Development of Digital Hadron Calorimeter for ILC Using GEM

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Large GEM Training/CERN
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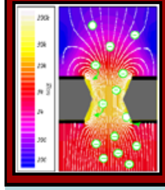

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- 30x30 cm^2 chamber at UTA
- KPiX readout electronics (SLAC)
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- Future plans
- Summary

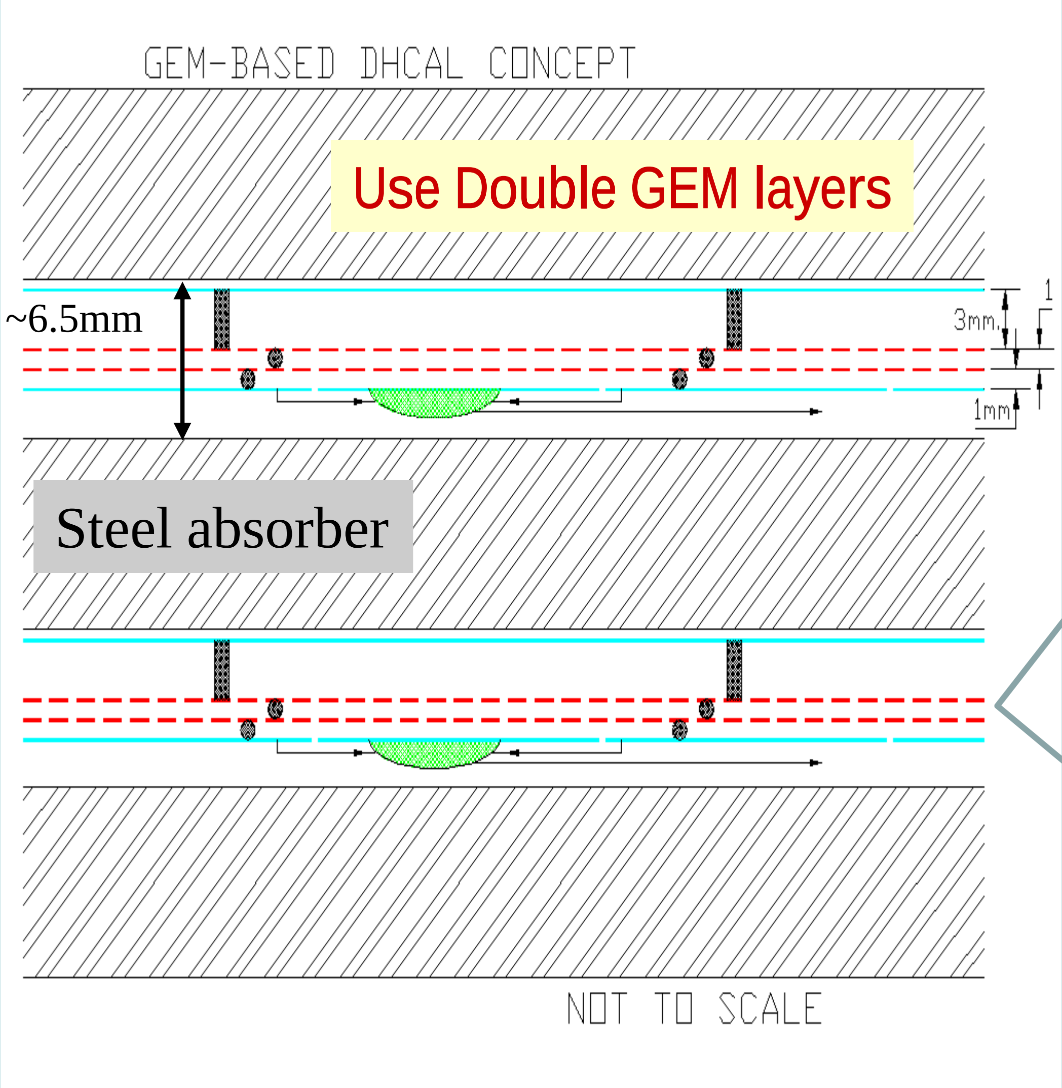
Introduction

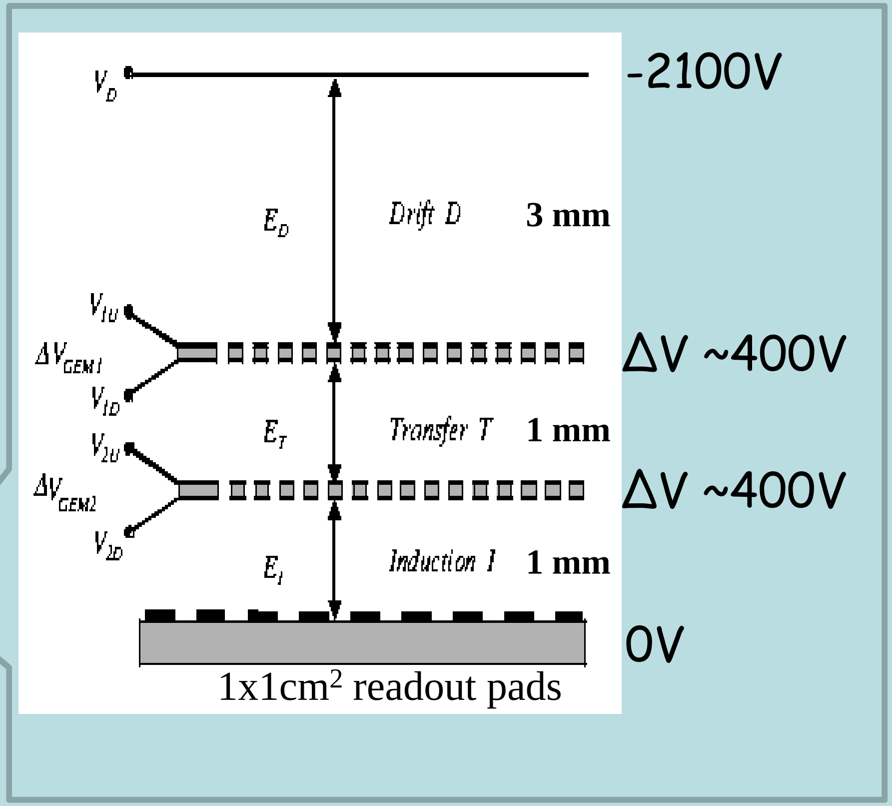
- Many critical physics measurements at the ILC require precision jet quantity measurements
  - Efficient jet separation and reconstruction
  - Excellent jet energy resolution
  - Excellent jet-jet mass resolution
- Particle Flow Algorithm is a solution for this
  - Use momenta measured in trackers for charged particles
  - Measure EM and neutral hadron energies using calorimeters
  - Require fine calorimeter granularity
  - Digital (one – two bit) readout a way to control costs

Why GEM's for DHCAL?

- Flexible configurations: allows small anode pads for high granularity
- Robust: survives ~10^{12} particles/mm^2 with no performance degradations
- Fast: based on electron collection, ~few ns rise time
- Short recovery time → can handle high rates
- Uses simple gas (Ar/CO_2) – no long-term issues
- Runs at relatively low HV (~400V across a foil)
- Stable and robust operations

