Thick-GEM sampling element for DHCAL: First beam tests & more

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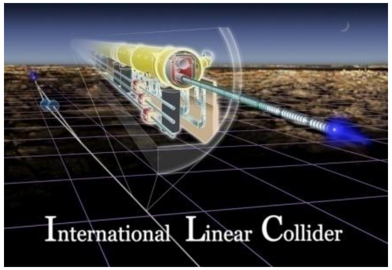
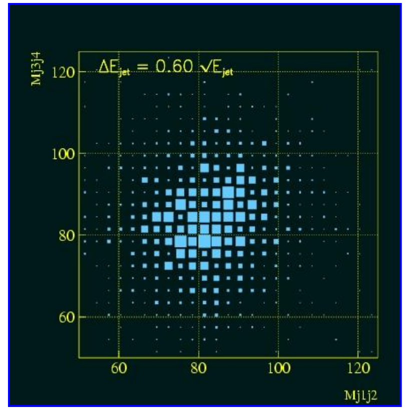
Digital Hadron Calorimetry for ILC



Precision studies of new physics

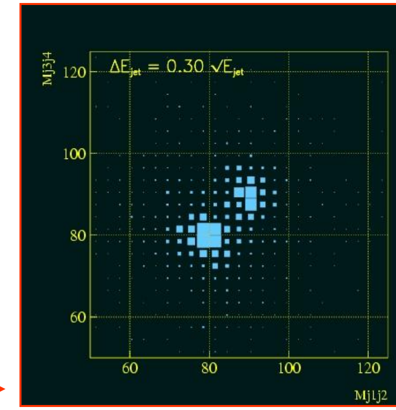
ILC: Separate W,Z boson masses on event-by event basis



60%/√E

Best JET resolution with traditional calorimetry

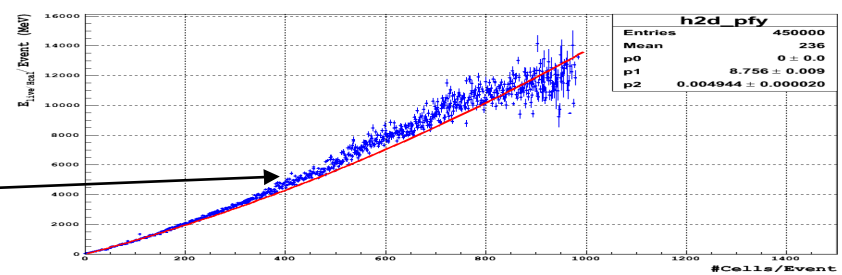
Need 30%/√E



Generally need σ/E_{jet} ~3-4%

Digital calorimetry

associate “hits” with charged tracks, remove hits, measure neutrals in calorimeter using **hits vs. energy**



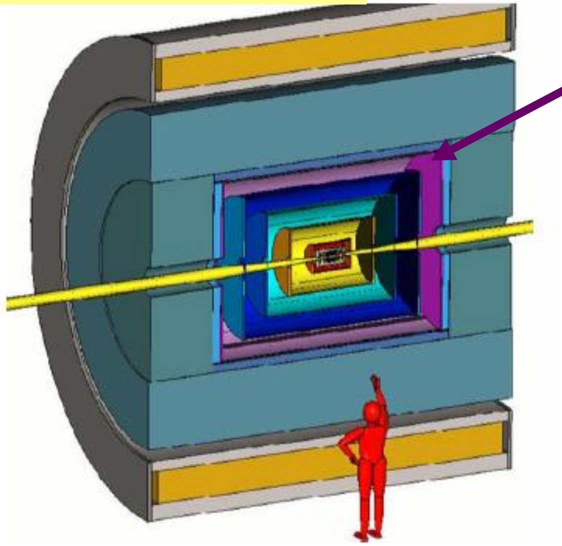
Particle Flow Algorithms now achieve the required energy resolution!

Requires thin, efficient, highly segmented, compact, robust medium,
(**competitors**: **D-GEM, Micromegas, RPC, THGEM**)

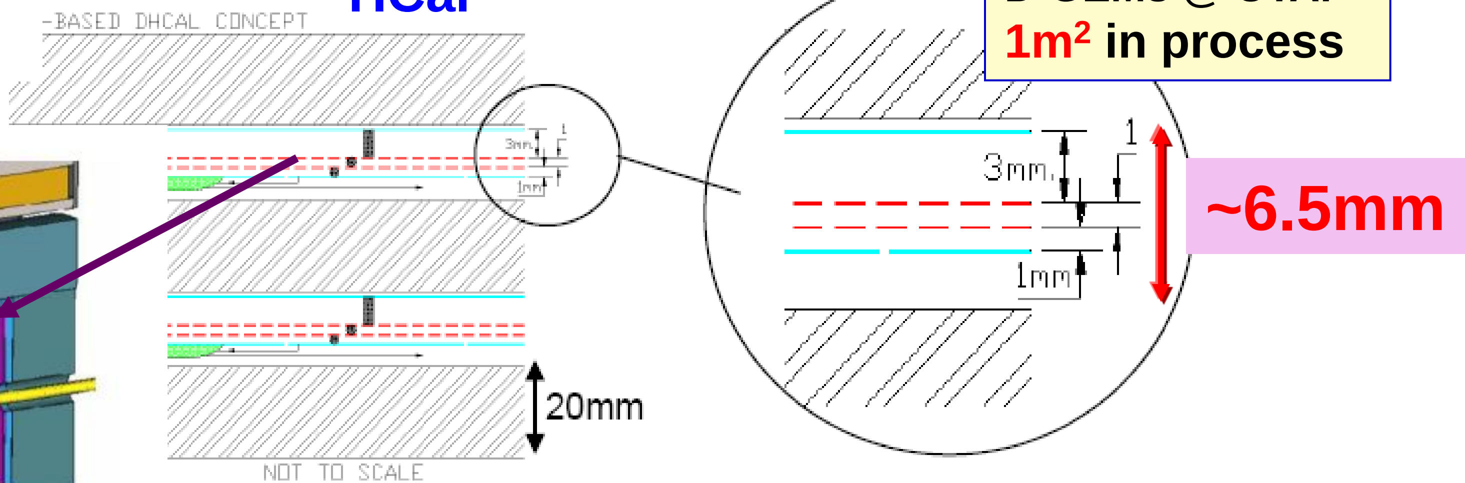
New concept for DHCAL: THGEM

A. White et al UTA

General detector scheme



HCal

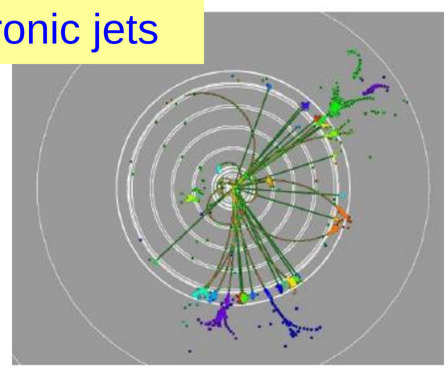


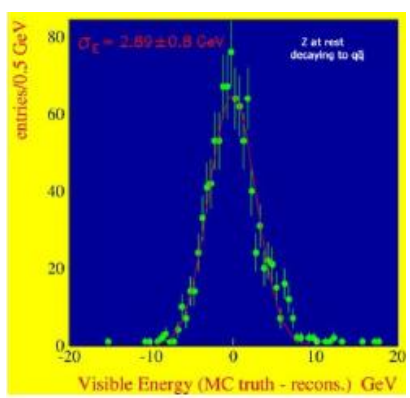
D-GEMs @ UTA:
1m² in process

2 sampling layers (**out of 40**) with THGEM-based elements

Sampling jets + advanced pattern recognition algorithms
➔ Very **high-precision jet energy** measurement.

