DHCAL for ILC

THGEM

Detector

KPiX

Optimization

Conclusions

Thin active elements for DHCAL based on Thick-GEMs

H. Natal da Luz[1] J. Veloso[1] C. Azeved[1] D. Covita[1] A. Breskin[2] R. Chechik[2] M. Cortesi[2] L. Arazi[2] M. Pitt[2] A. White[3] S. Park[3] J. Yu[3] M. Breidenbach[4] D. Freytag[4] G. Haller[4] R. Herbst[4]

[1]Aveiro & Coimbra Univ. – Portugal (RD51)

[2]Weizmann Institute of Science – Israel (RD51)

[3]UTA – USA (RD51)

[4]SLAC - USA

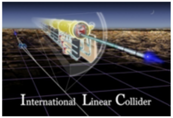
June, 11 2011

Summary

DHCAL for ILC
THGEM
Detector
KPiX
Optimization
Conclusions

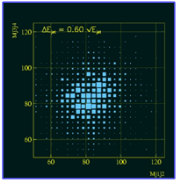
1. **Digital Hadron Calorimetry for ILC**
2. **Thick-Gas Electron Multiplier (THGEM)**
3. **Detector performance**
4. **Integration with KPiX ASIC**
5. **Optimization approaches**
6. **Conclusions and near future work**

Digital Hadron Calorimetry for ILC



Precision studies of new physics

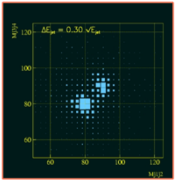
ILC: Separate W,Z boson masses on event-by event basis



60%/√E

Best JET resolution with traditional calorimetry

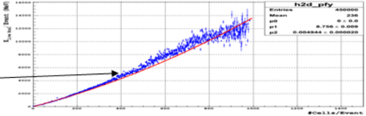
Need 30%/√E



Generally need σ/E_{jet} ~3-4%

Digital calorimetry

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



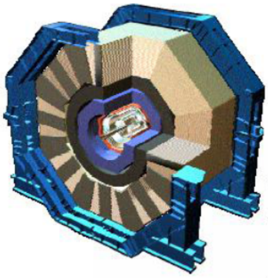
Particle Flow Algorithms now achieve the required energy resolution!

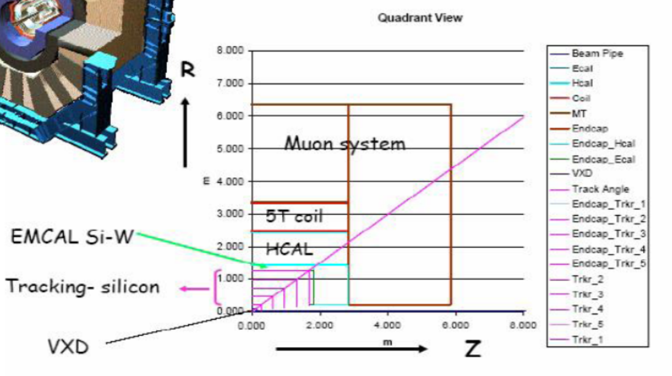
- Requires thin, efficient, highly segmented, compact, robust medium
- Possible technologies: D-GEM, Micromegas, RPC, **THGEM**

Digital Hadron Calorimetry for ILC

Design within the SiD Detector Concept, but also as part of the CALICE collaboration