GEM-based Digital Calorimeter Concept



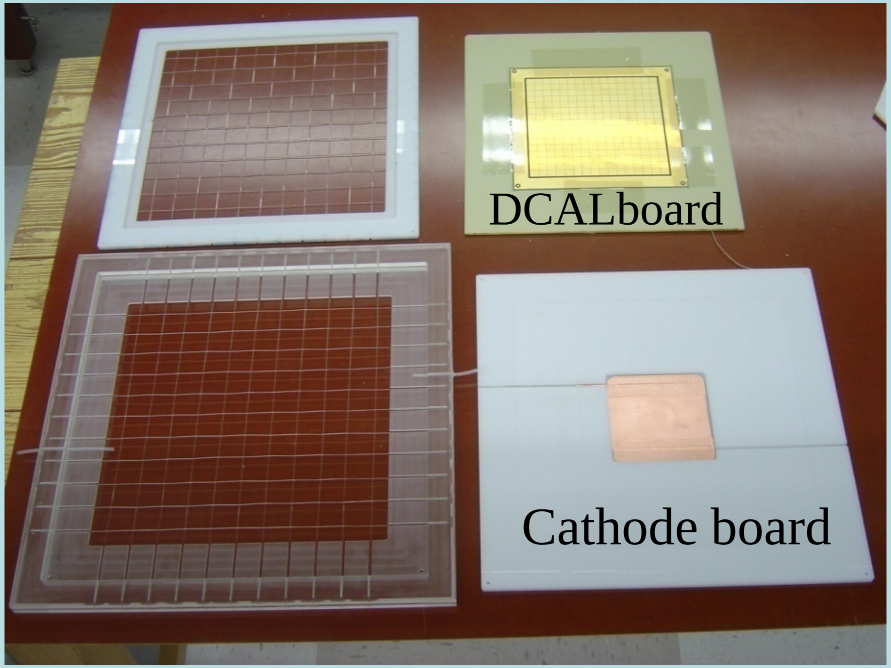


- Passive (material) and Active (GEM) layers
- Increase spatial resolution (1 x 1 cm^2 readout pads)

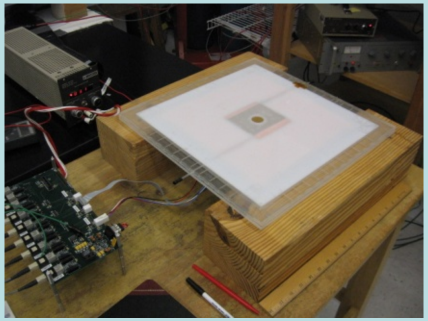
What have been done so far?

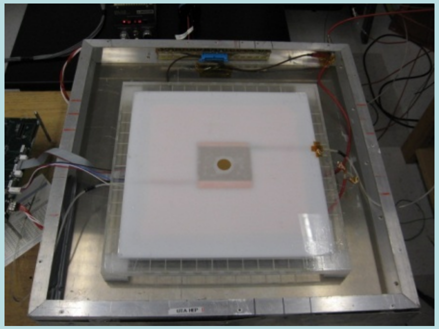
- Bench tested with various source and cosmic ray
  - Used QPA02(32 ch, FermiLab) chip based preamp
  - Verified the signal shape, responses and gain
- Took a beam test at a high flux electron beam
  - First chamber built with 3M's 30x30cm^2 GEM
  - Used QPA02 chip based preamp
  - Verified that the chamber can survive
- Took two beam tests at FNAL's MTBF
  - Used QPA02 chip based preamp
  - 8 GeV pion beams and 120GeV proton beams
  - Measured chamber responses, efficiencies and gain
- Multiple channel readout w/ Analog KPiX chips

Currently running chamber structure

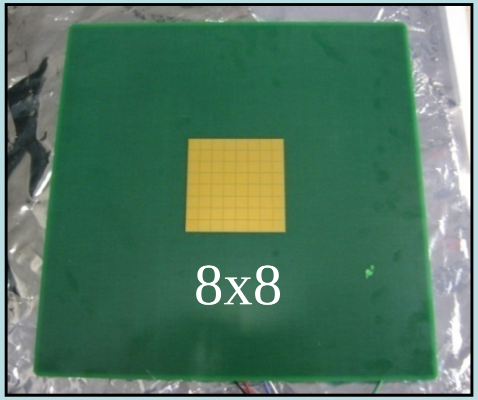


- ✓ 30x30 cm^2 foils(3M)
- ✓ Used fishing lines as spacers
- ✓ 256(16x16) readout pads in DCAL board
- ✓ 64(8x8) readout pads in KPiX board; 10x10 mm^2 pads with 0.2 mm gap
- ✓ Constructed with plastic as the frame materials → weak to noise
- ✓ Use additional metal enclosure to shield from noise



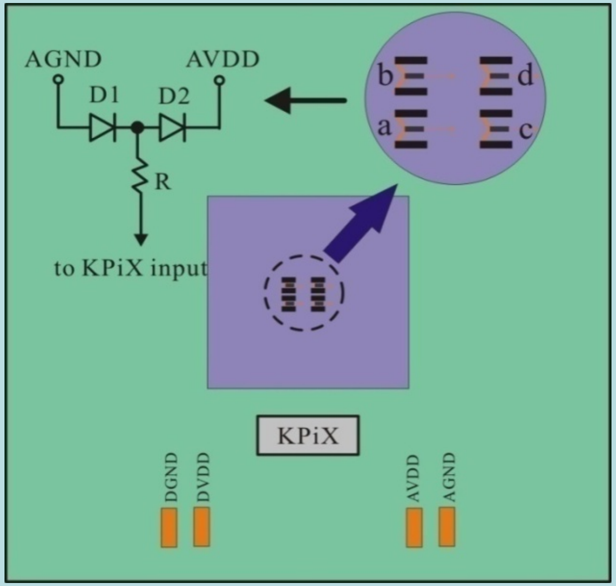


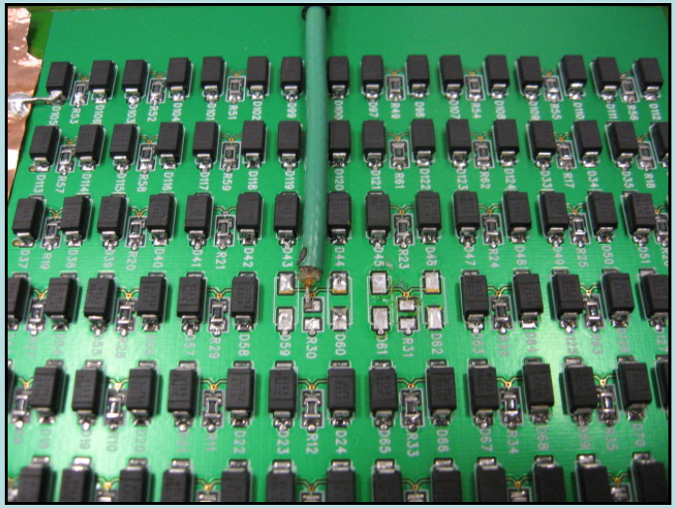
KPiX board



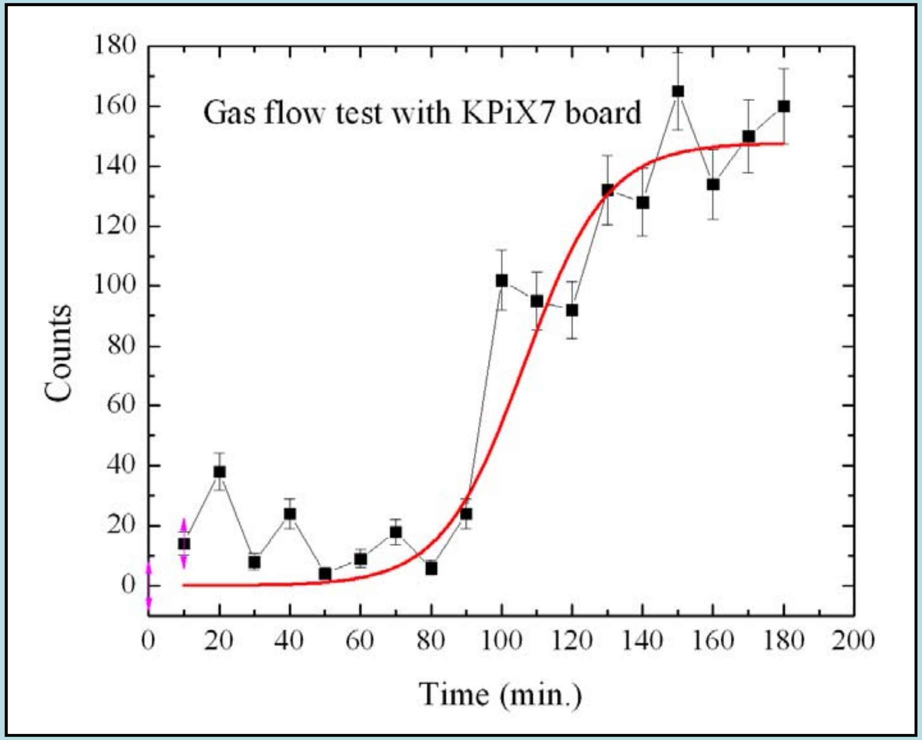
Analog signal test

- ✓ In order to check analog signal from the chamber, external charge sensitive preamplifier (FermiLab, QPA02) was used.
- ✓ One of the readout pads was directly connected to the input of the QPA02. In this test the KPiX system was inactivated.
- ✓ The output was monitored with a oscilloscope.