Simulated event w 2 hadronic jets

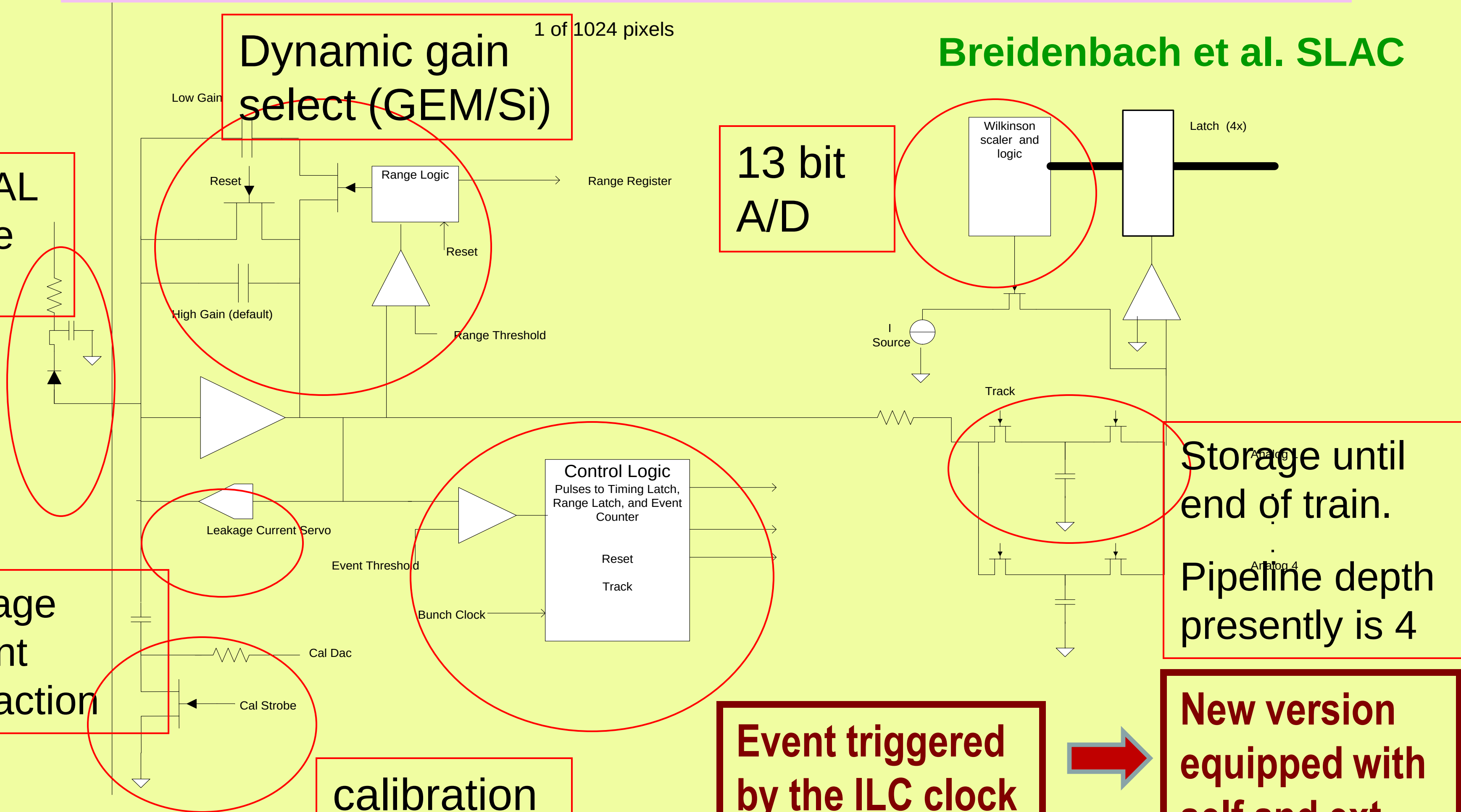




Reconstructed jet:
Simulated energy resolution
$\sigma/E_{jet} \sim 3\%$
(CALICE)

KPiX Analog Readout for GEM & THGEM DHCAL

Breidenbach et al. SLAC



DHCAL anode pad

Dynamic gain select (GEM/Si)

13 bit A/D

Storage until end of train. Pipeline depth presently is 4

Leakage current subtraction

calibration

Event triggered by the ILC clock

New version equipped with self and ext. trigger

Simplified Timing:

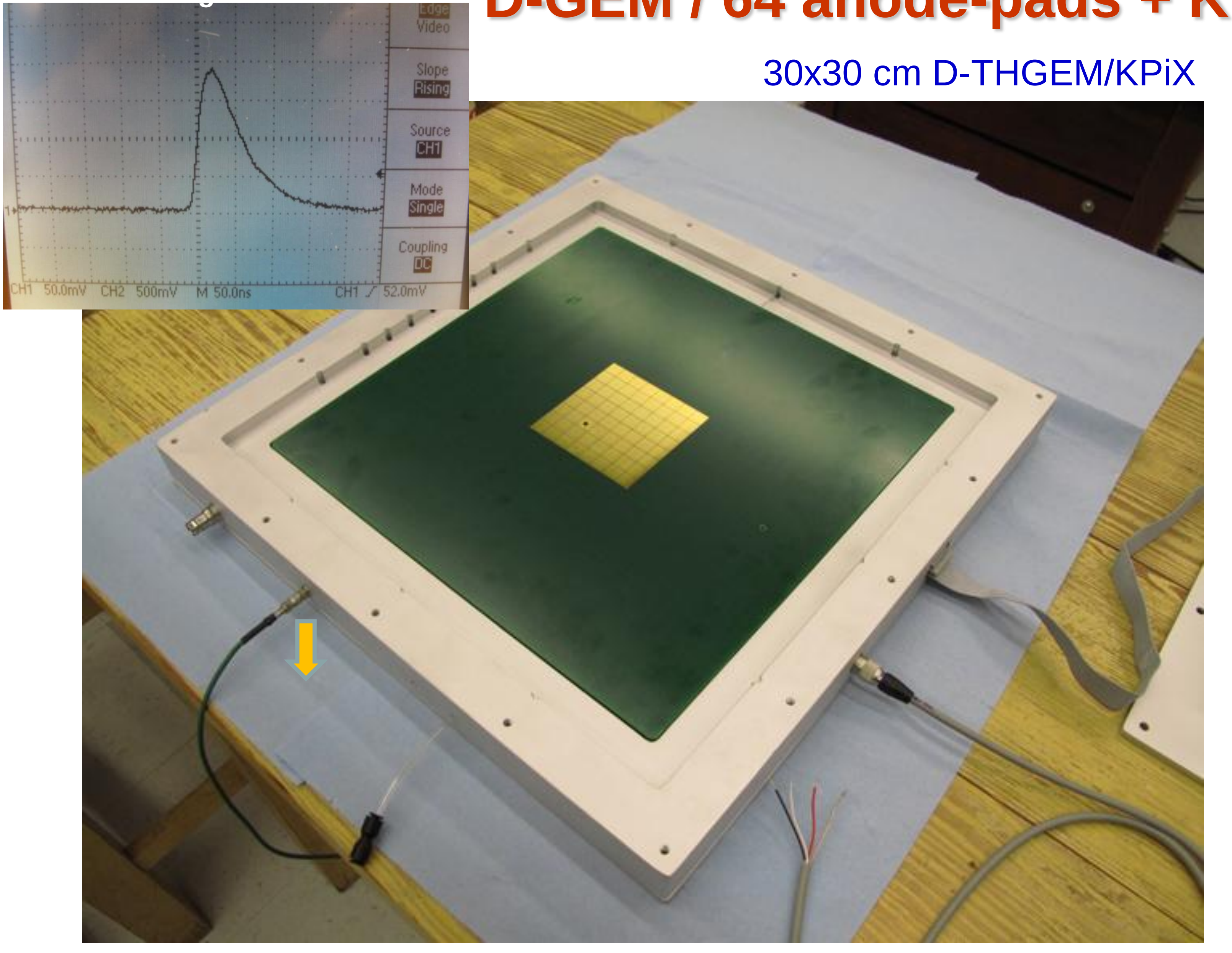
There are ~ 3000 bunches separated by ~300 ns in a train, and trains are separated by ~200 ms.

Say a signal above event threshold happens at bunch n and time T0.
The Event discriminator triggers in ~100 ns and removes resets and strobes the Timing Latch (12 bit), range latch (1 bit) and Event Counter (5 bits)
The Range discriminator triggers in ~100 ns if the signal exceeds the Range Threshold.
When the glitch from the Range switch has had time to settle, Track connects the sample capacitor to the amplifier outp
The Track signal opens the switch isolating the sample capacitor at T0 + 1 micro s. At this time, the amplitude of the sig
Reset is asserted (synched to the bunch clock) . Note that the second capacitor is reset at startup and following an eve
while processing an event)
The system is ready for another signal in ~1.2 microsec.
After the bunch train, the capacitor charge is measured by a Wilkinson converter.

