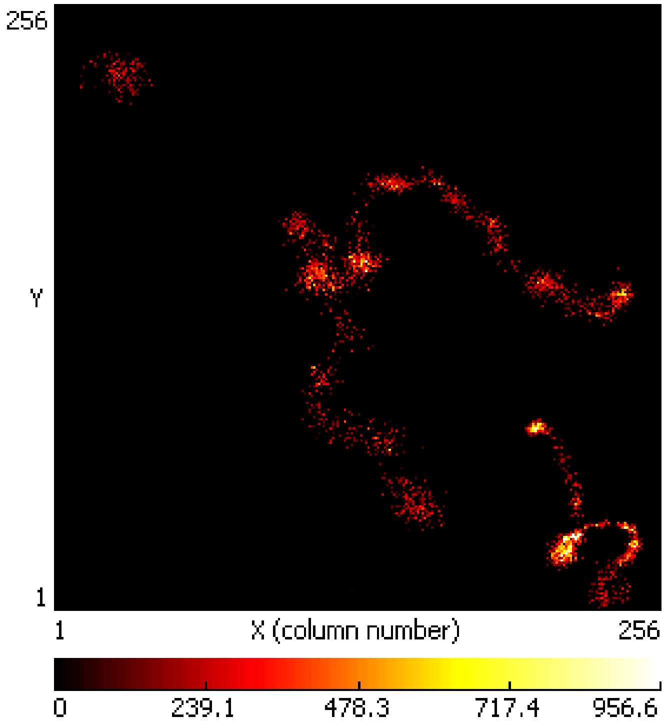
With ECAP/University of Erlangen

PolaPix

GridPix as (gas-filled) photon detector for applications in space observatories via tracking photo-electron or Compton-electron. Measurement of

- photon energy
- photon direction
- polarisation

in the range of 1 – 511 keV photons



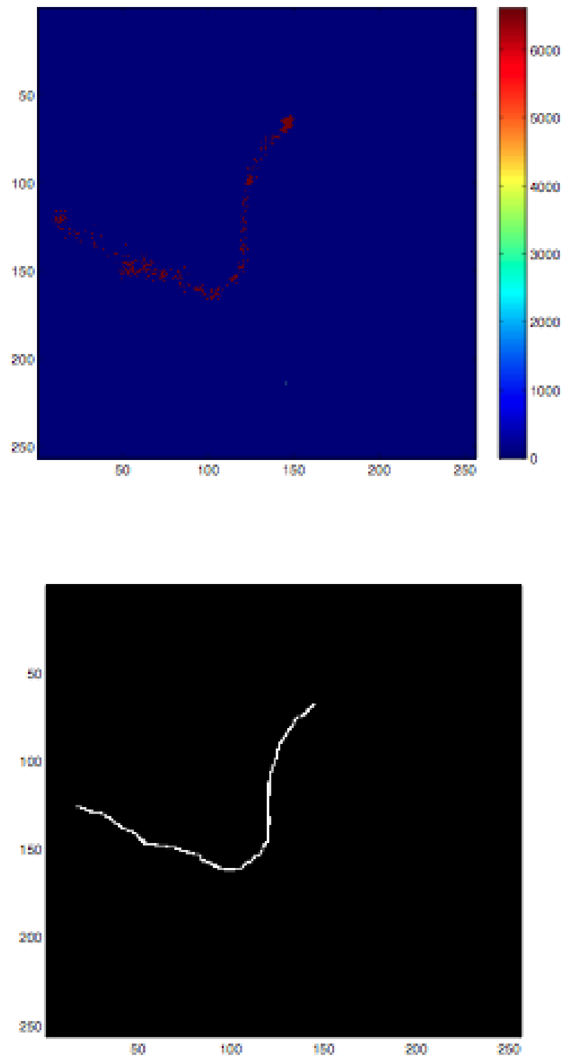
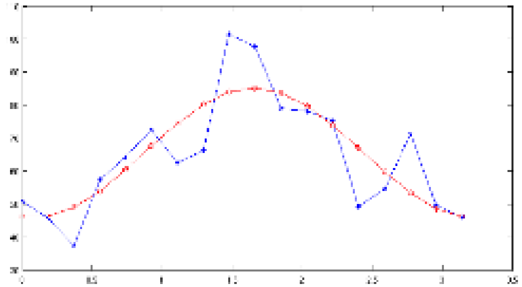
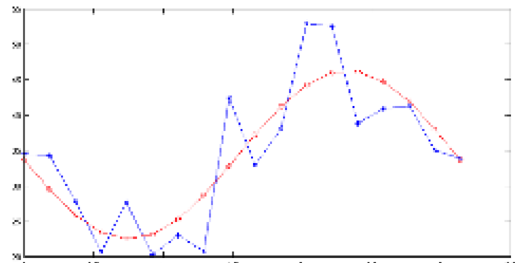


Figure 4.11: An example of a skeletonized track. On the left, the original measurement is shown, on the right the skeletonized version of the same track is shown. This picture has been made by the group at the university of Erlangen.