Gas flow test result



How long time should we wait for the gas to be stable?

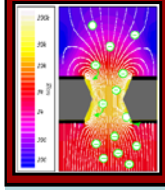
→ Measured counting rates of the signals with gas flow time.

✓ Sometimes environmental noise affected the counting and this increased the counting uncertainty, however from this test we could estimate the approximate time to wait before doing measurement.

Q1: Should we really wait for 3 hrs to get the stable system?

Q2: Where the noise comes from? Can we block off the noise by modifying the structure of the chamber?

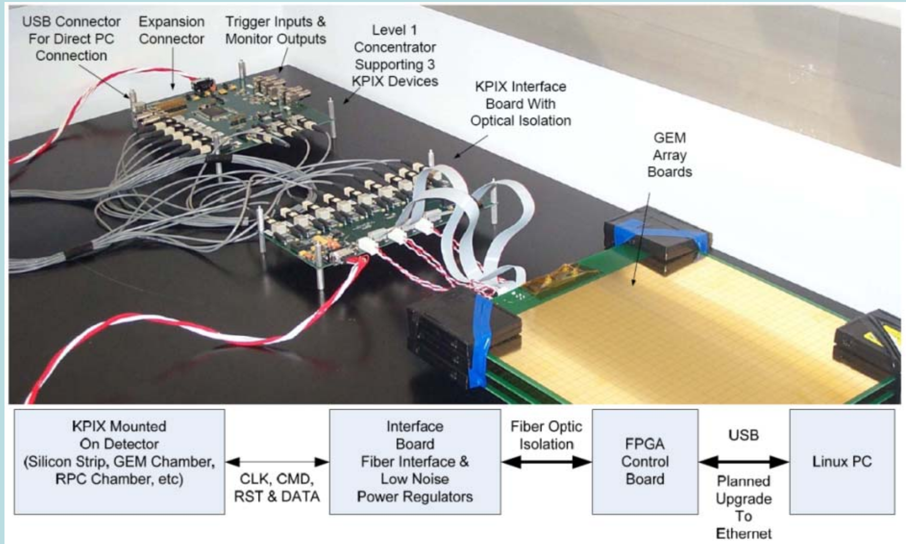
→ New chamber design is needed.

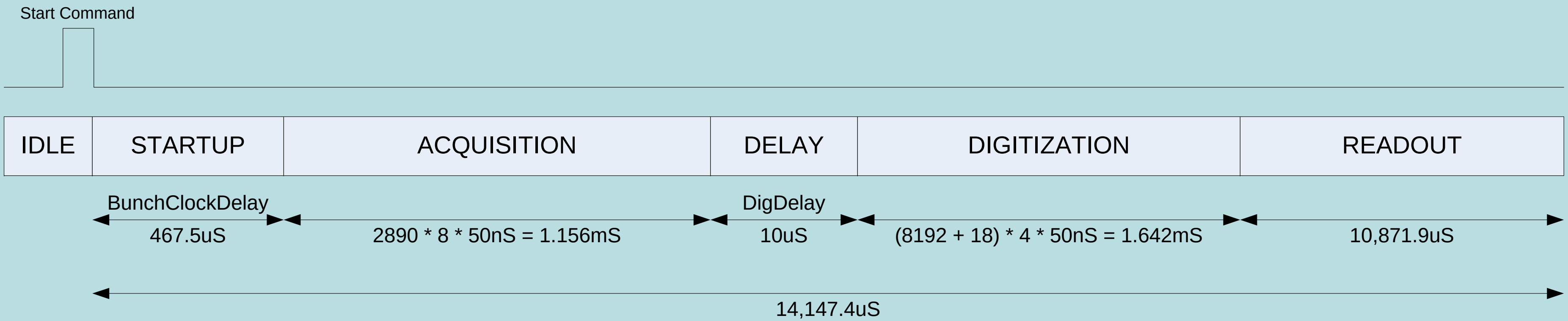


Readout electronics / KPiX(SLAC)

- 1024 pixels / ROC → Thus working name KPiX

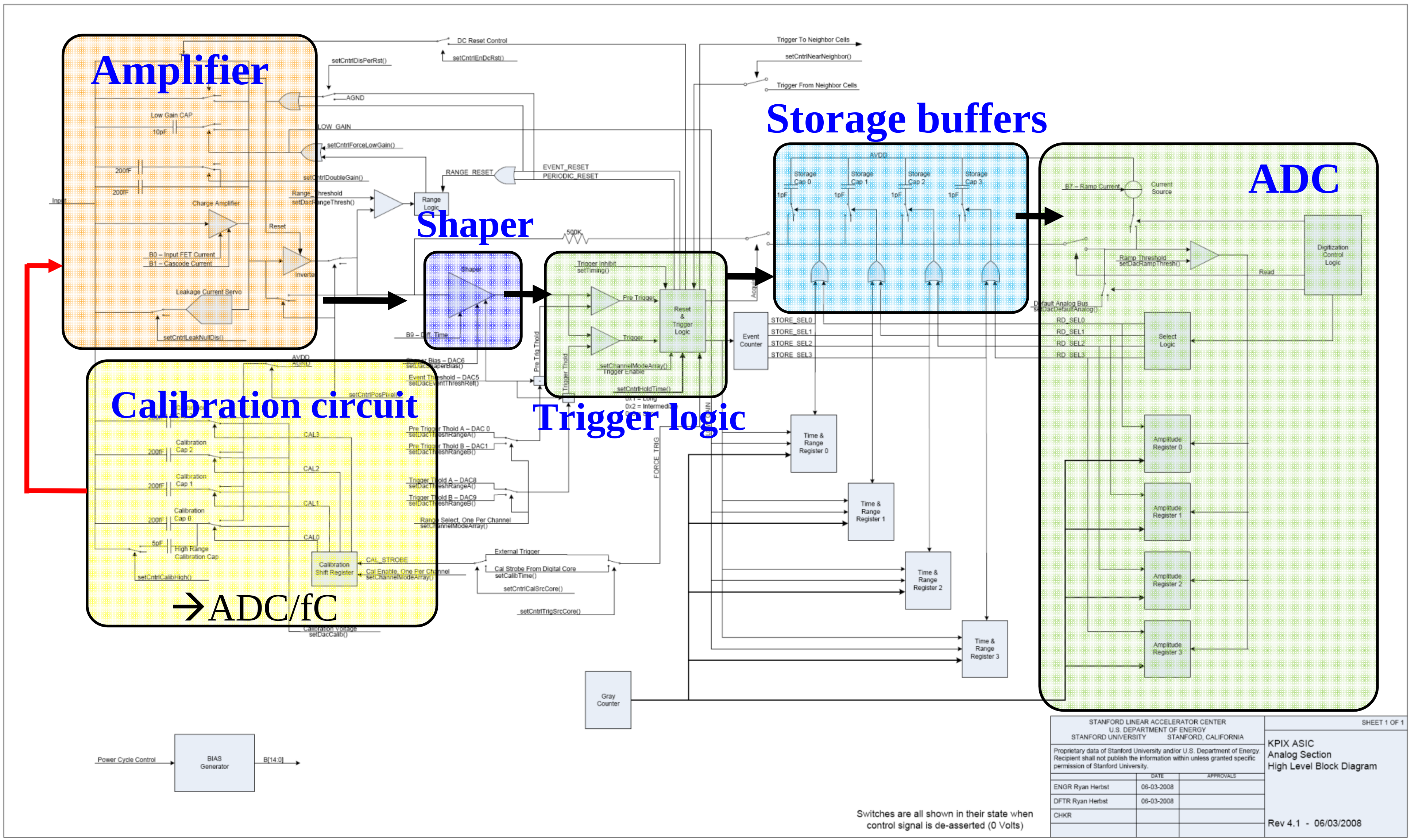
- **FPGA Control Board**
  - USB Interface to PC
  - Interface To External Logic
    - Beam Line Triggers
    - Scintillators
    - Laser Triggers
- Optically Isolated To **KPIX Interface Board**
- C++ API Under Linux