- 1024 channel 13 bit ADC chip
- Developed for Si/W ECAL@ SLAC

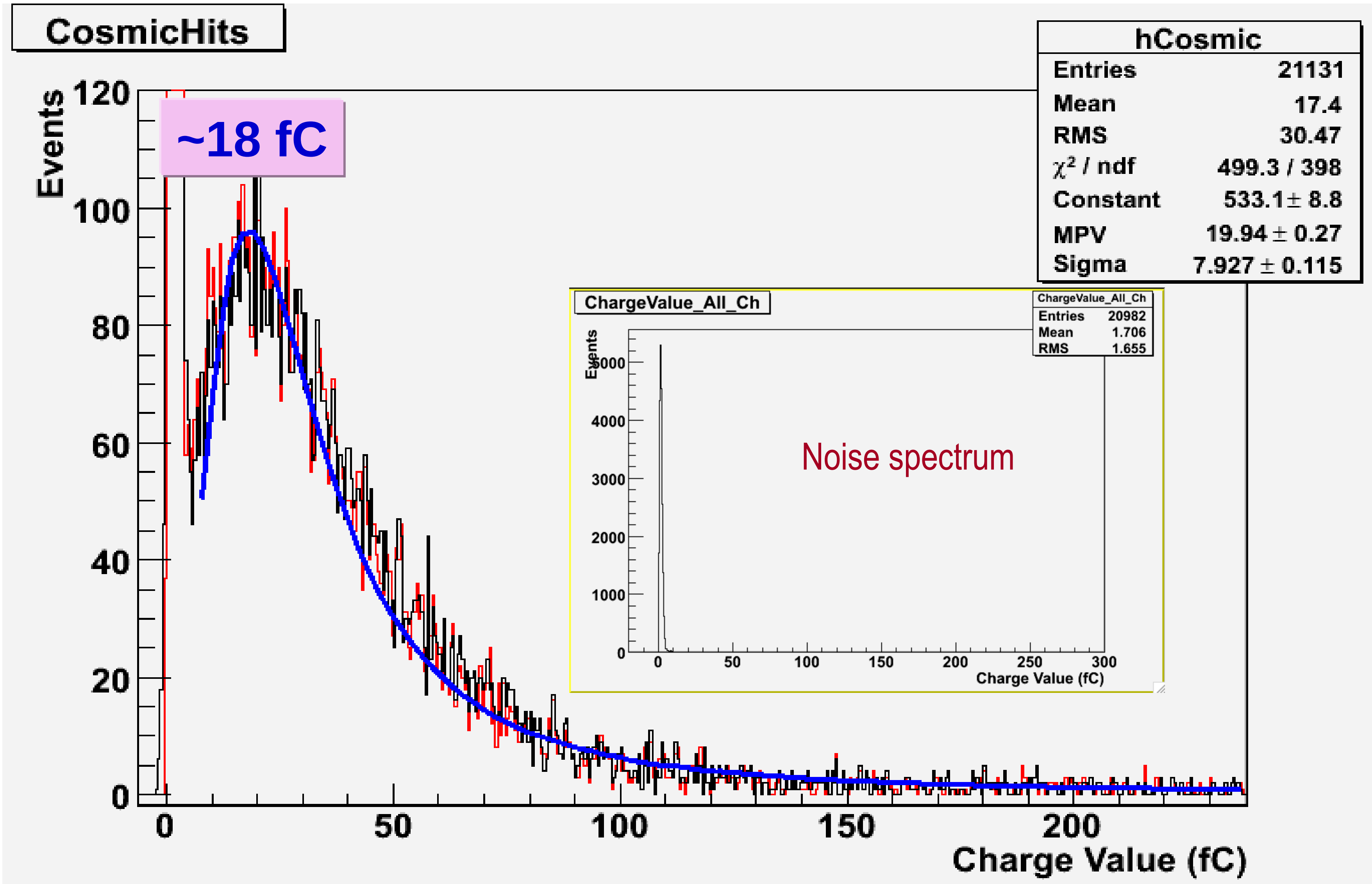
D-GEM / 64 anode-pads + KPiX

30x30 cm D-THGEM/KPiX



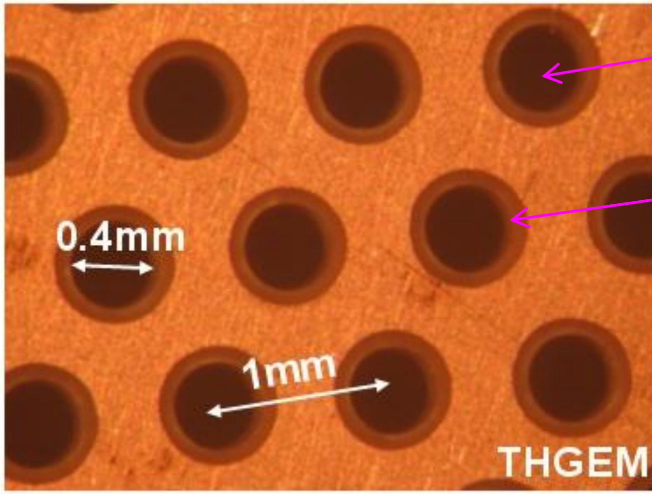
A. White et al UTA

D-GEM / kPiX with Cosmics - with Ext. Trigger

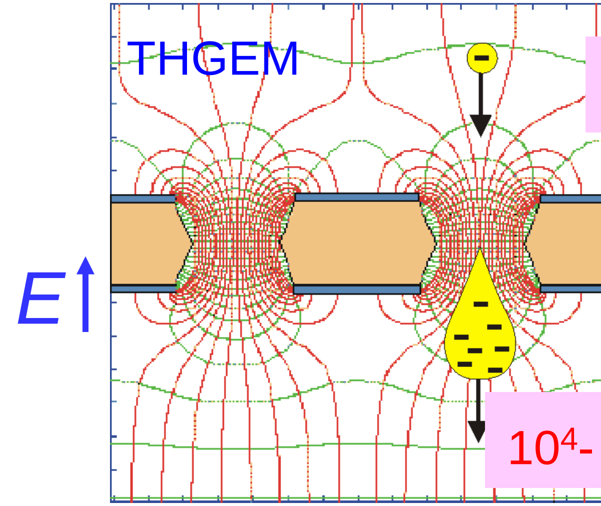


Thick Gas Electron Multiplier (THGEM)

~ 10-fold expanded GEM



Thickness 0.5-1mm



Double-THGEM: 10-100 higher gains

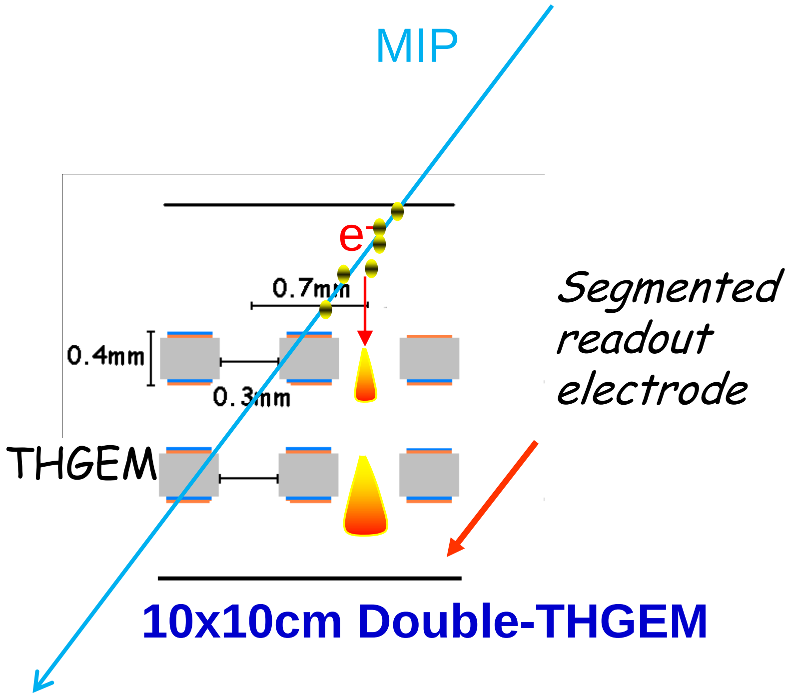
THGEM advantage for DHCAL:
SIMPLE, ROBUST, LARGE-AREA
Cheap: Printed-circuit technology
Digital counting➔
gain fluctuations not important

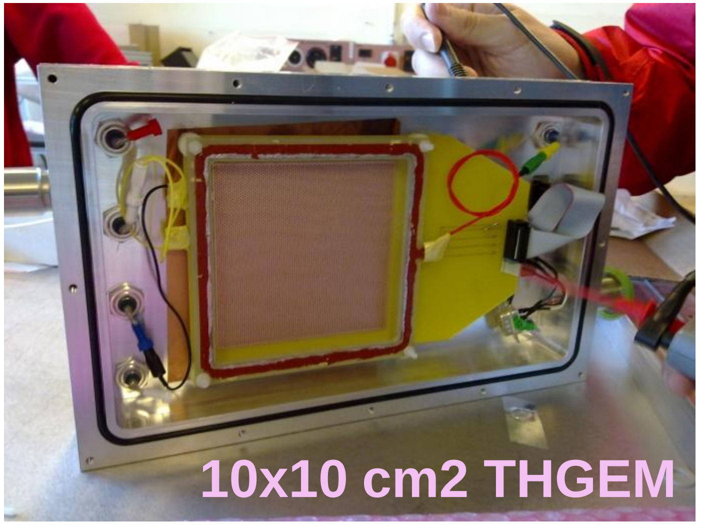
- Robust, if discharge no damage
- Effective single-electron detection
- Few-ns RMS time resolution
- Sub-mm position resolution
- >MHz/mm^2 rate capability
- Broad pressure range: 1mbar - few bar