SiD

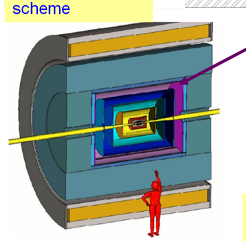


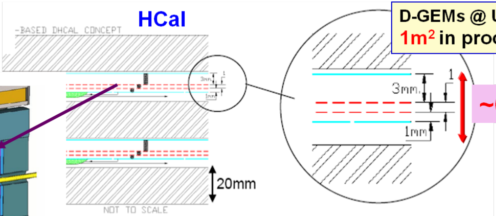


New concept for DHCAL: THGEM

A. White et al UTA

General detector scheme





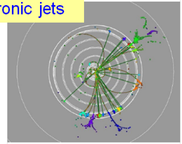
D-GEMs @ UTA:
1m² in process

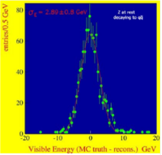
~6.5mm

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

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

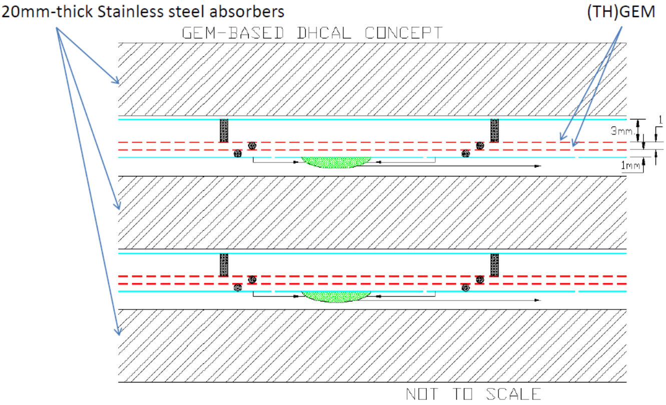
Simulated event w 2 hadronic jets





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

THGEM–based Digital HadronCalorimeter concept

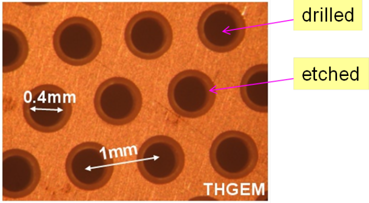


Aims

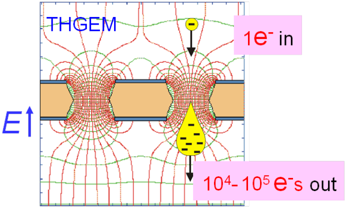
- Thickness of sensitive region: 6–8 mm, including readout electronics.
- 95 % efficiency;
- up to 1.7 particles/pad overlap is acceptable.

Thick Gas Electron Multiplier (THGEM)

~ 10-fold expanded GEM



Thickness 0.5-1mm



Double-THGEM: 10-100 higher gains

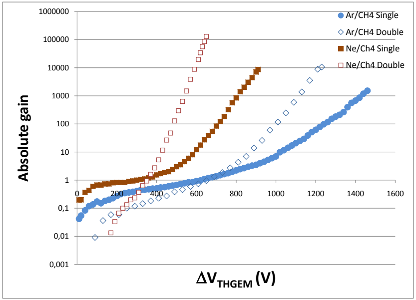
THGEM advantage for DHCAL:
SIMPLE, ROBUST, LARGE-AREA
Cheap: Printed-circuit technology
Digital counting→
gain fluctuations not important

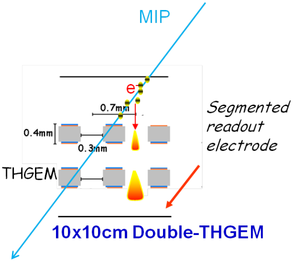
- Robust, if discharge no damage
- Effective single-electron detection
- Few-ns RMS time resolution
- Sub-mm position resolution
- >MHz/mm^2 rate capability
- Broad pressure range: 1mbar - few bar

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

Elements for DHCAL based on THGEMs
H. Natal da Luz et al.

DHCAL for ILC
THGEM
Detector
KPiX
Optimization
Conclusions



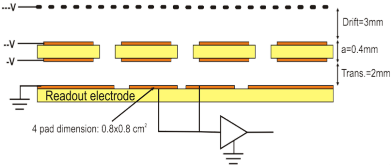


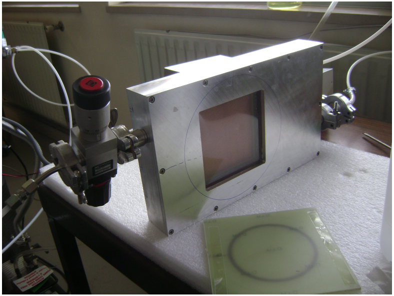
- Higher gain in Ne mixtures
  but: lower ionization — $n_{tot} \sim 40$ e/MIP
- 2-THGEM: higher gains/lower HV
  but: too thick.