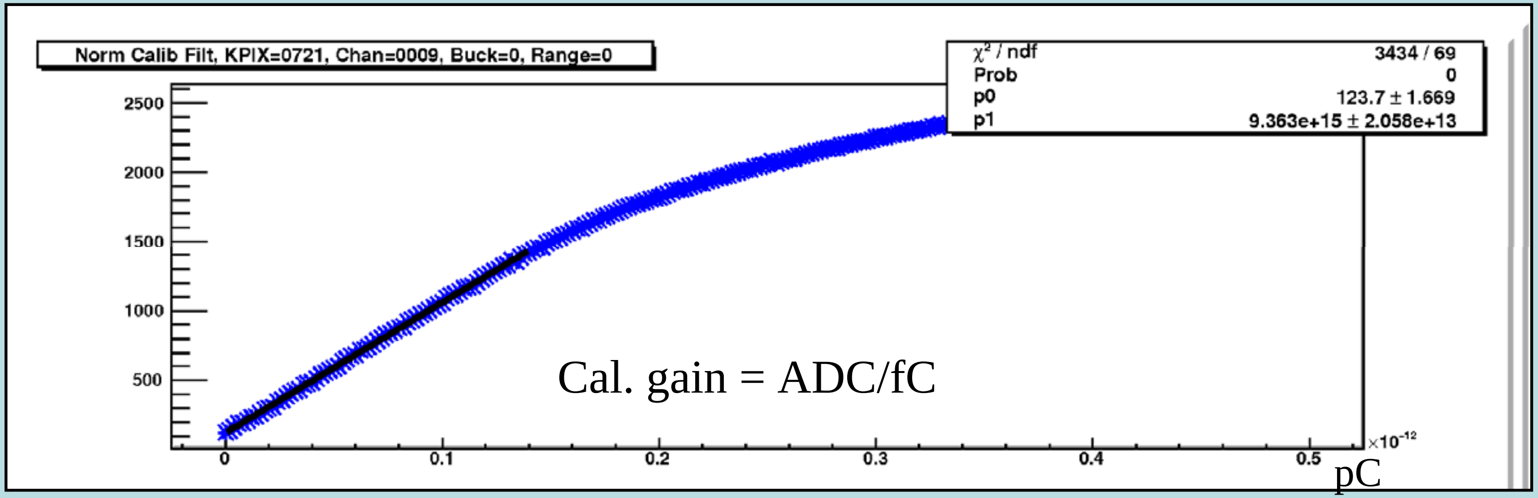


Software drive acquisition results in ~24 cycles per second

KPiX Readout scheme



Calibrations/Range selection

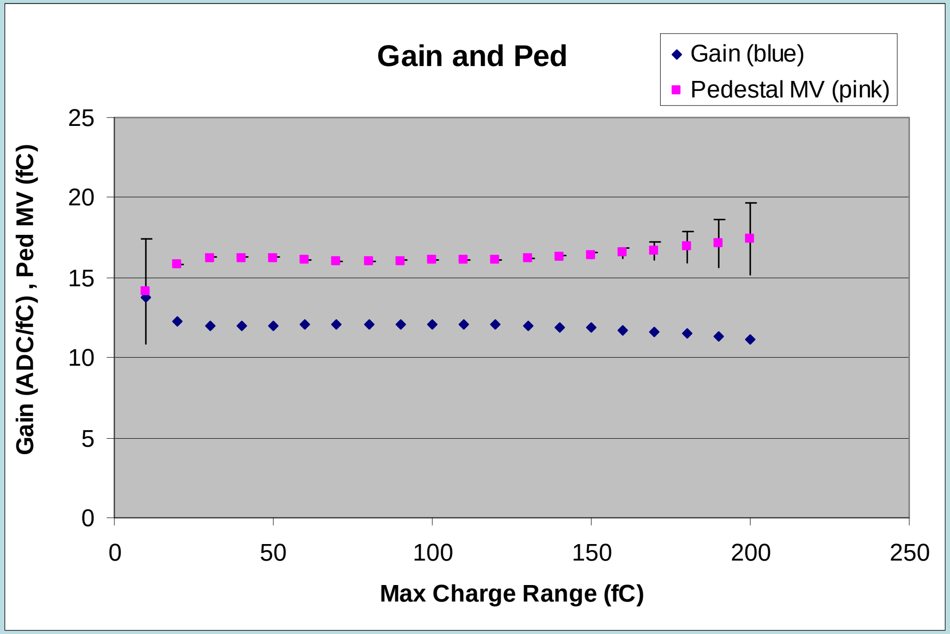


- **Gain Calibration depends on user choosing fit range** to decide the slope of ADC/fC line
  - For normal gain, range is usually 0~130 fC
- The current method to determine this range is to look at the gain graph to find the range where the line best overlaps all the data points
  - Note: if range extends to 200fC (0.2pC), the line drops because graph curves slightly starting at 150 fC
- Note: the low end is very important to fit accurately

HEP/UTA

Fit range study

❖ In an attempt to make the range choice for fitting calibrations more systematic. **-Jacob-**

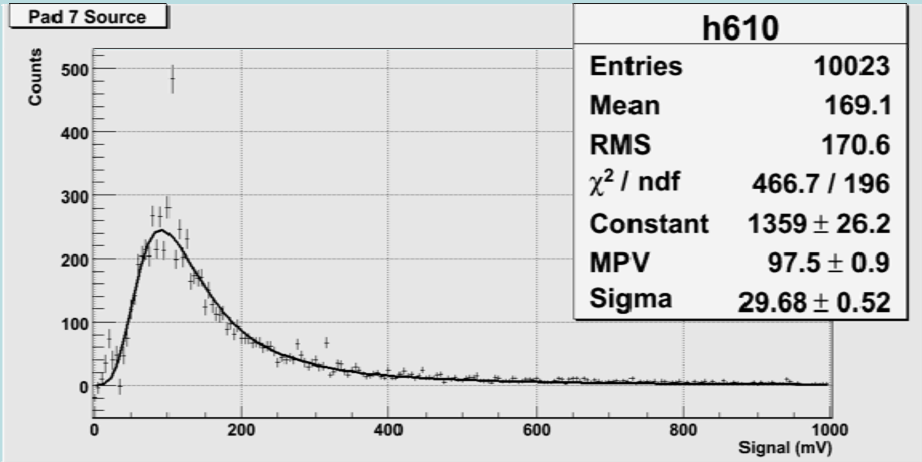


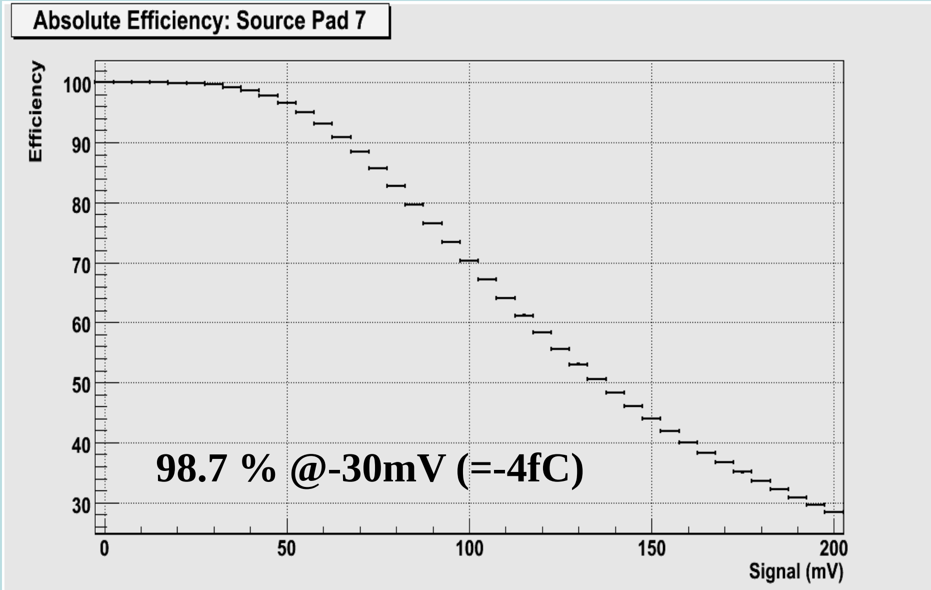
- Graph shows that ranges up to 200 fC, excluding 0~10 range, have at most a 12% error to mean, even up to 150 fC, the error is only 2% to mean, at 0~130fC range error to mean is 0.4%