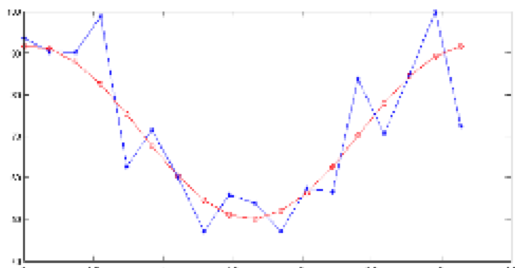
photo-electron
after photon interaction



(a) Detector at 0 degrees



(b) Detector at 45 degrees

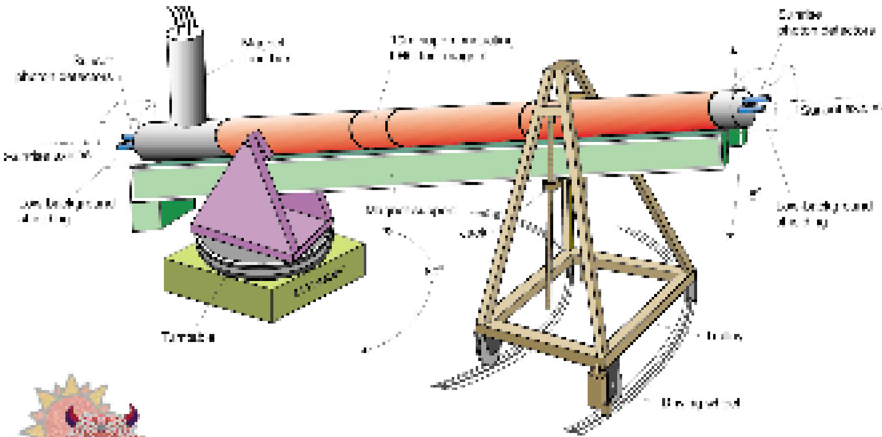


(c) Detector at 90 degrees

Figure 4.12: Distribution of angles of the polarized measurement data determined by analysis with the skeletonization algorithm (this analysis was done in Erlangen). The determined phases and asymmetries were: for 0 degrees: 3.5°, 29.4 %; for 45 degrees: 46.6°, 34.5%; for 90 degrees: 85.2°, 29.7 %. The plots were made by the astroparticle physics group in Erlangen. To make these plots, the data was corrected by using the angular distribution of a run made with an (unpolarized) Americium source. A correction factor was determined for each bin.

measured polarisation (beams was ~ 90 % polarized)

Ingrid for CAST



Cern Axion Solar Telescope

Special attention on:

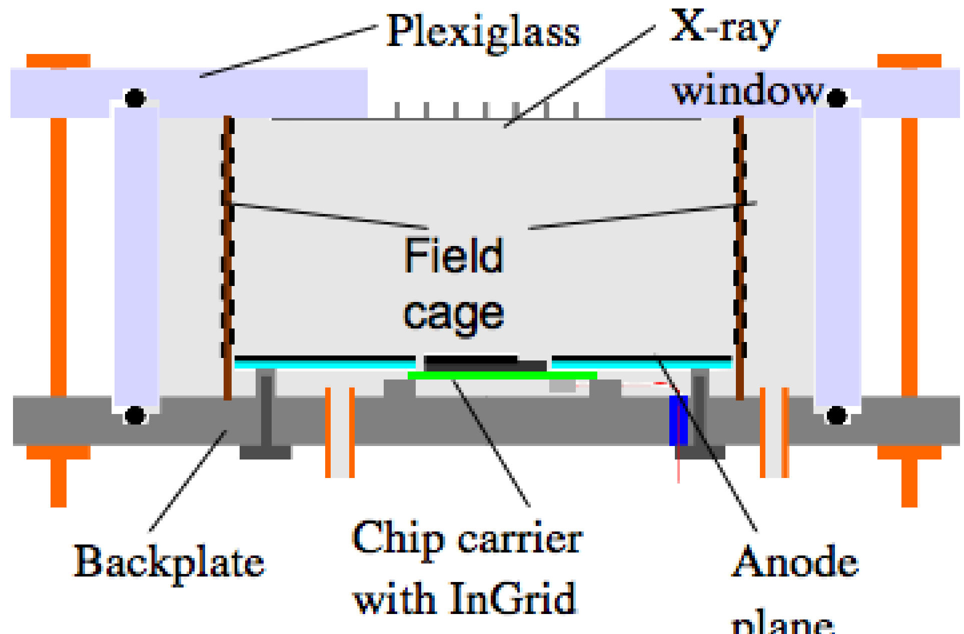
- As little copper as possible
- Radiopurity of materials