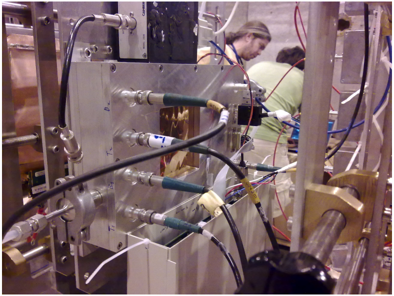
The detector

THGEM chamber

- THGEM area: $10 \times 10\,\mathrm{cm}^2$;
- Gas volume: $\sim 280 \times 180 \times 32\,\mathrm{mm}^3$;
- Gas: Ne/CH_4 (95:5) (non-flammable);
- Single THGEM, gaps: 3/2 mm (d/i) or Double THGEM, gaps: 3/2/2 mm (d/t/i).

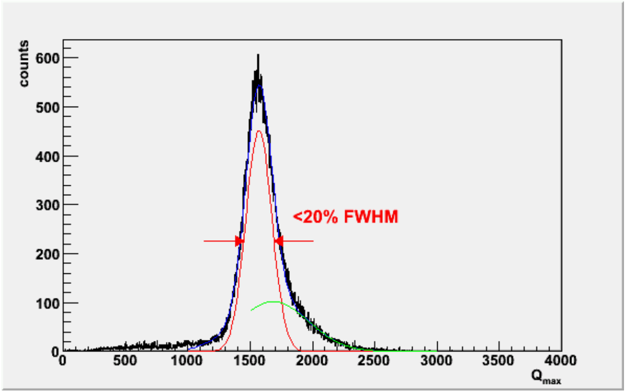






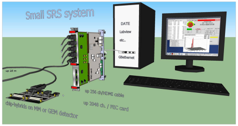
Integration with KPiX readout electrode in course.

Performance in Ne/CH_4 (95:5), using ^{55}Fe

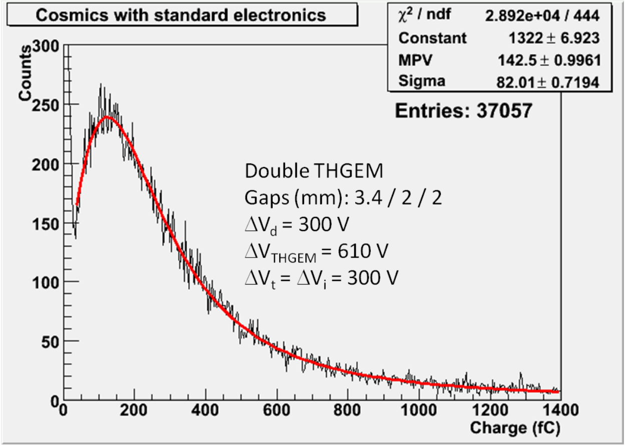


Data taken using RD51 Scalable Readout System.

$\frac{\Delta E}{E} < 20\,\%$ at moderate/safe gain (no sparks).

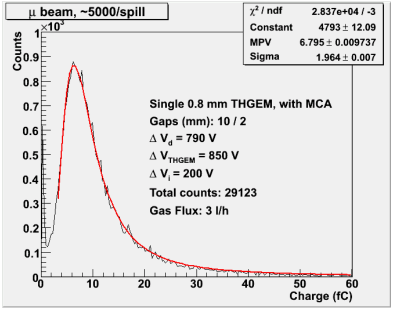


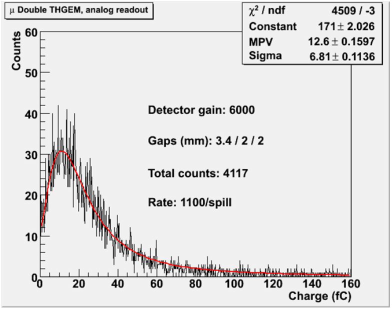
Performance in Ne/CH_4 (95:5)



Cosmic data, standard analog electronics.
Operation at huge gain ($\sim$ 65k)!