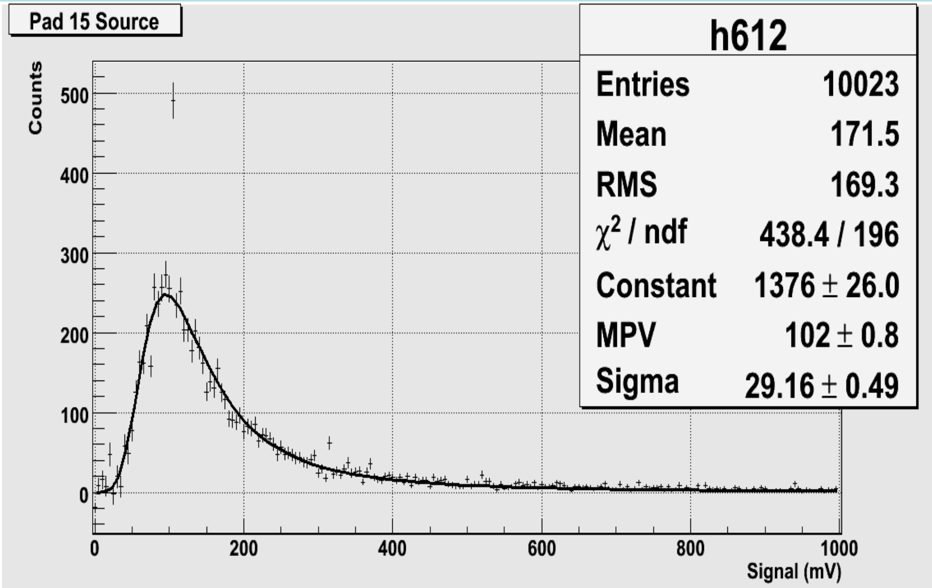
☞ **0~130 fC range is a good selection !**