When construction is finished:

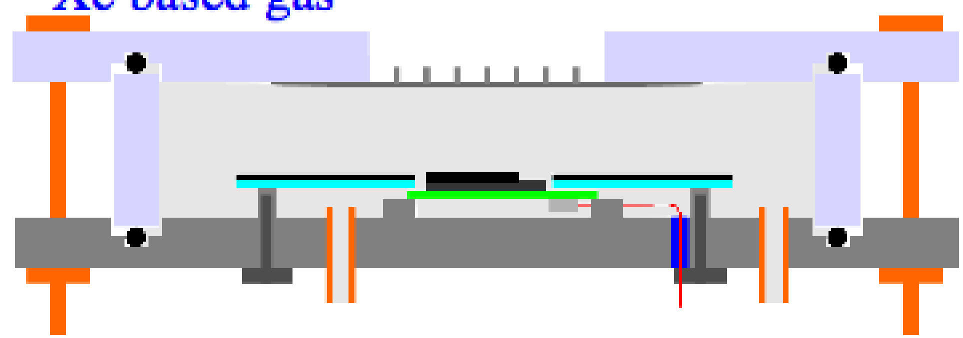
- Background rates
- X-ray spectra
- Study n background

Two detectors under discussion:

- 3 cm drift distance, field cage, Ar based gas



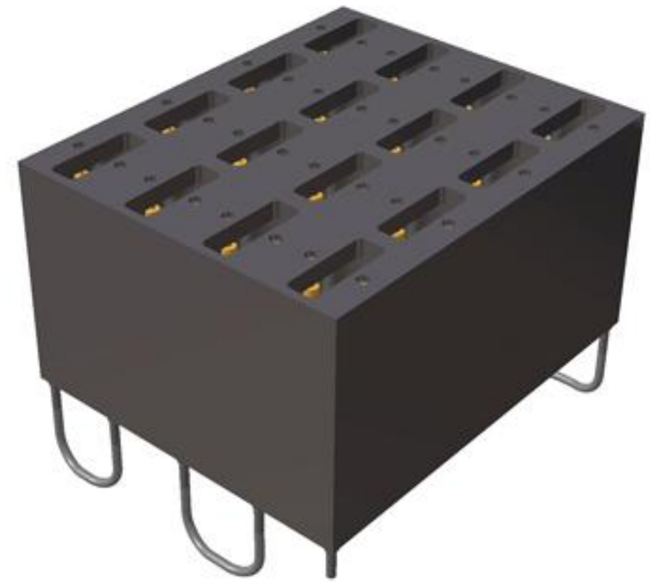
- 1 cm drift distance, without field cage, Xe based gas

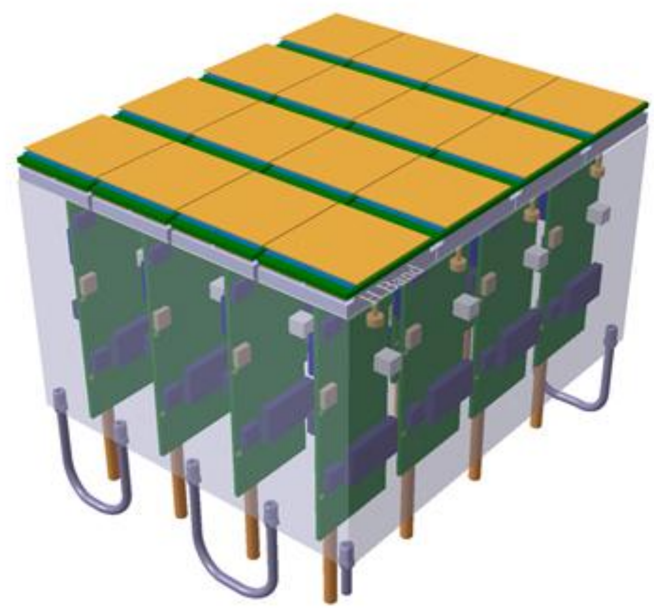


Testbeam Aug 2010: ReLaXd readout for Medipix/TimePix works

Next-64 / ReLaXd / ReNexd

CO_2 cooling!