Beam tests

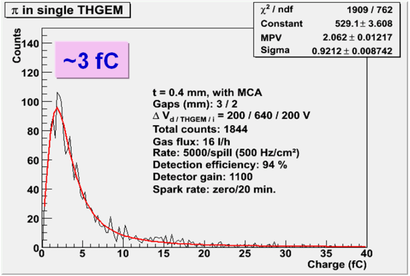




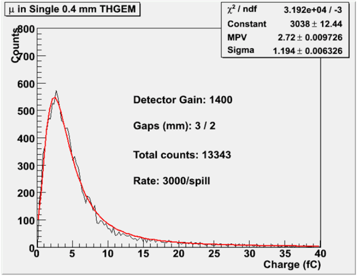
- RD51 test beam facility at CERN (SPS/H4),
- Several geometries tested.
- System triggered with 3 $10 \times 10\,\text{cm}^2$ scintillators, plus one small $1\,\text{cm}^2$ to select different smaller regions on THGEM area.

Beam tests - μ vs π

PIONS



MUONS

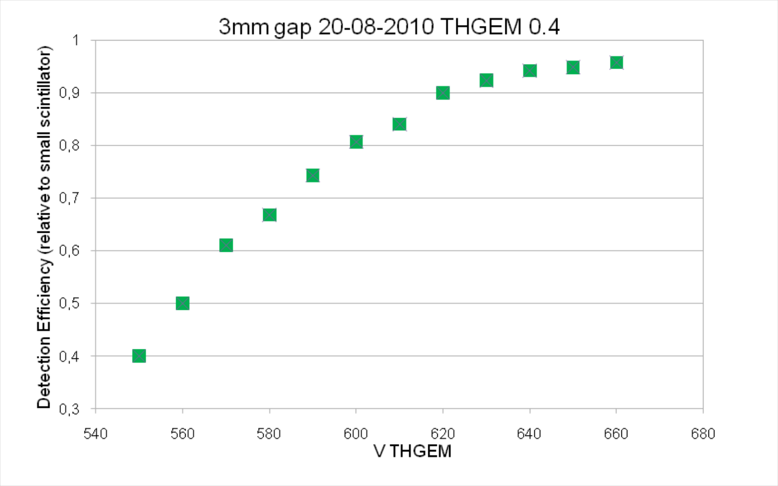


Measured very low discharge rates even with pions @ rates >>ILC

THGEM: 0.4mm
Gain: 1200-1400

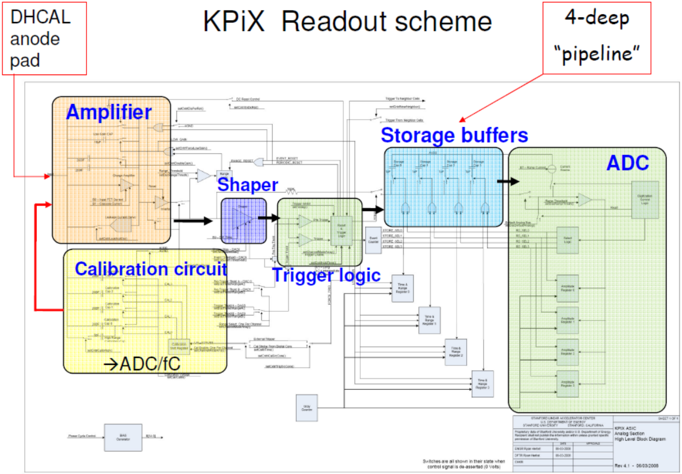
- Muons and pions easily measured, but charge signals very low;
- Spark rate was fine, but KPiX might need higher signals.