THGEM Recent review
NIM A **598** (2009) 107

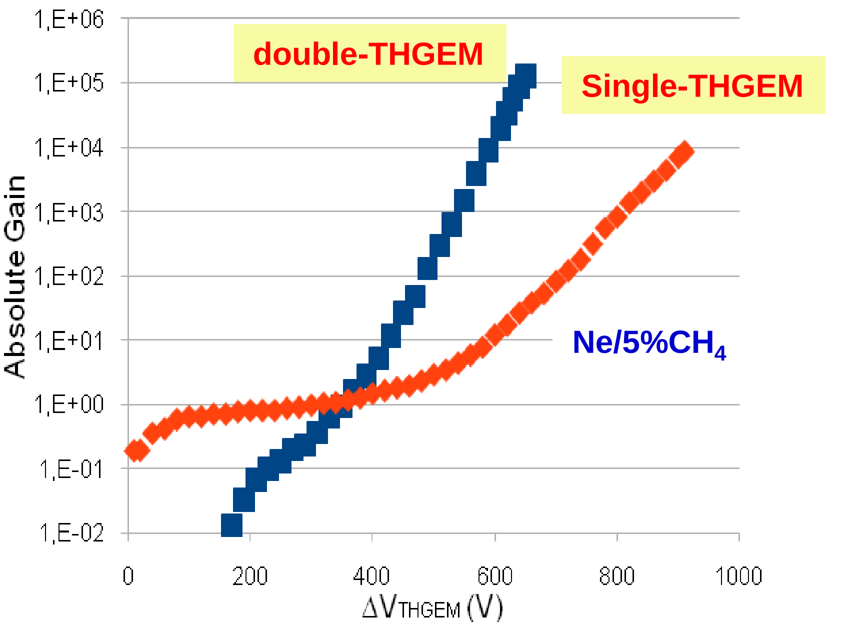
Gain: THGEM in Ne-mixtures

2009 *JINST* 4 P08001



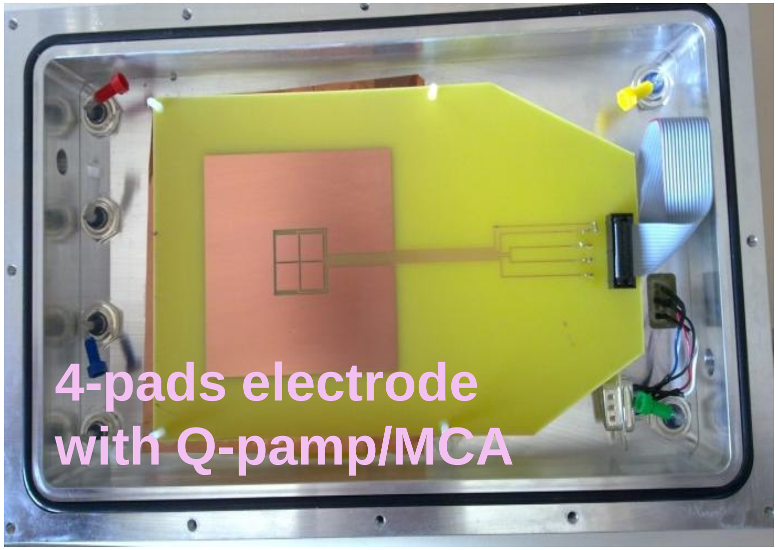


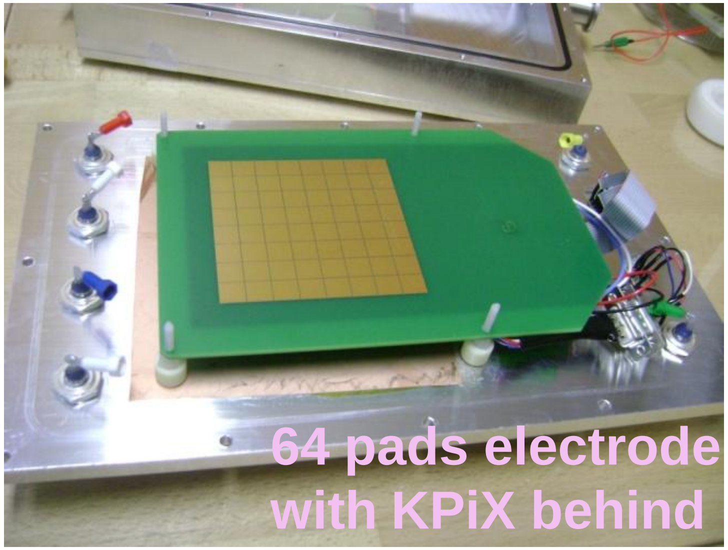
Gain: single UV-photons

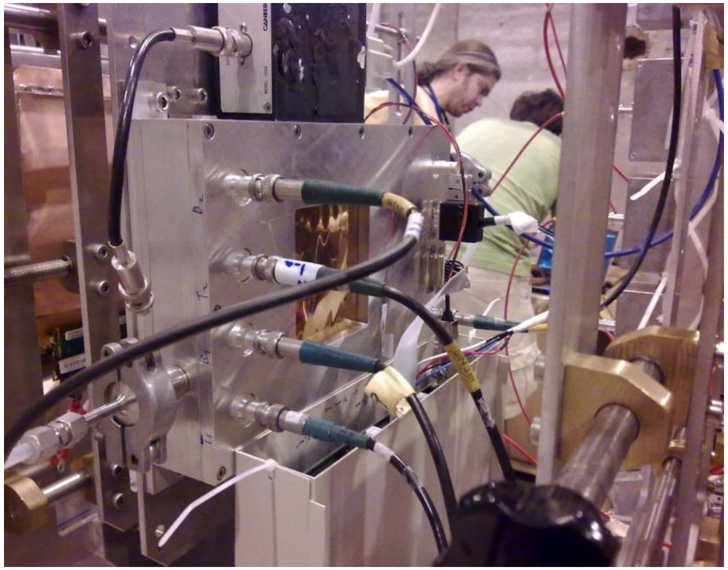


- High gain in Ne mixtures
- **2-THGEM: higher gains/lower HV**
- But: low ionization (**n_{tot}~40 e/MIP**)

CERN test-beam detector



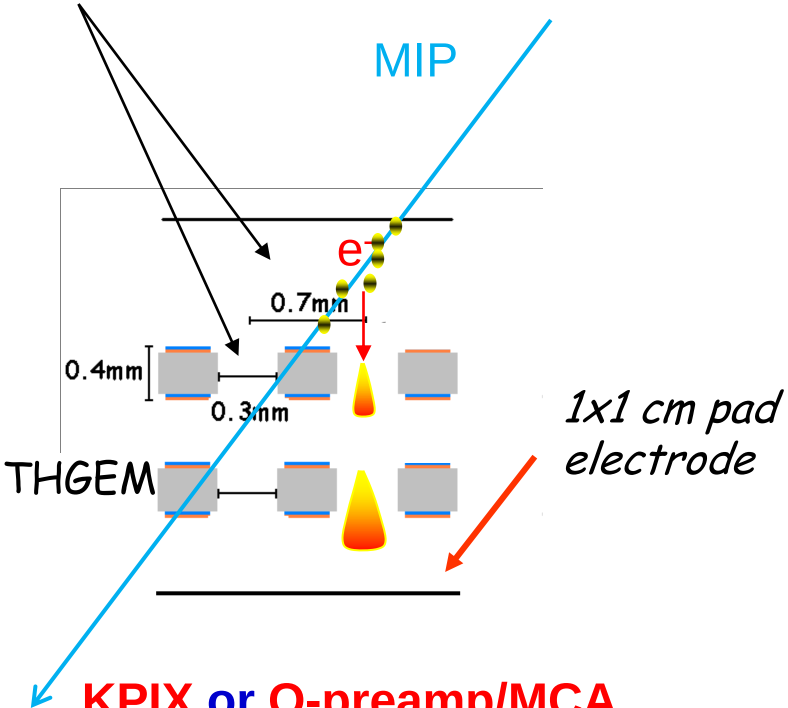




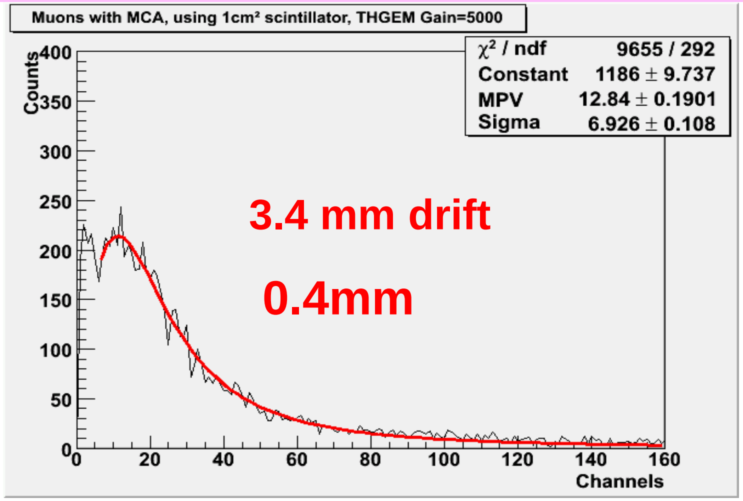
Muons w Double-THGEM KPIX or Q-preamp/MCA

Here we had:

0.5mm holes / 1mm space

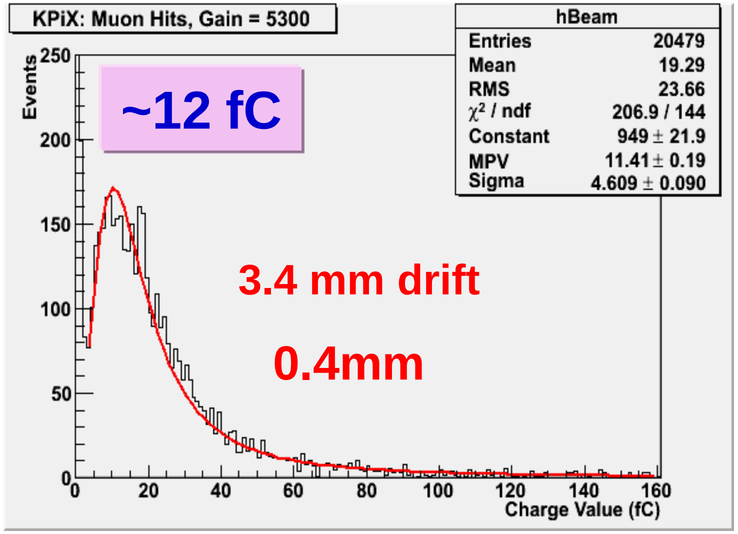


2-THGEM BEAM TESTS with Q-preamp/MCA



Double-THGEM, Ne/5%CH4; Average gain ~5000

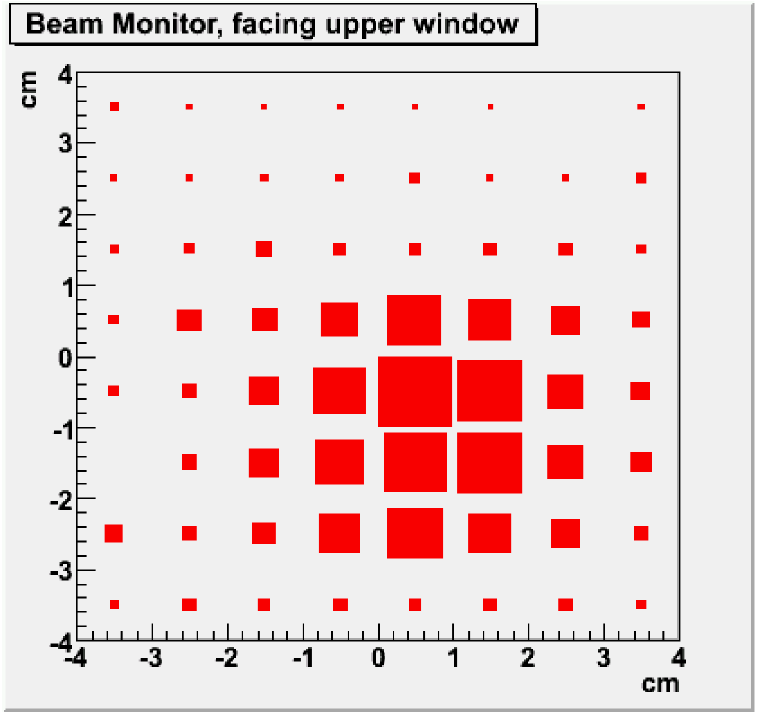
2-THGEM BEAM TESTS with KPIX



Double-THGEM, Ne/5%CH4; Average gain ~5300

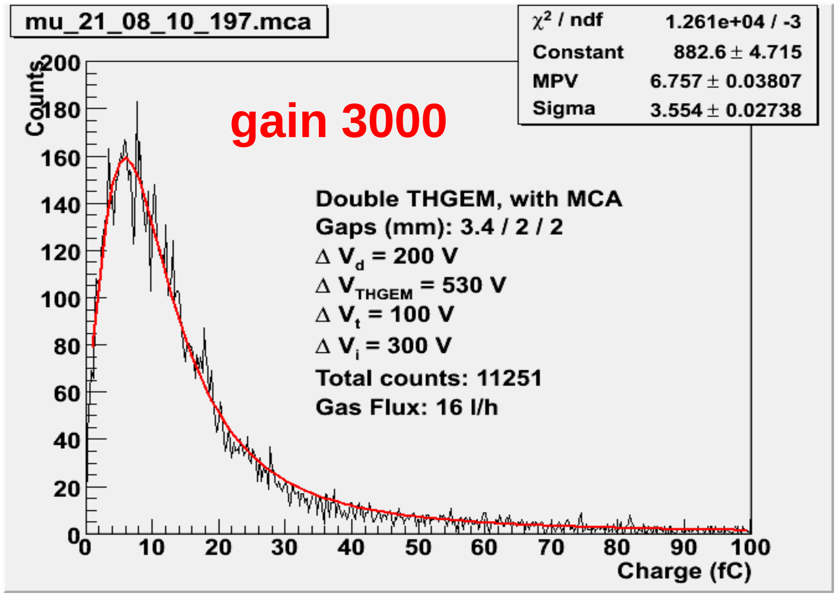
August 2010

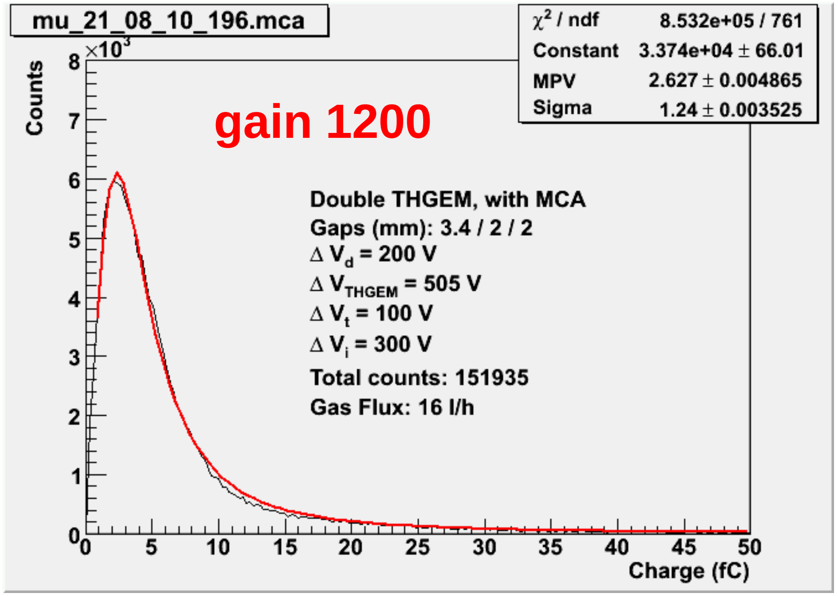
Double-THGEM & KPiX



Muon beam profile

Muons with double-THGEM



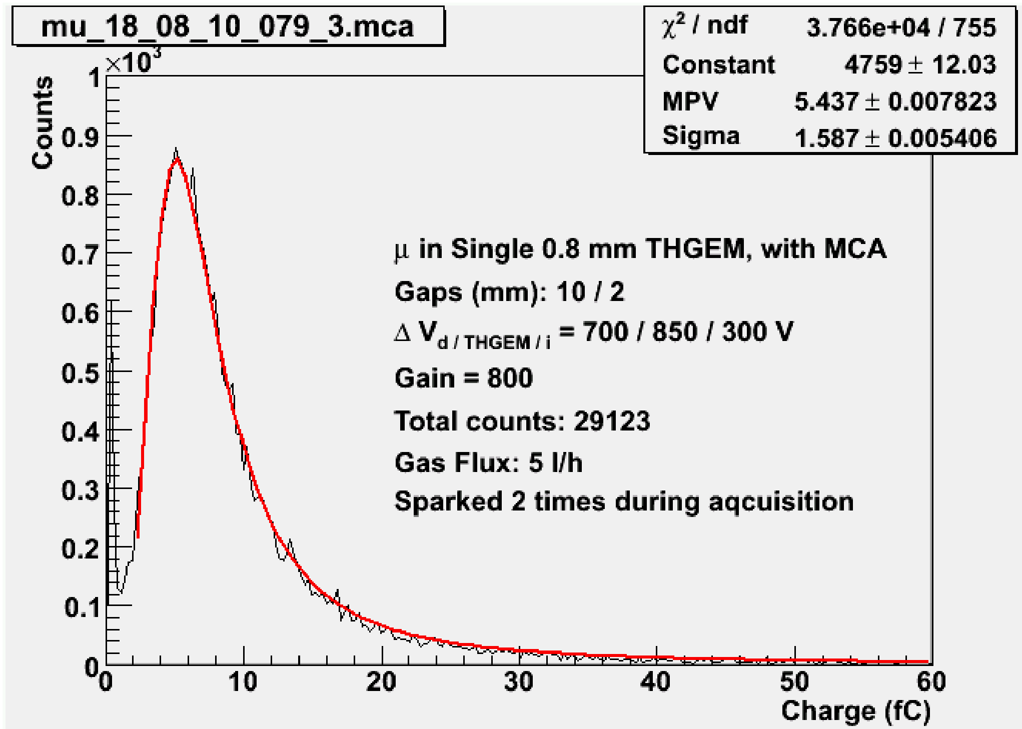


Double-THGEMs in Ne/5%CH_4. Landau distributions recorded with an MCA.

Thickness: 0.4mm

Drift gap: 3.4mm

Single-THGEM, 10mm drift gap, muons



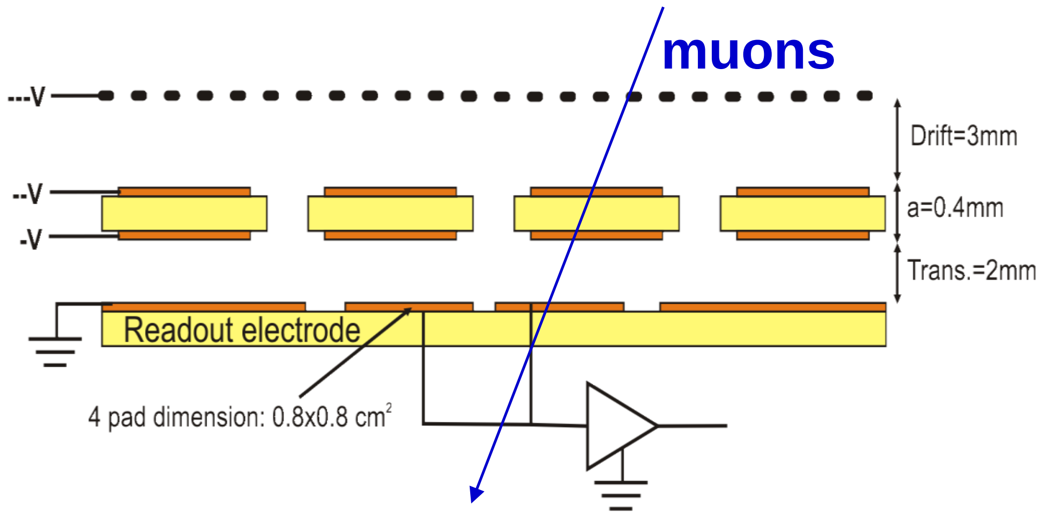
Single-THGEM with muons

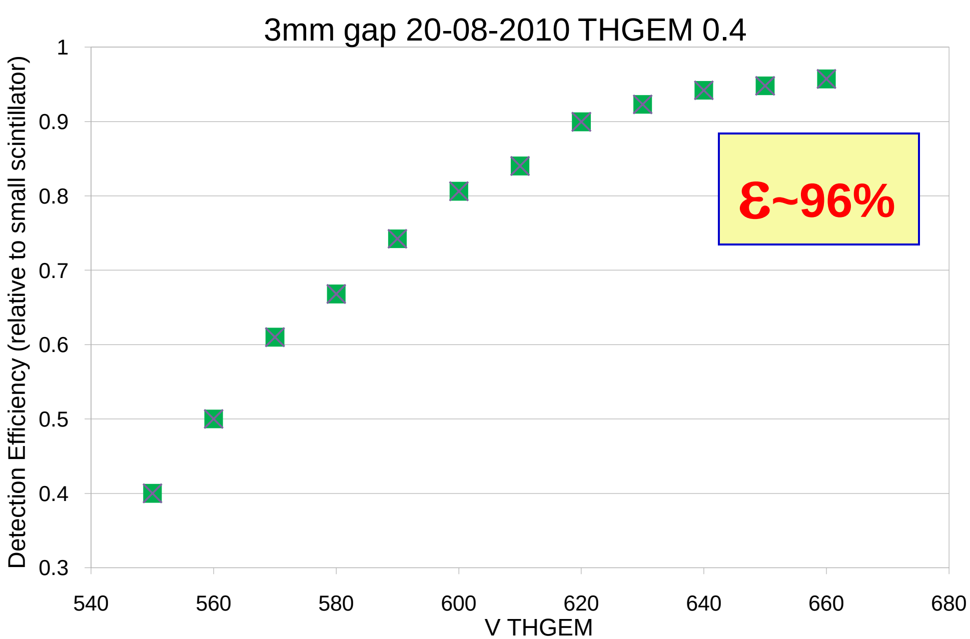
Landau distribution at a gain of 800.