Development of miniHV at Nikhef

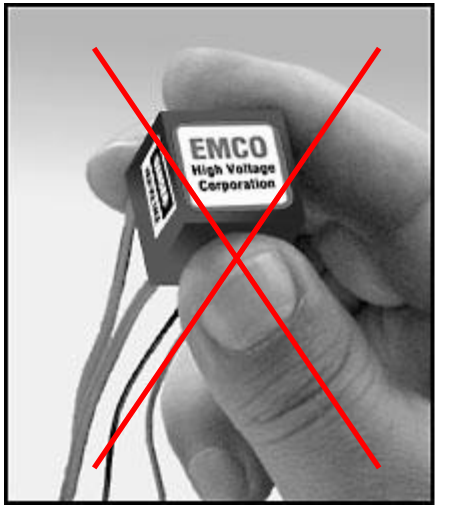
Small HV modules for laboratory use

Henk Boterenbrood, Harry van der Graaf, Henk Groenstege, Ruud Kluit, Fred Hartjes and Jaap Kuijt

6th RD51 Collaboration workshop
Bari, 9 October 2010

Why developing HV power supplies?

- Getting a HV supply that is dedicated for gaseous detectors
  - Fast trip in sub µA region
  - Accurate current measurement in nA region
  - Small unit, not too expensive
  - Fast remote control
  - Gently ramping to target voltage