Beam results - efficiency



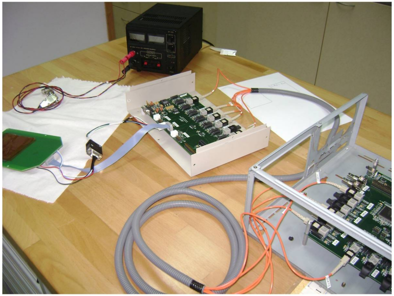
Maximum detection efficiency ($\epsilon = 96\,\%$) was reached very early, even with a small drift gap.

KPiX charge readout chip

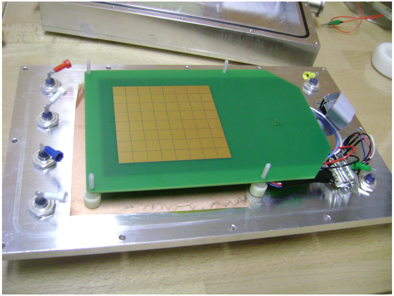


- Developed for Si/W ECAL at SLAC,
- KPiX 9: 512 13-bit ADC (our THGEMs only use 64),
- Self-Calibrating (distributions can immediately be given in fC).

KPiX charge readout chip



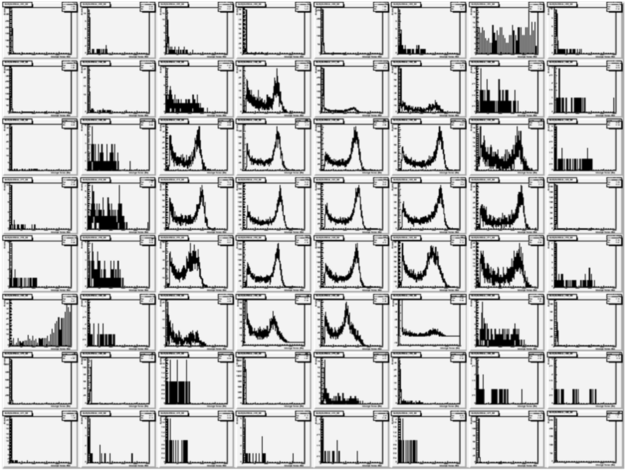
FPGA, interface and KPiX ASIC board



64 pad electrodes with KPiX ASIC behind.

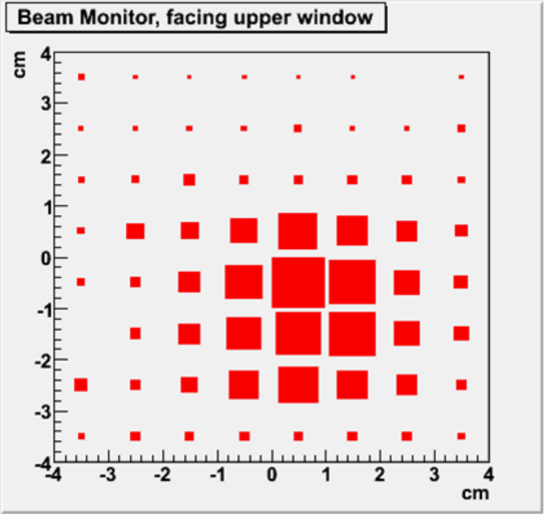
- 64 pads in a $8 \times 8\,\mathrm{cm}^2$ matrix.
- Communication with a PC by USB through interface and FPGA boards.
- Very low efficiency ($\sim 4\,\%$) due to ILC synchronized timing structure.

KPiX with X-rays



Non collimated ^{55}Fe source.

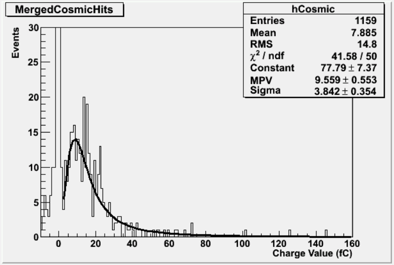
KPiX in beam



- Integral of charge in each channel.
- Each pad has 1 cm^2.