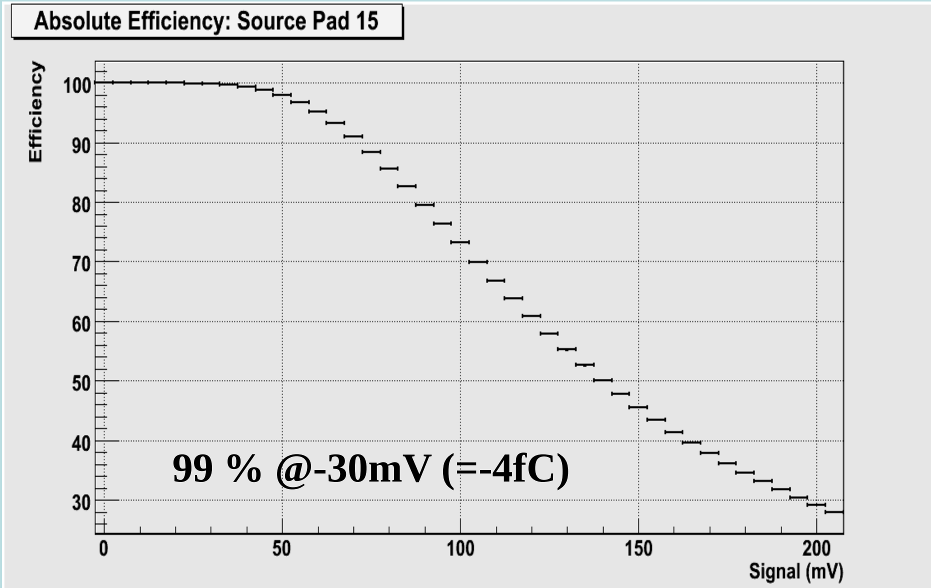
Efficiency vs Threshold

- FNAL experiment

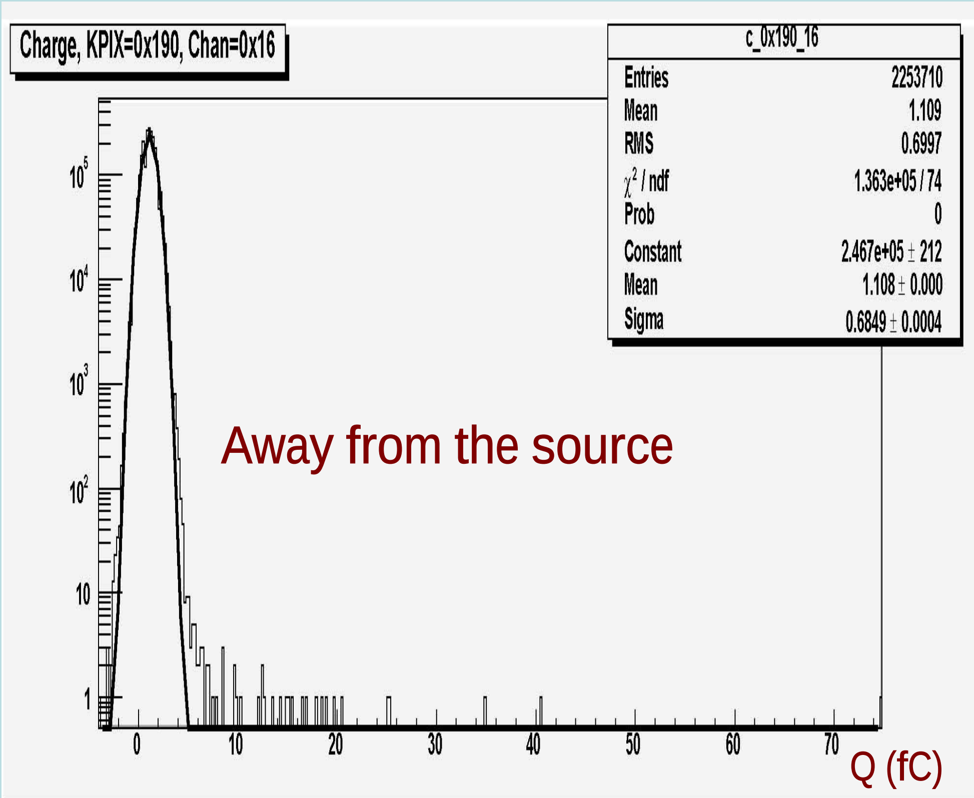


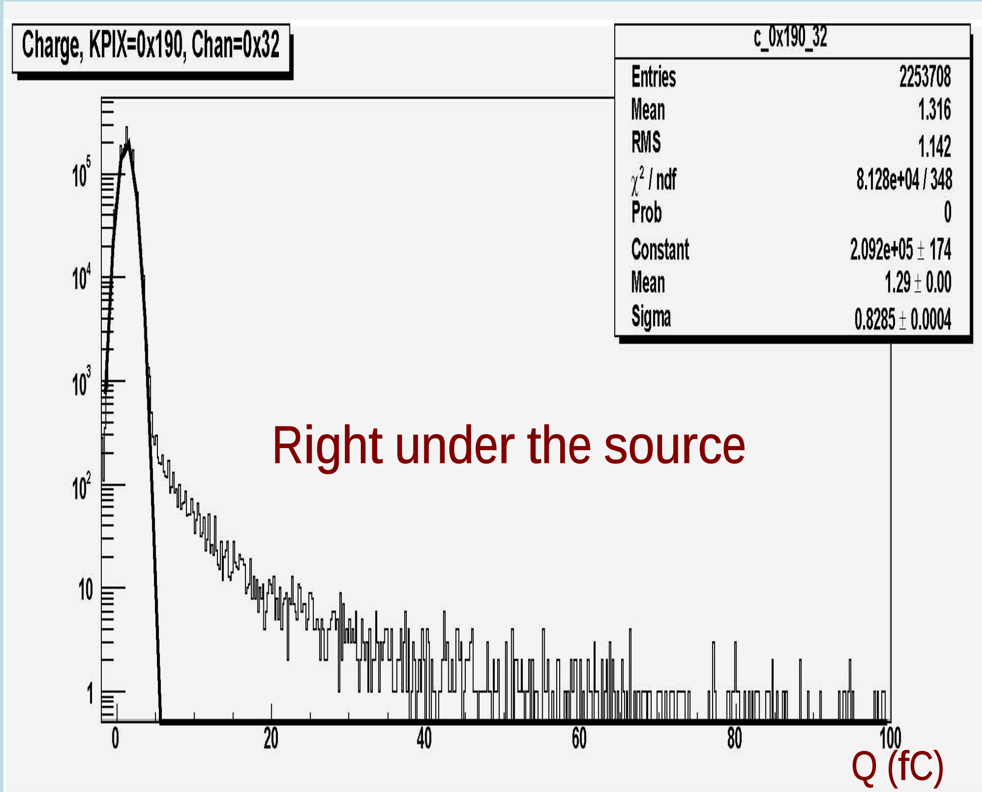






Reponses to Source – GEM-KPiX





New chamber design

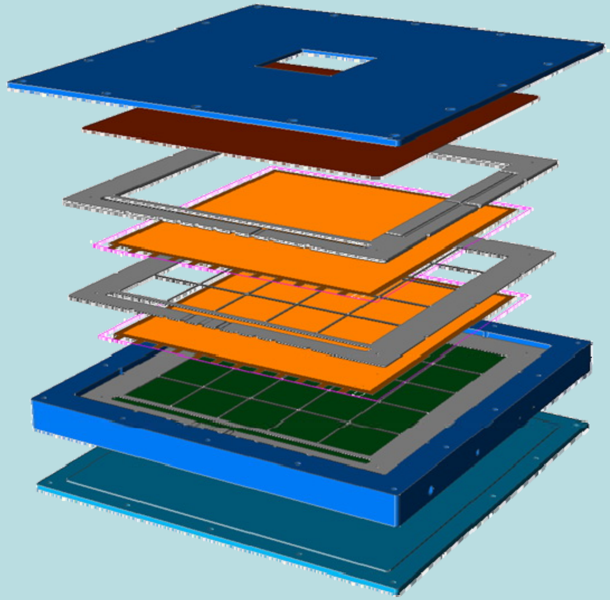
- Two main problems with current chamber
  - More effective gas distribution required.
  - Weak to environmental noise → need additional shielding enclosure.

- New design
  - Use specially designed spacers for an effective gas distribution
  - Complete enclosure the entire detector system with metal box
    - ✓ No additional shielding box required
    - ✓ The chamber will have several feed through for HV/LV power, signal and data transmission between KPiX chip and interface board.
    - ✓ Effective HV distribution
  - Don't use glues, all components reusable → makes maintenance easy

Dimensions

➢ GEM Foils(3M)

- 310x310 mm^2
- Active area : 280x280 mm^2



➢ Chamber

- 410x410 x40.6 mm^3
- Material : Aluminum or Stainless

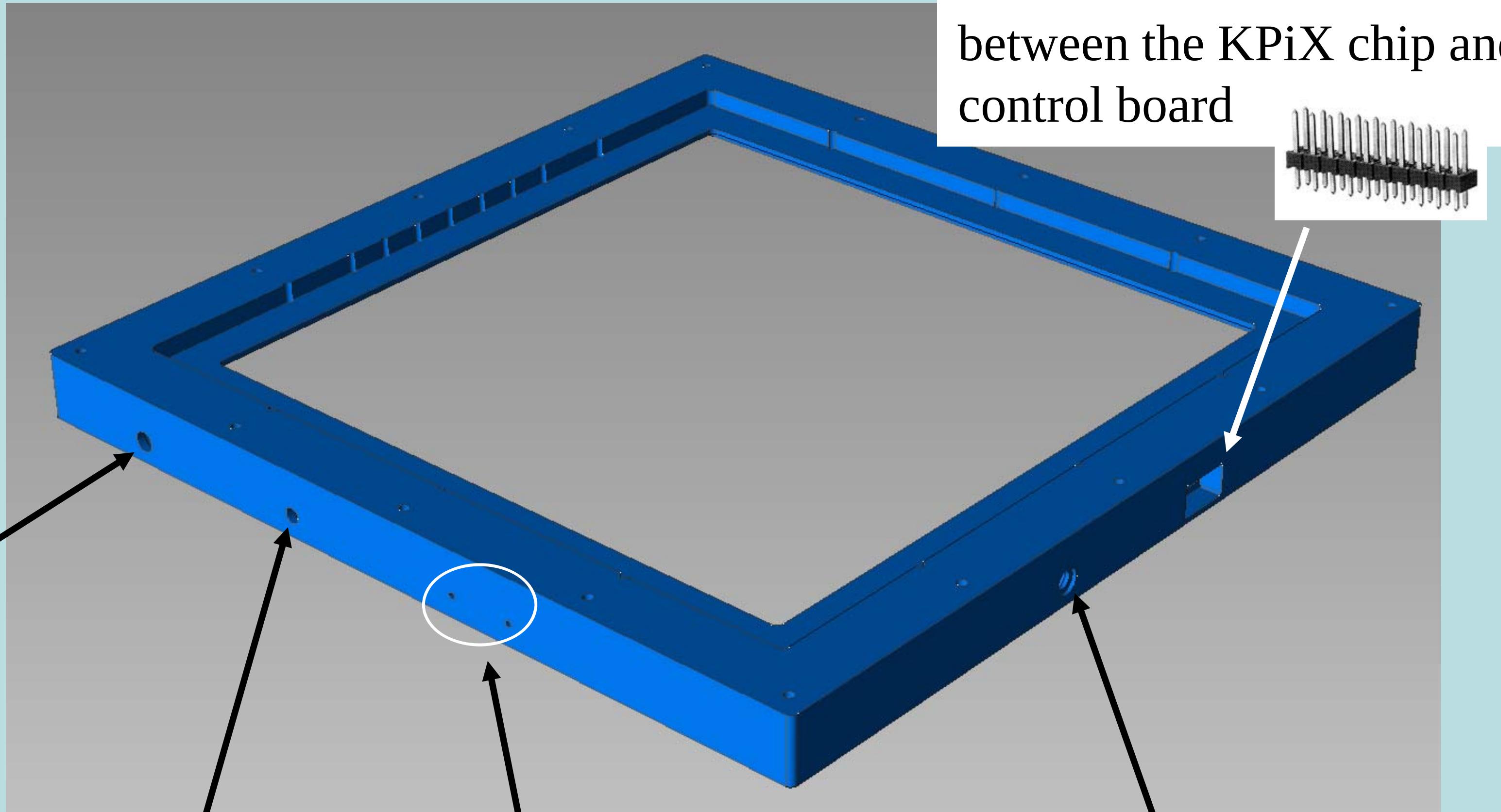
→ Chamber will completely enclosure the KPiX system
→ Don't need metal enclosure for shielding