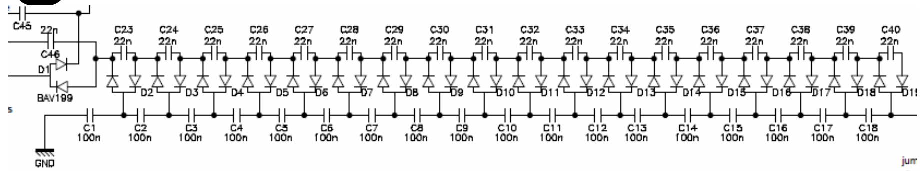


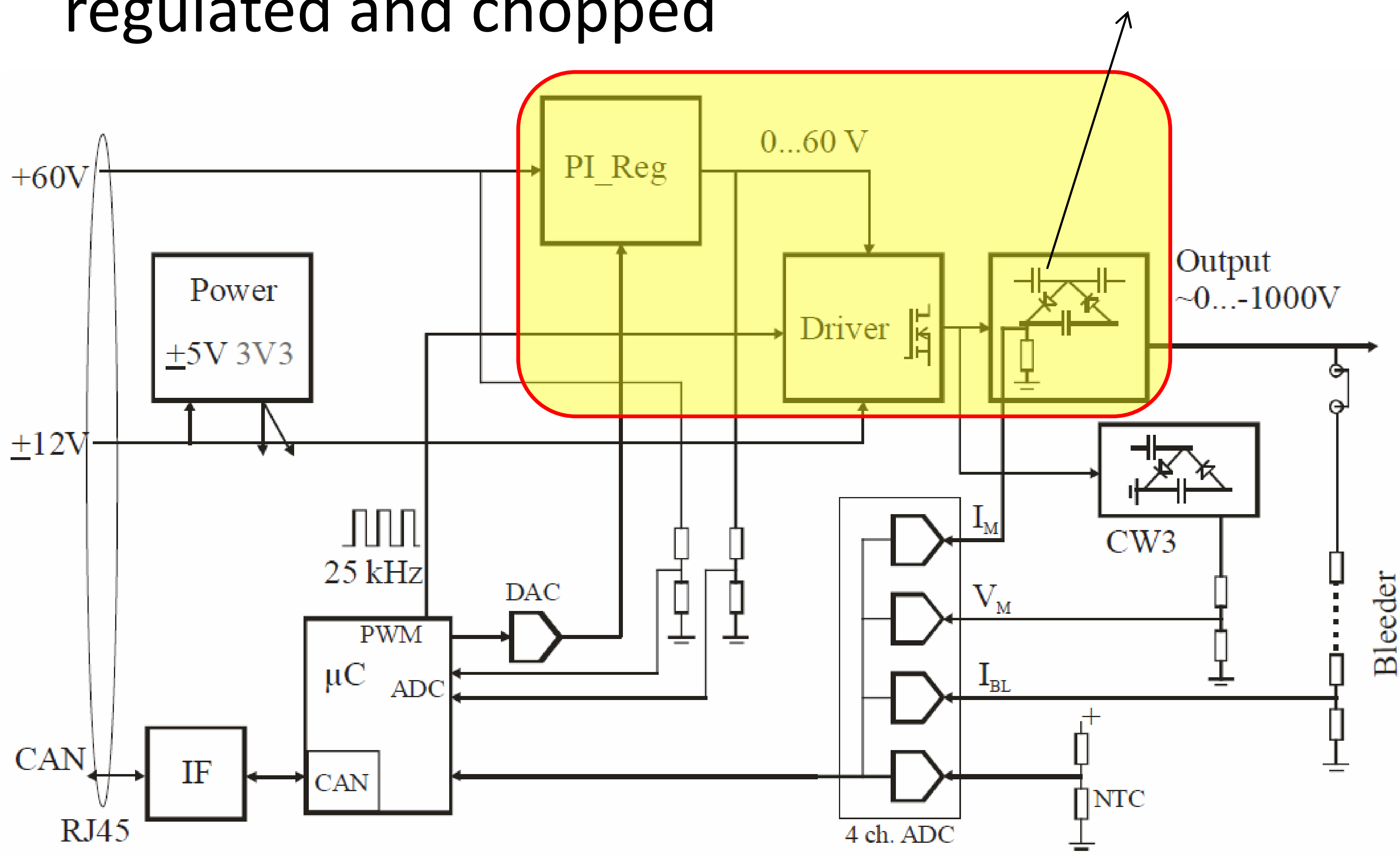
Preliminary specs of mini HV, version 2

- Current measurement by 24 bit ADC
  - => high dynamic range
- Communication by **CANopen** protocol
- Single RJ45 cable for CAN communication **and supply**

High voltage generation

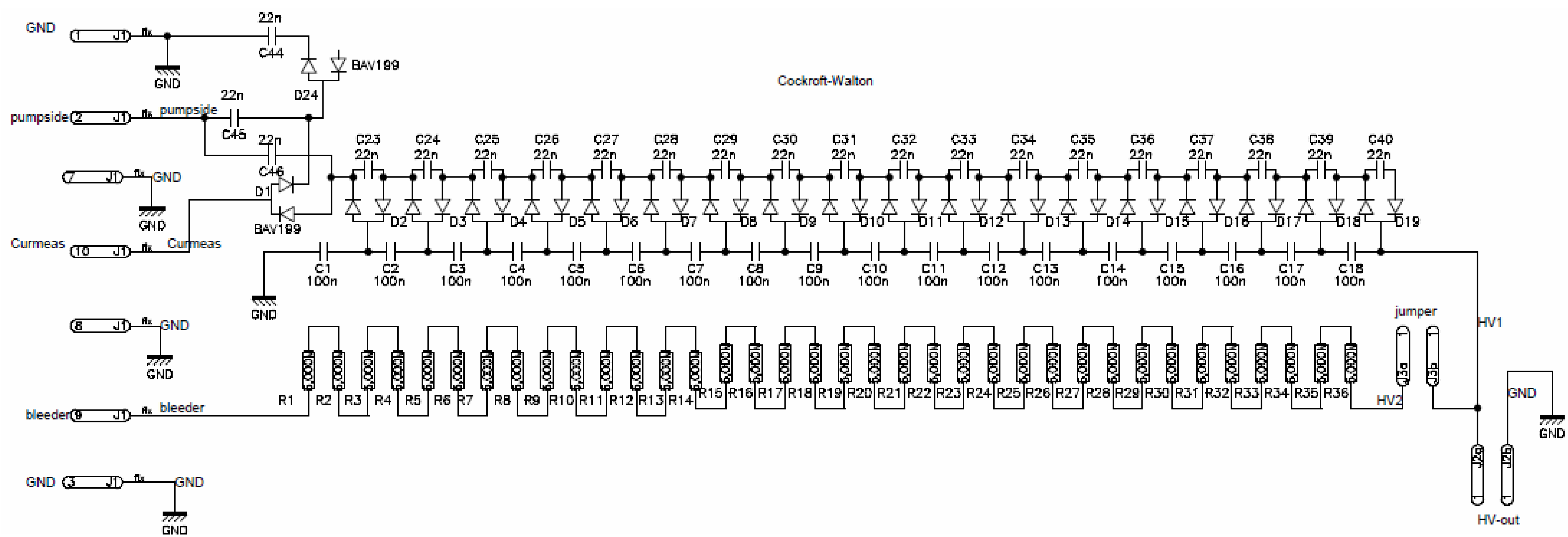
- 60 V input voltage regulated and chopped