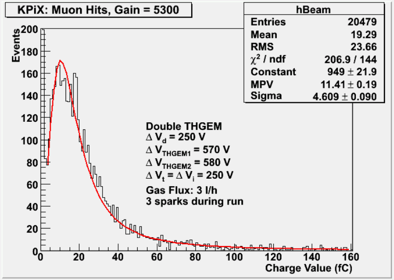
KPiX with MIPs

Cosmics



Double THGEM with large drift gap, operating at low gain (~ 1000)

Muons



Double THGEM

- Electronics very sensitive to sparks. Got damaged before end of tests in beam.
- Problem partially solved, but sparks still originate glitches in the LV power circuit and strange things happen in KPiX (latch up in some channels and software crashes).

Two different fronts to keep optimizing

DHCAL for ILC
THGEM
Detector
KPiX
Optimization
Conclusions

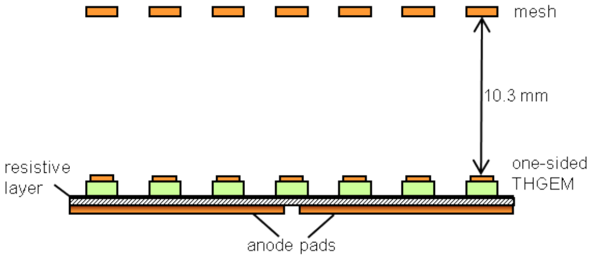
Improving KPiX robustness against sparks

- application of protection resistors and diodes in the circuit to prevent latching up of channels due to sparks,
- Application of inductances in the LV power supply lines to avoid propagation of the sparks to the interface and FPGA boards.

Minimize spark probability

- THGEMs used in more recent works seem to have a lower discharge probability,
- Noise optimization might allow to work at lower gain,
- Use resistive well geometry (see next slides).

Resistive Well-THGEM



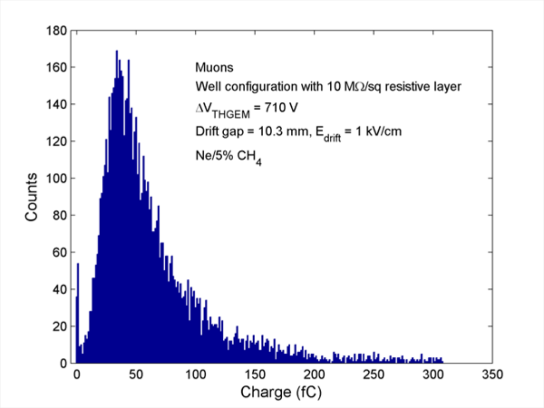
Advantages

- No induction gap
- Ground on both external electrodes
- Spark-protection of electronics

Under investigations at Weizmann

Resistive Well-THGEM

DHCAL for ILC
THGEM
Detector
KPiX
Optimization
Conclusions



- Acquisition with standard electronics chain (KPiX was not working);
- Very high gain with no sparks ($\sim$ 5600);
- Charge pulses more than enough for KPiX;
- Still unclear how it works when reading from separate pads.

Conclusions and near future work

DHCAL for ILC
THGEM
Detector
KPiX
Optimization
Conclusions

Conclusions

- Very promising structure, with a low cost per unit area,
- Results have shown that it is possible to see MIPs within 6 mm,
- Integration with KPiX about to be achieved thanks to close cooperation with SLAC.

Near future

- Establish working conditions of THGEM + KPiX in RD51 test beam,
- Combine with RD51 GEM/MicroMegas tracker information to determine multiplicity,
- Test chamber performance in the presence of hadronic showers.

DHCAL for ILC
THGEM
Detector
KPiX
Optimization
Conclusions

Thank you for your attention!