➢ Active gas room

- 350x350x6 mm^3 → For 3/1/1 gaps

Feed through and gas connectors

Connector for data transmission between the KPiX chip and the control board



HV Connector

Gas inlet and outlet

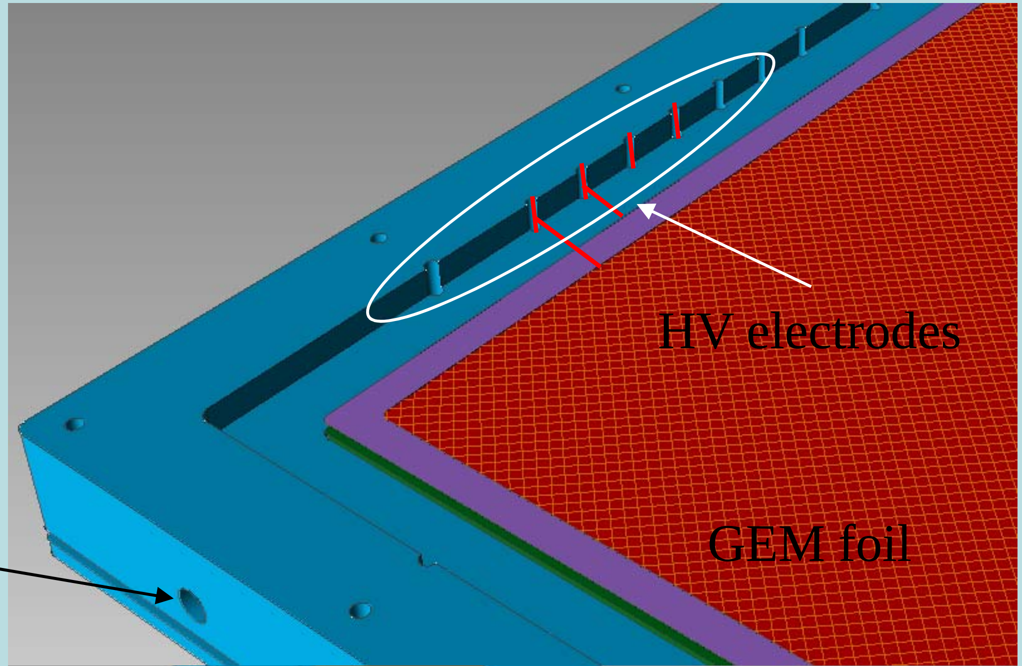
Connector for analog signal check

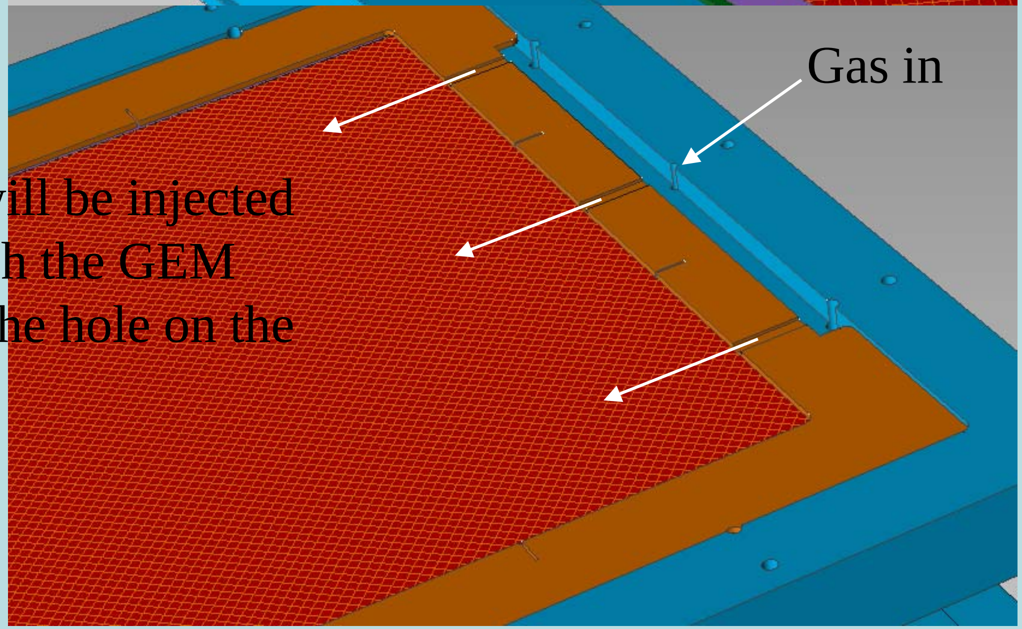
Low voltage power connector for KPiX

HV and Gas

➢ **HV supply** : from bottom to top, resister network will be set under the bottom side of the chamber, electrodes will stand vertically

HV connector

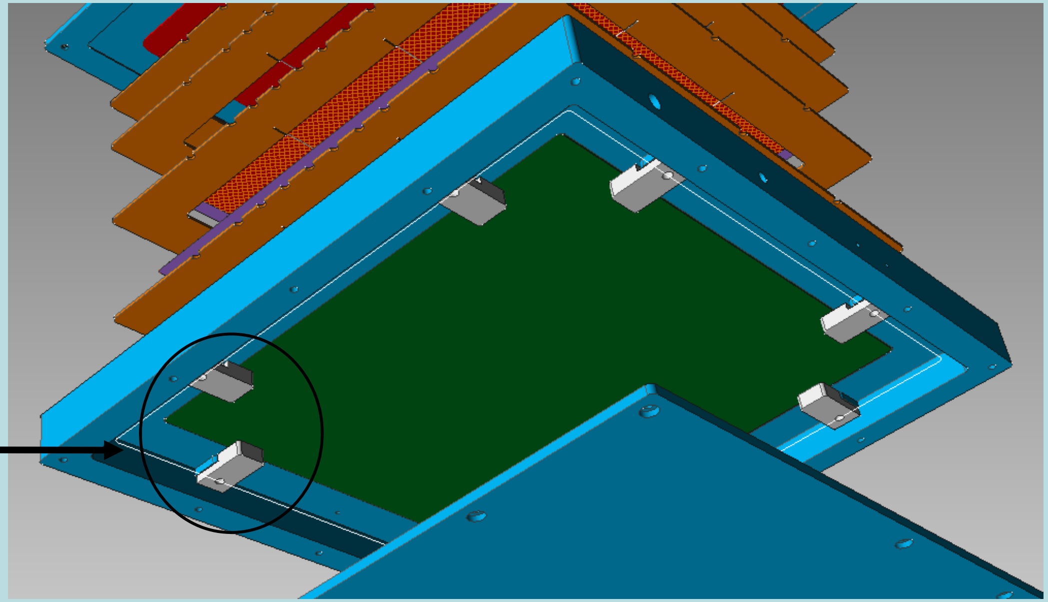




➢ **Gas flow** : from top to bottom; gas will be injected into the drift region and flows through the GEM foils, finally it is exhausted through the hole on the bottom of the chamber

Fixing the system

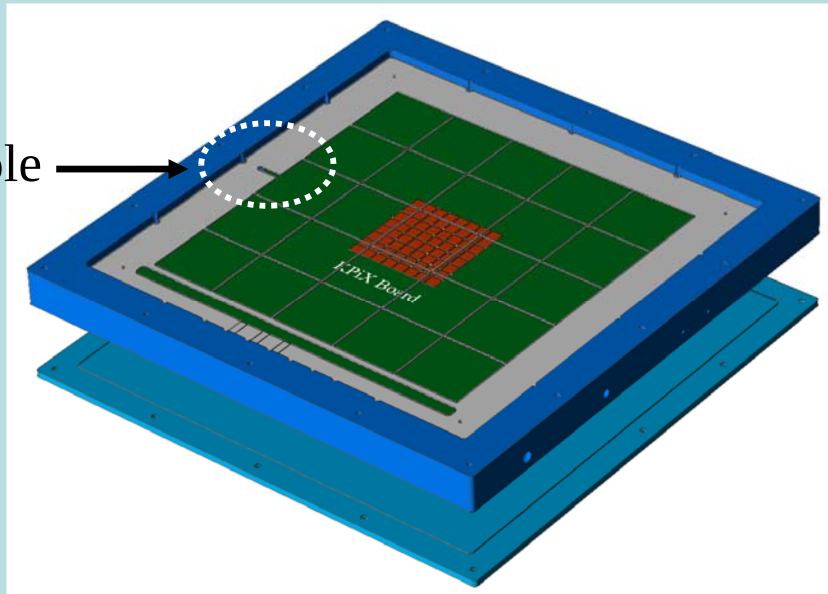
- **Easy access from the bottom side: in case of problems with the KPiX readout board, it is accessible from the bottom side to fix the problems.**