Cockcroft-Walton circuit

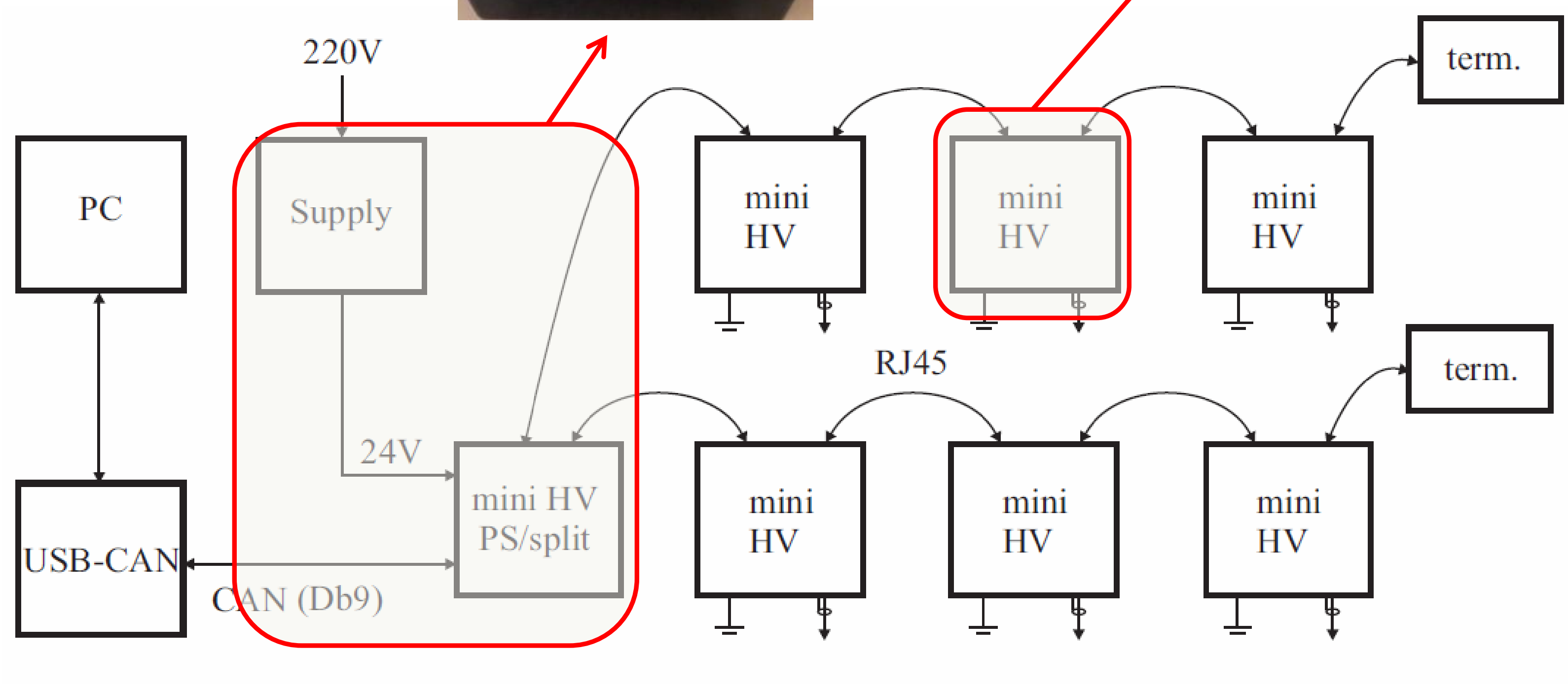
- In principle no feedback at end of diode chain, only from idle diode circuit
  - Regulation less direct, depending on diode