Thickness: 0.8mm

Drift-gap: 10mm

Single-THGEM with muons: efficiency

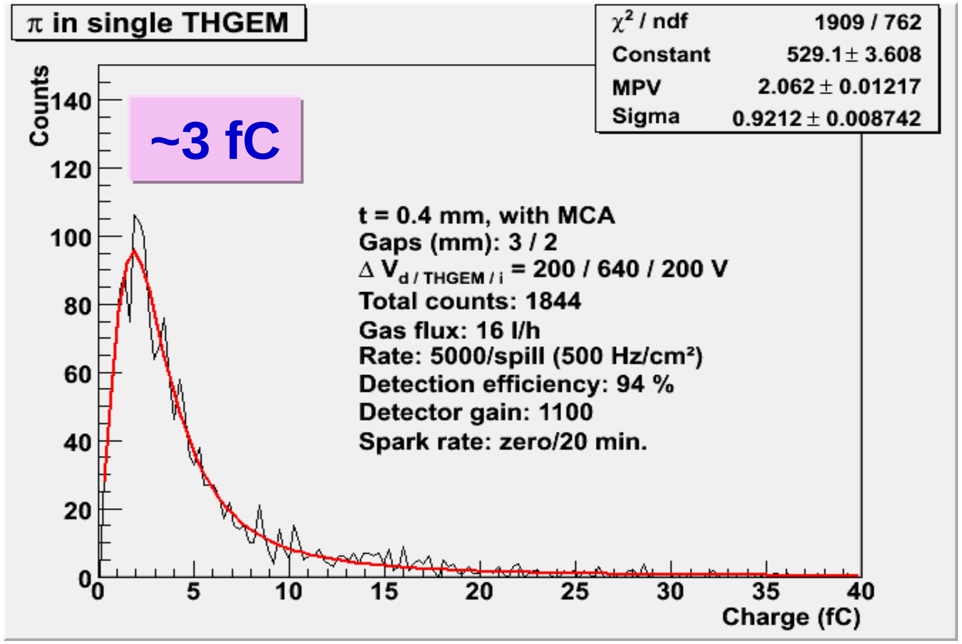




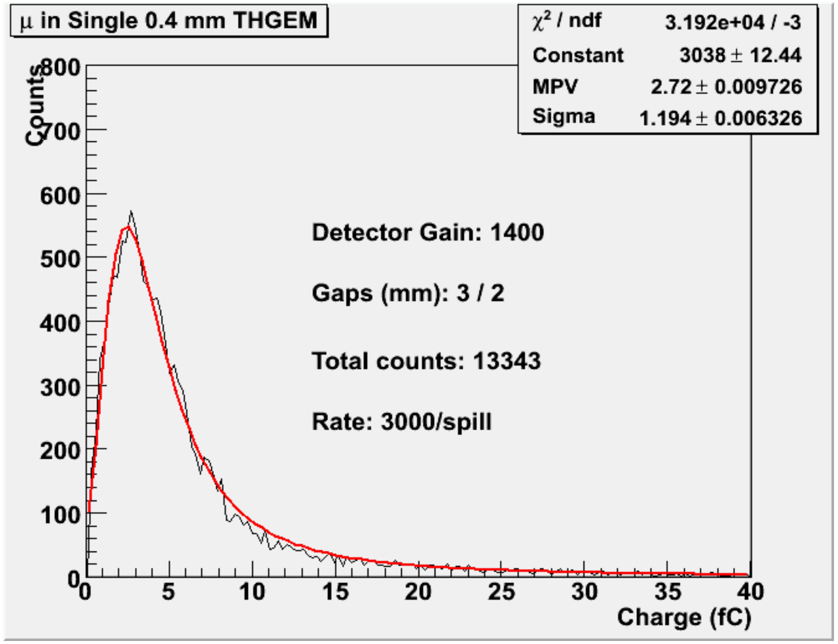
Single THGEM
10x10 cm
Thicknes: **0.4 mm**
Particles: muons
Gas: Ne/5%CH_4
Drift gap: **3 mm**
Charge preamp/MCA
0.5 cm^2 trigger

Single-THGEM/3mm drift

PIONS



MUONS



Measured very low discharge rates even with pions @ rates >>ILC

THGEM: 0.4mm

Gain: 1200-1400

THGEM for DHCAL: next…

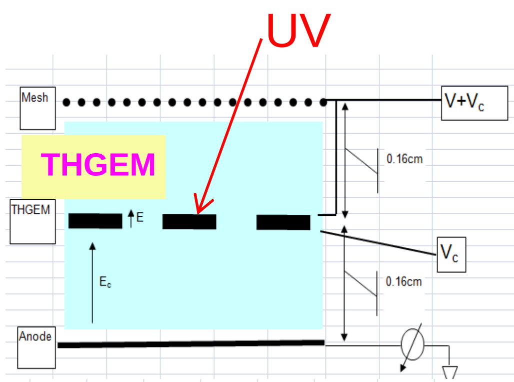
- October 2010: run at CERN with muons/pions
- Investigations with **1-THGEM & 2-THGEM with KPIX**
- Gain & Efficiency
- Crosstalk between pads
- Discharge rates with μ/π (continuation study)
- With SLAC: improving KPIX protection
- 30x30 cm THGEMs
- **OCT RUN**: New multiplier geometries & operation modes

  ➔ **well, gain in ind gap, resistive film…**
- Other gases (Ne/CF4?)

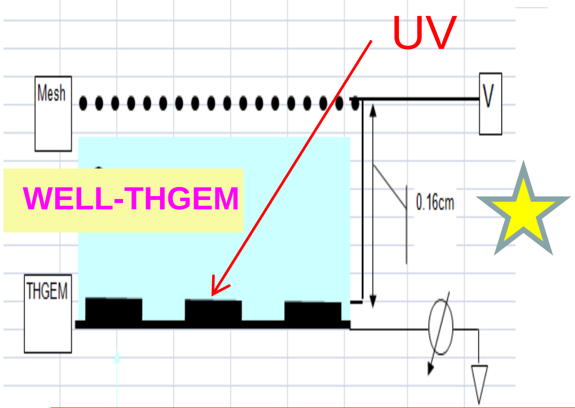
Compact WELL-THGEM

(similar to:
Well-Counter of Bellazzini &
of Alfonsi et al. CRETE 09)

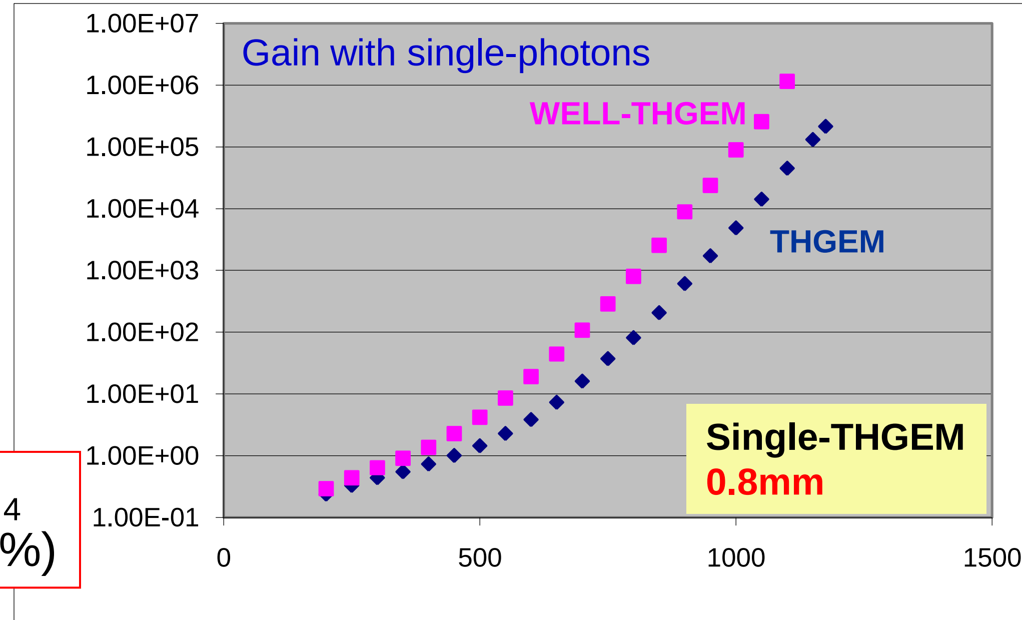
Present goal:
Reduce to minimum multiplier thickness

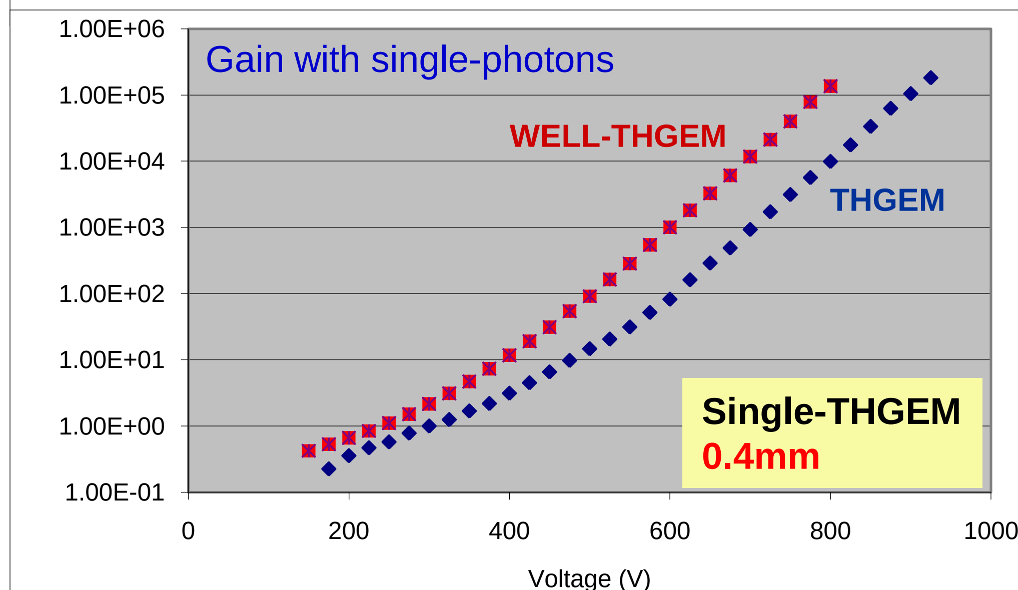


Gas: Ne/CH_4
(%CH_4 ~ 10%)