  - Bleeder current ~ 5 nA

CANopen communication to multiple mini HVs

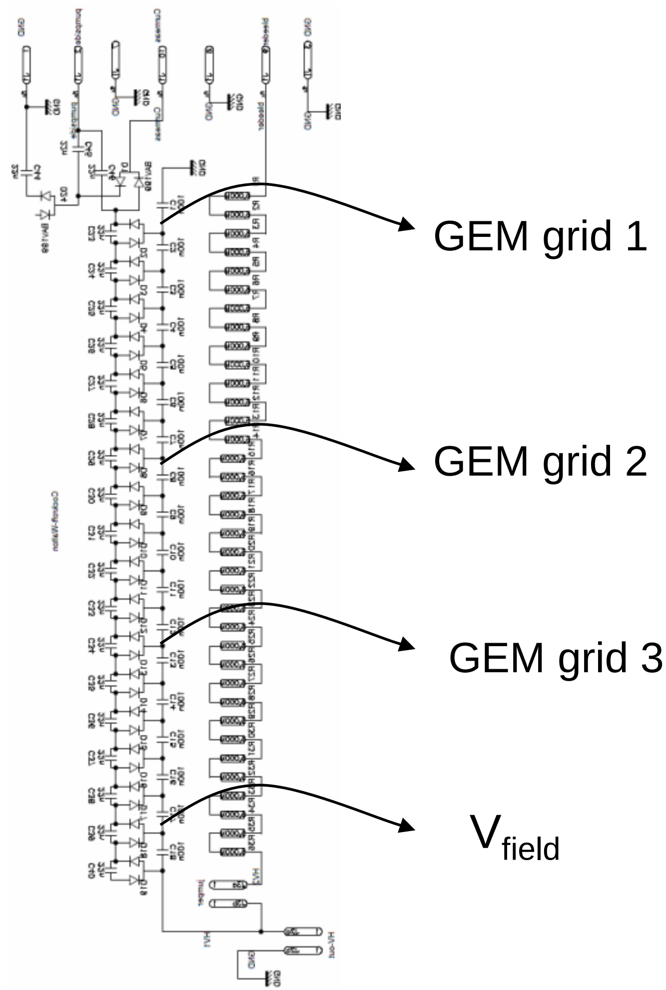
- Two RJ45 cables to supply up to V units



Ideas for other miniHV modules

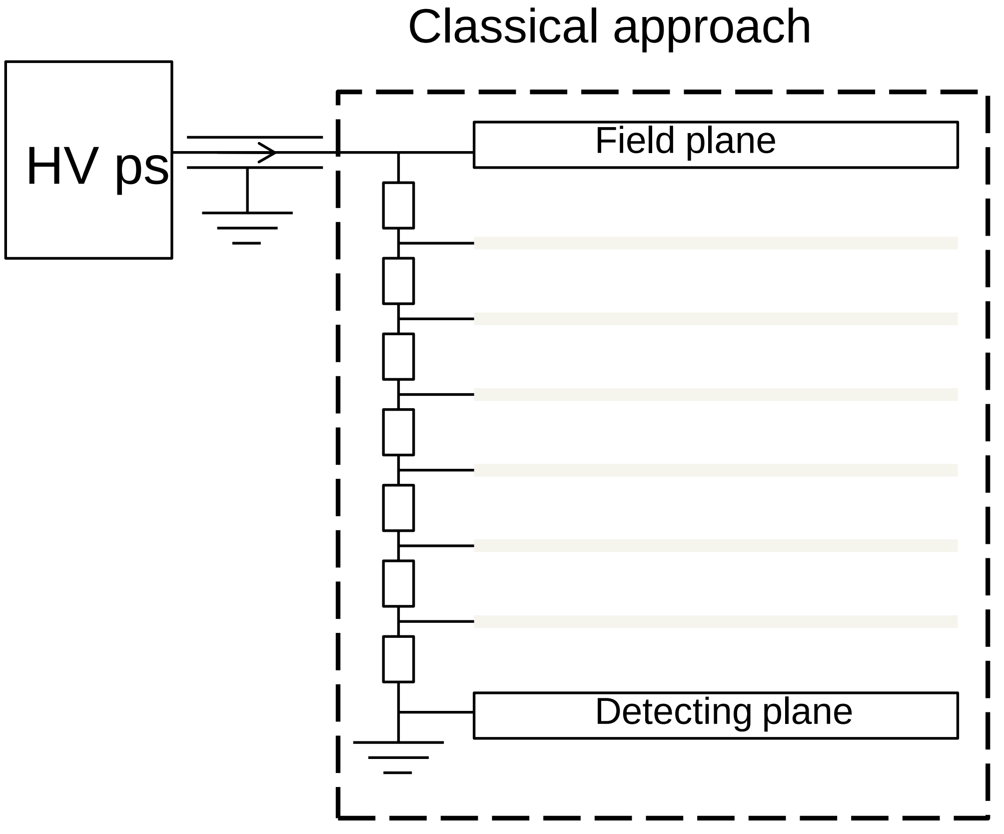
1. **-2000 V version**

2. **Single MiniHV** with 3 - 5 outputs (-3000 V?) from Cockroft Walton circuit for **triple GEM**
   – Regulating GEM voltages by selecting the desired CW



Filed cage for large TPCs

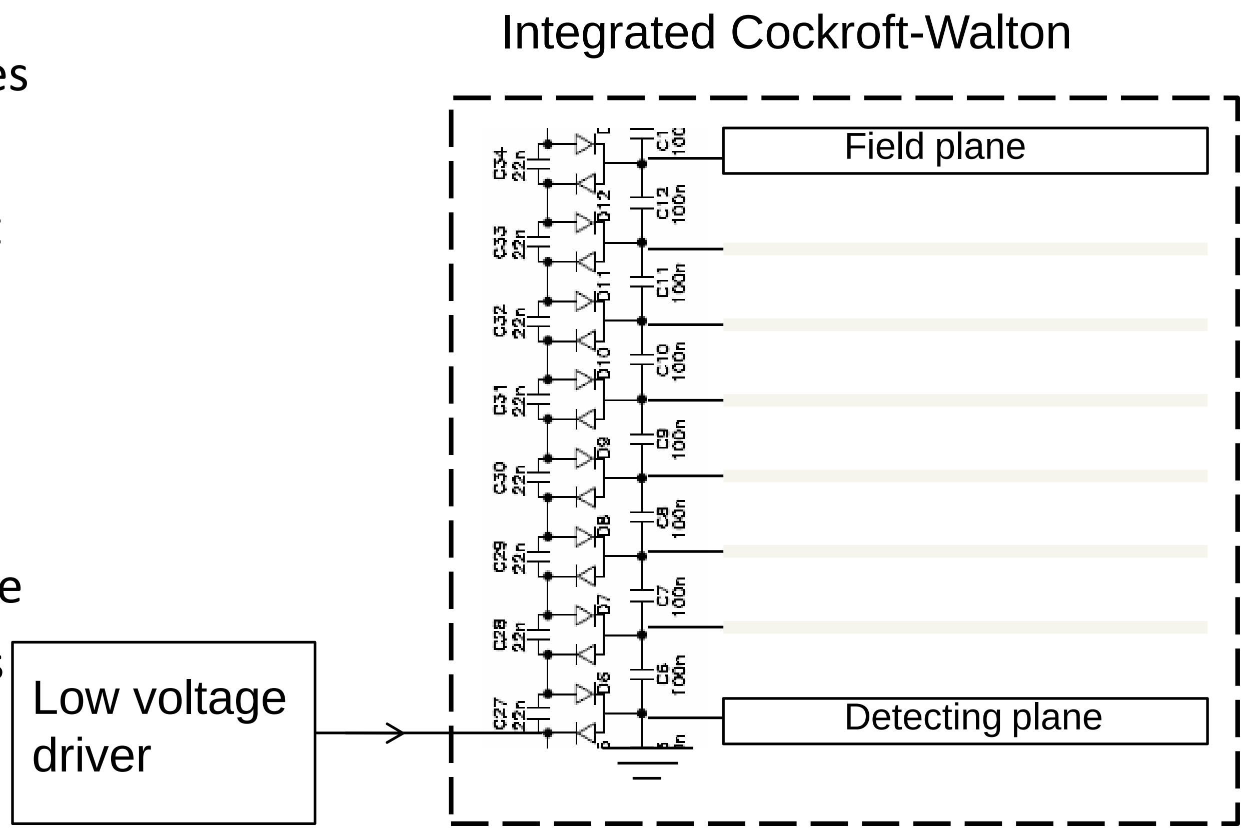
- Large TPC (1 m) requires very high voltage and low driftfield gas (CF4 mixtures)
  - Field shaping strips to define proper drift field
- Substantial HV needed



Integrating Cockroft Walton technology

- Cockroft-Walton chain integrated in field cage
  - No external HV lines
  - Only LV driver
  - No bleeder current
  - => low trip level possible

- HVs in 100 kV region relatively easy to realize
  - Everything remains within the cage structure



- change name GridPix in GasPix (Bellazzini's naming!)

- need to start up production of Victor/Yevgen InGrids

- need to do R&D for all-ceramic GridPix

- formulate problems of gas gain: influence of UV photon:

    - how can Ar/CO2 work in GasPix, while is causes multi-avalanches in ATLAS MDTs?
    - discharge quenching is now known, but
        - discharge sources/causes? high rate effects? Sharp edges?
        - Raether condition: rather empirical. Can we make a model?
        - Why is P10 (Ar/Methane 90/10) a MUCH good quenching mixture in GridPix?