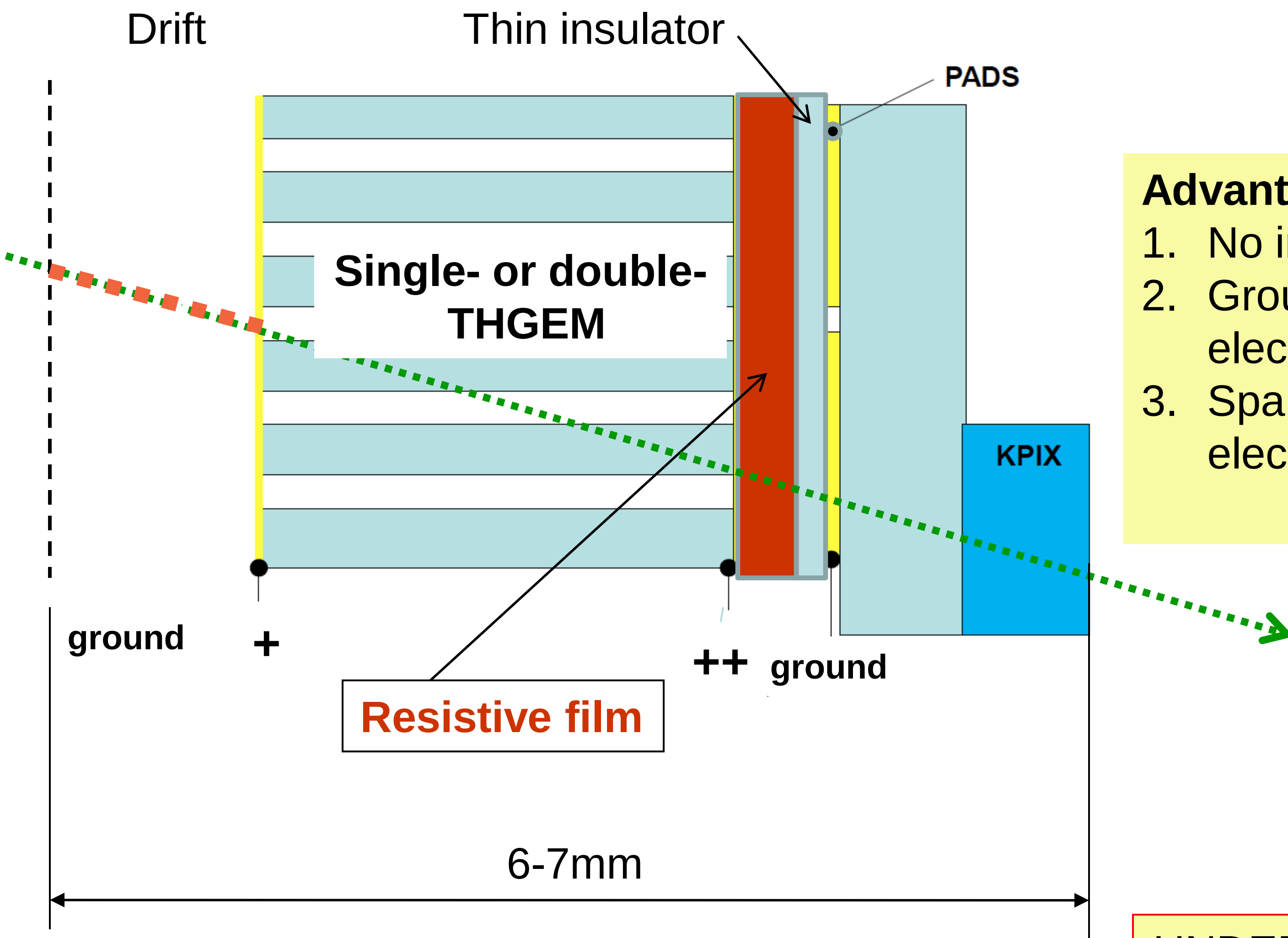


WELL: lower HV
0.8mm ➔ higher gain





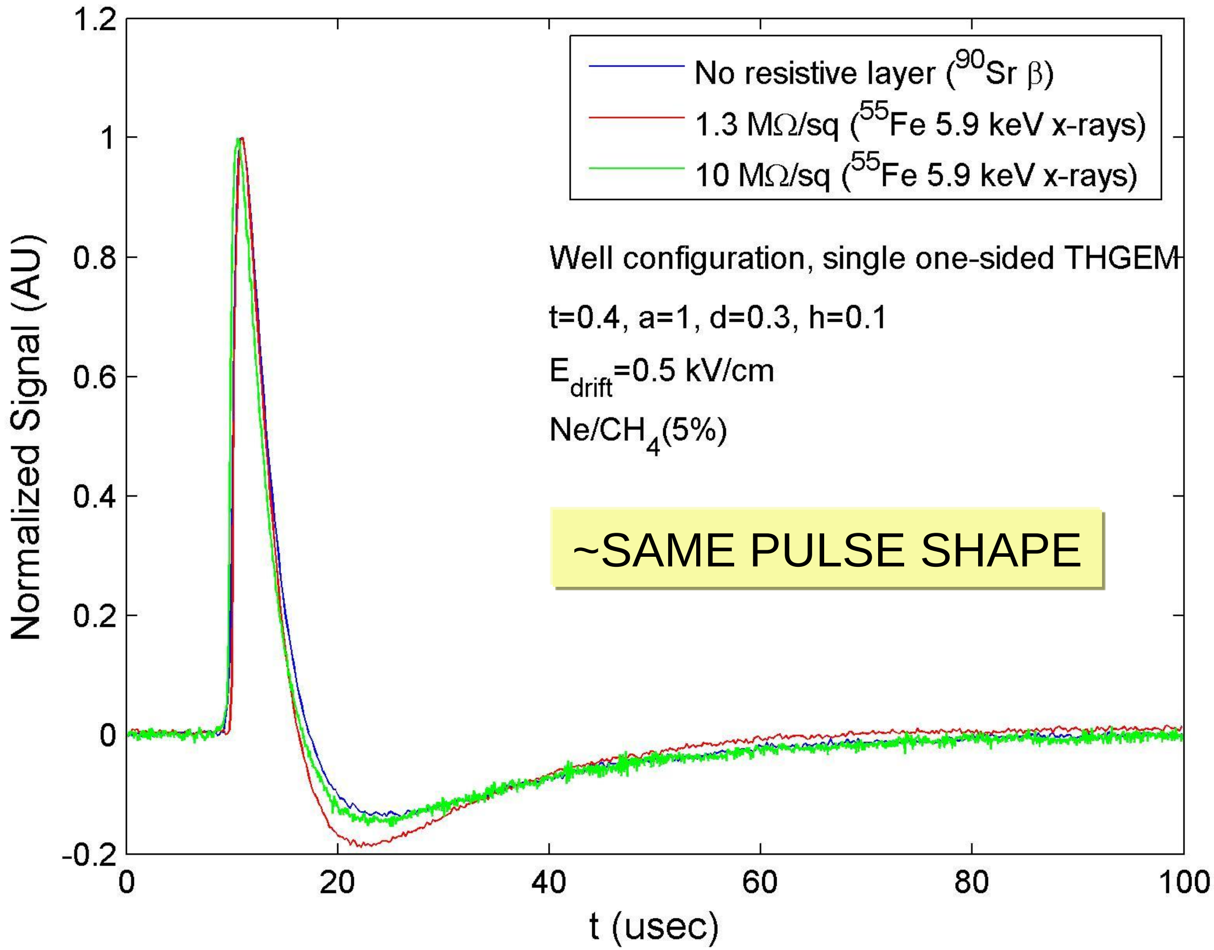
RESISTIVE-WELL-THGEM

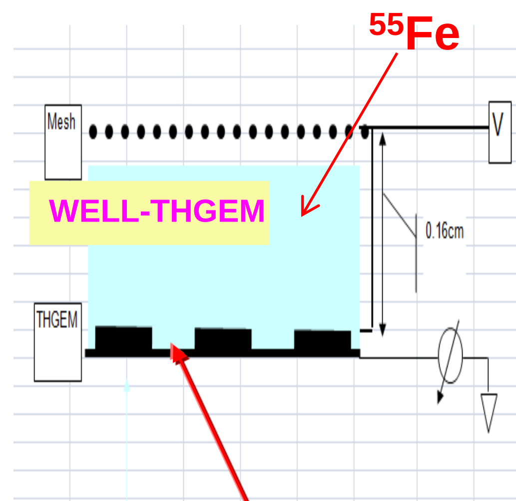


Advantages:
1. No induction gap
2. Ground on both external electrodes
3. Spark-protection of electronics

UNDER INVESTIGATIONS @ Weizmann

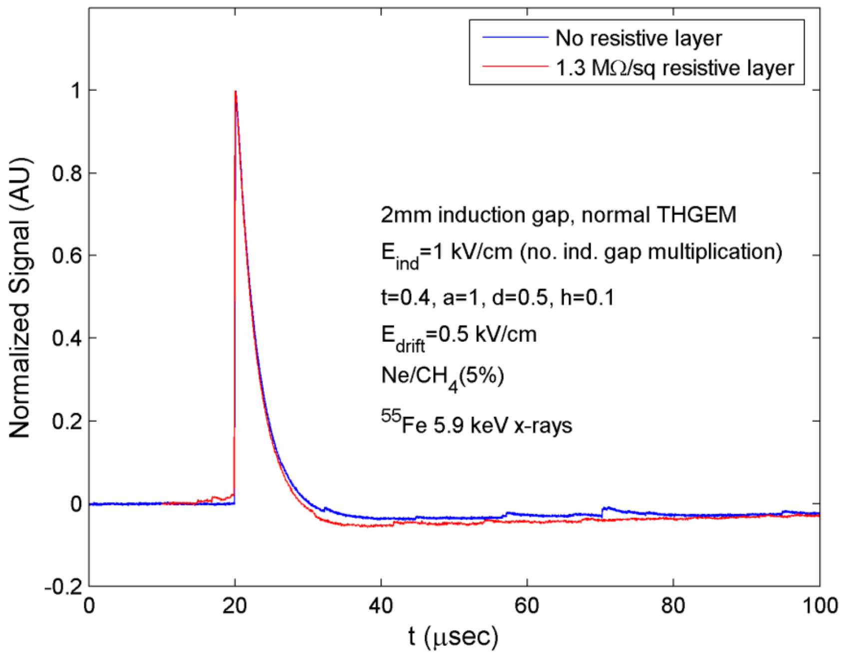
Well: Charge pulses on pad



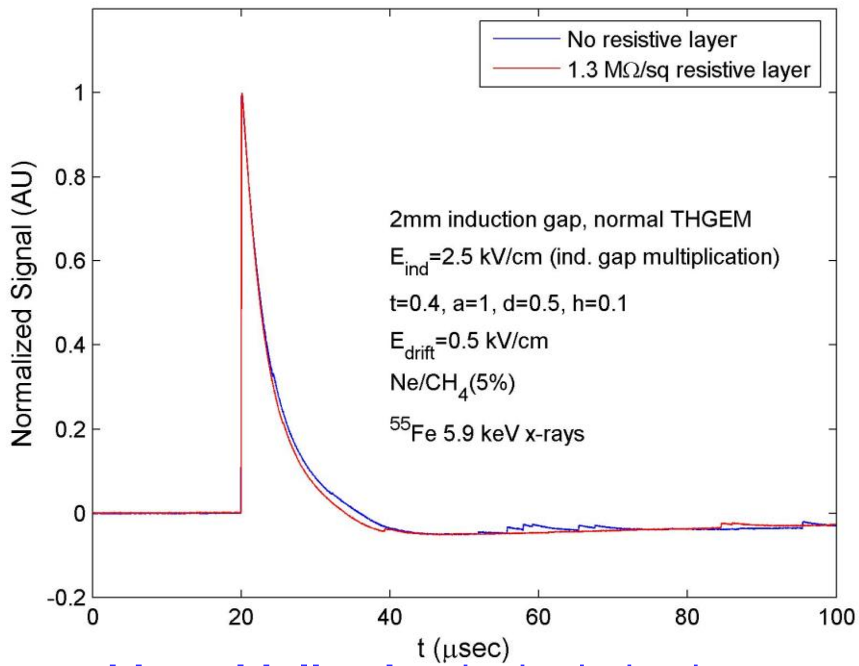


With/without resistive film

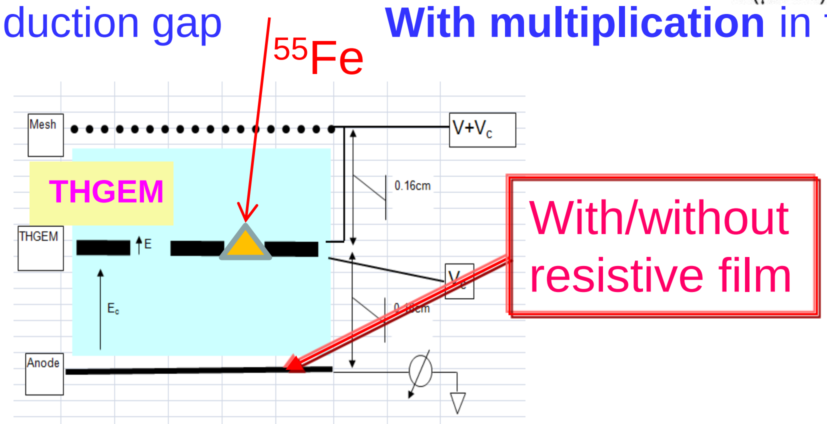
THGEM: Induction gap configuration: effect of adding a resistive layer (1.3 MΩ/□)



Without multiplication in the induction gap

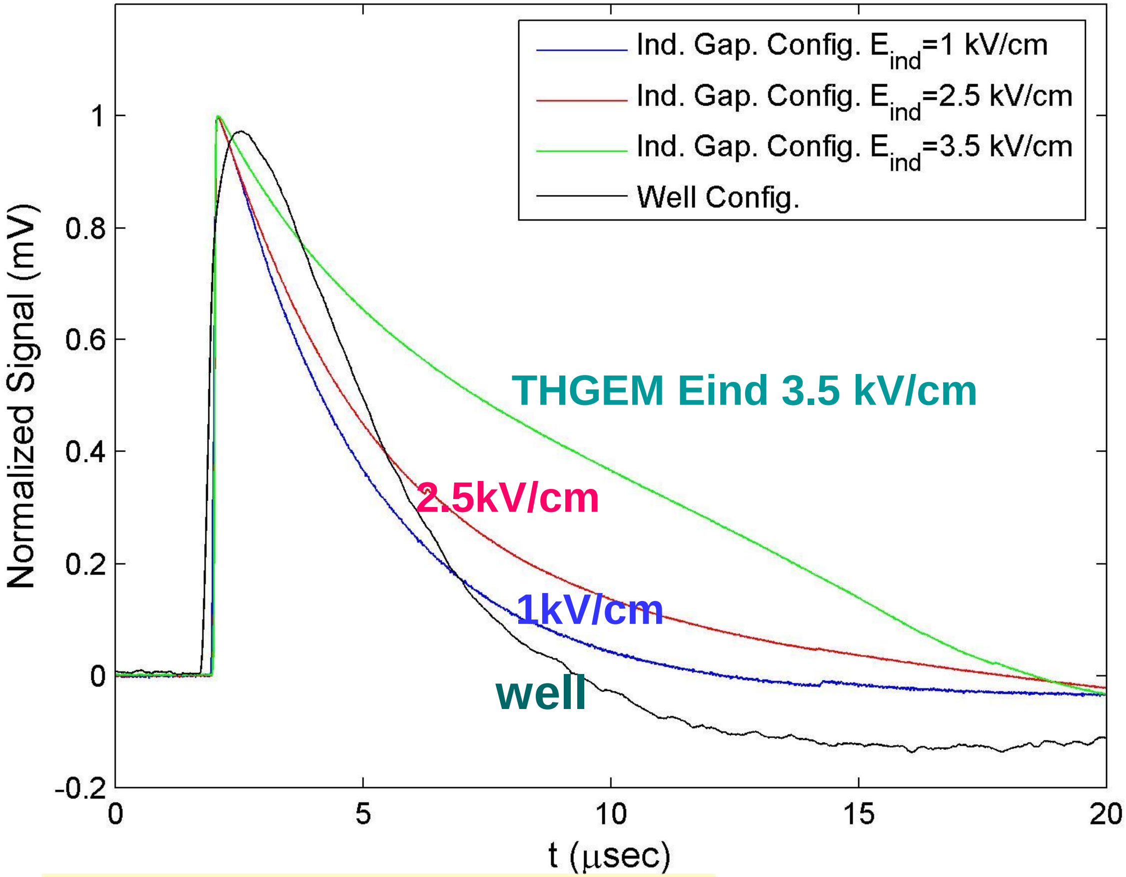


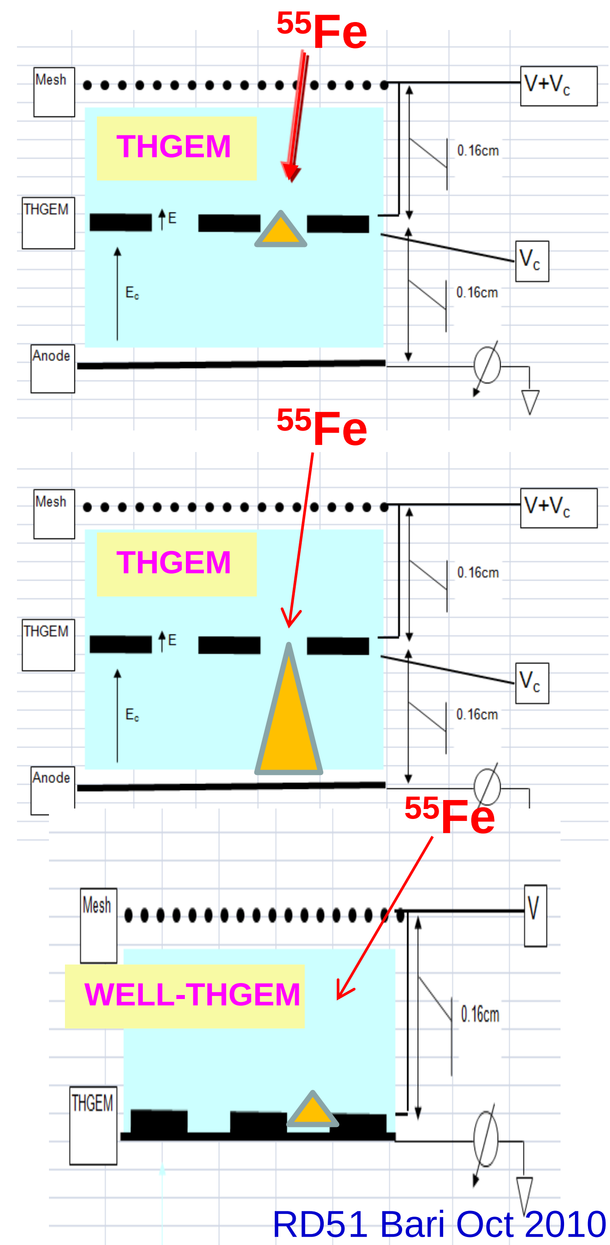
With multiplication in the induction gap



THGEM Charge pulses

WELL, THGEM and with multiplication in induction gap





Gain in induction gap:
Broader pulse (IONS!)
Might be beneficial for KPiX