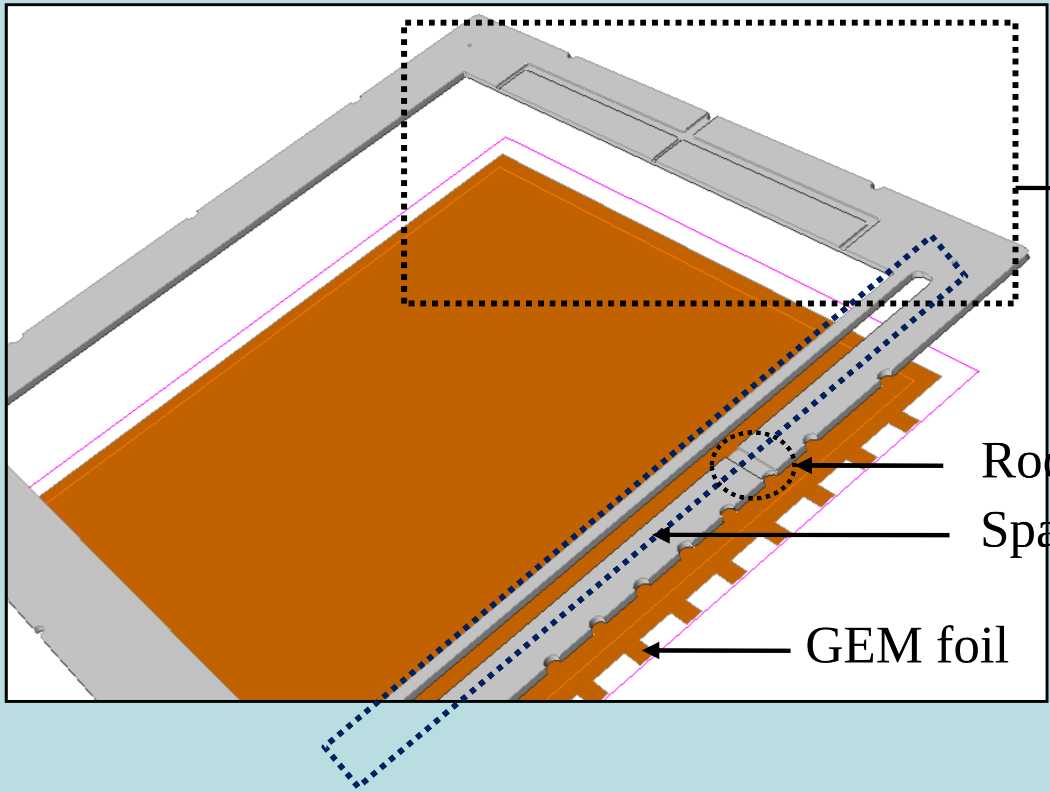
- **The KPiX board is supported by 8 pieces of brackets**

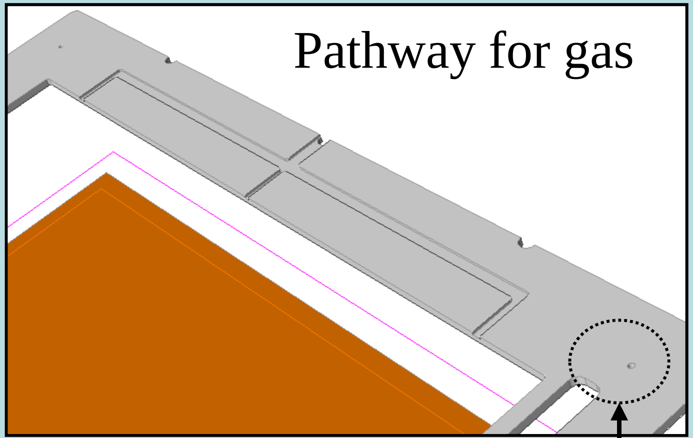
- **The chamber is easily assembled and disassembled with 16 screws**

Gas exhaust hole



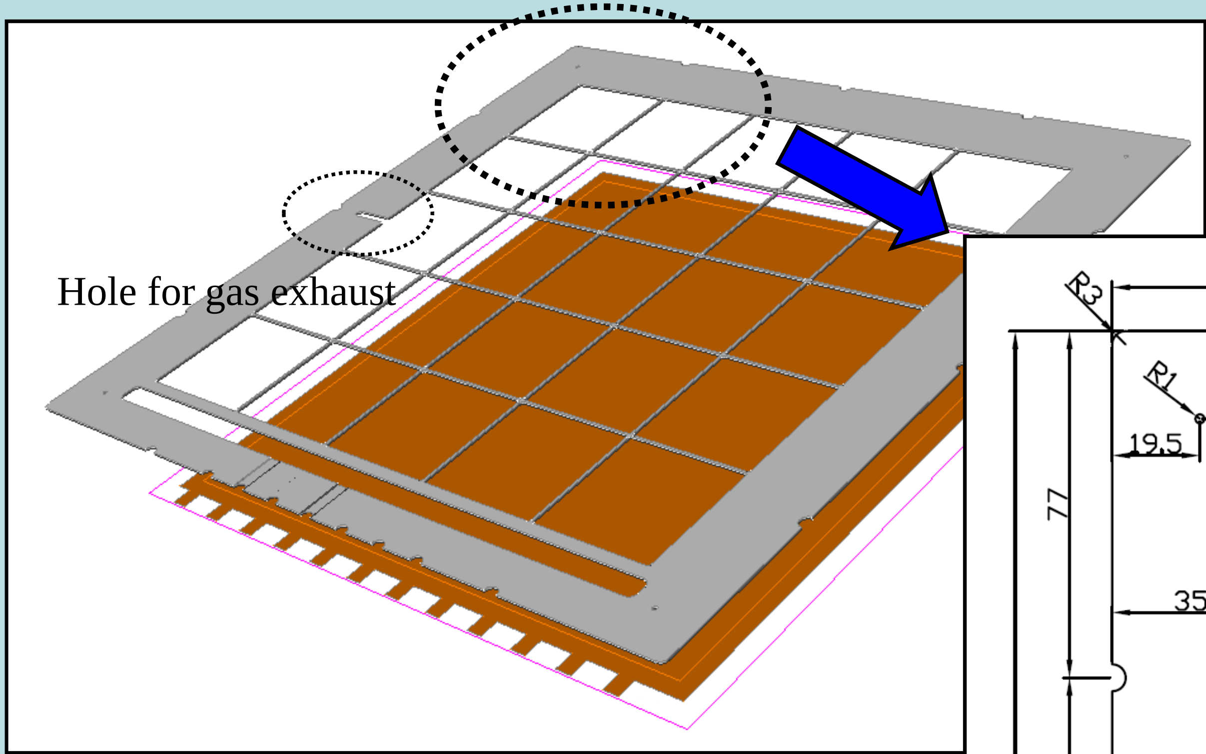
Spacer/drift

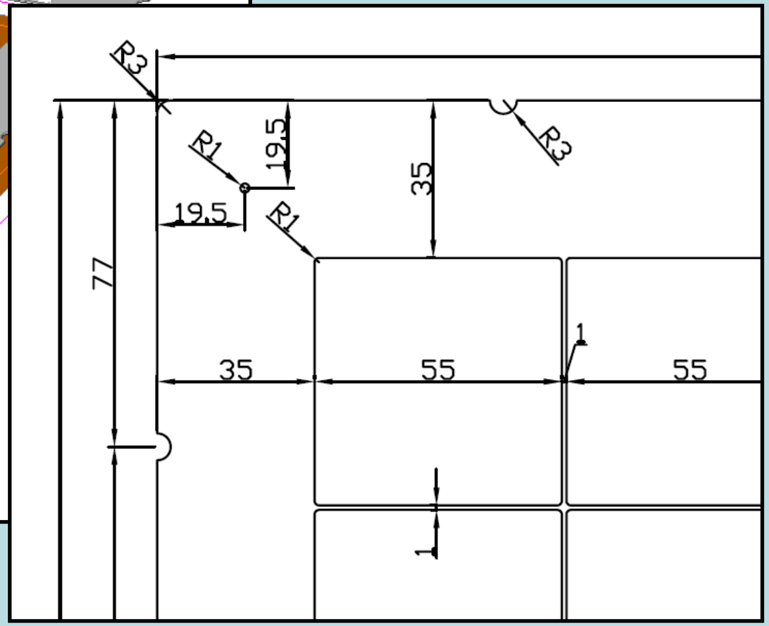




- ❖ Thickness: 3 mm
- ❖ Material : Epoxy glass (PERMAGLAS ME 730, Resarm)
  - → Low dust emission

Spacer/transfer, induction





- Grid thickness: 1 mm
- Cell size: 55x55 mm^2

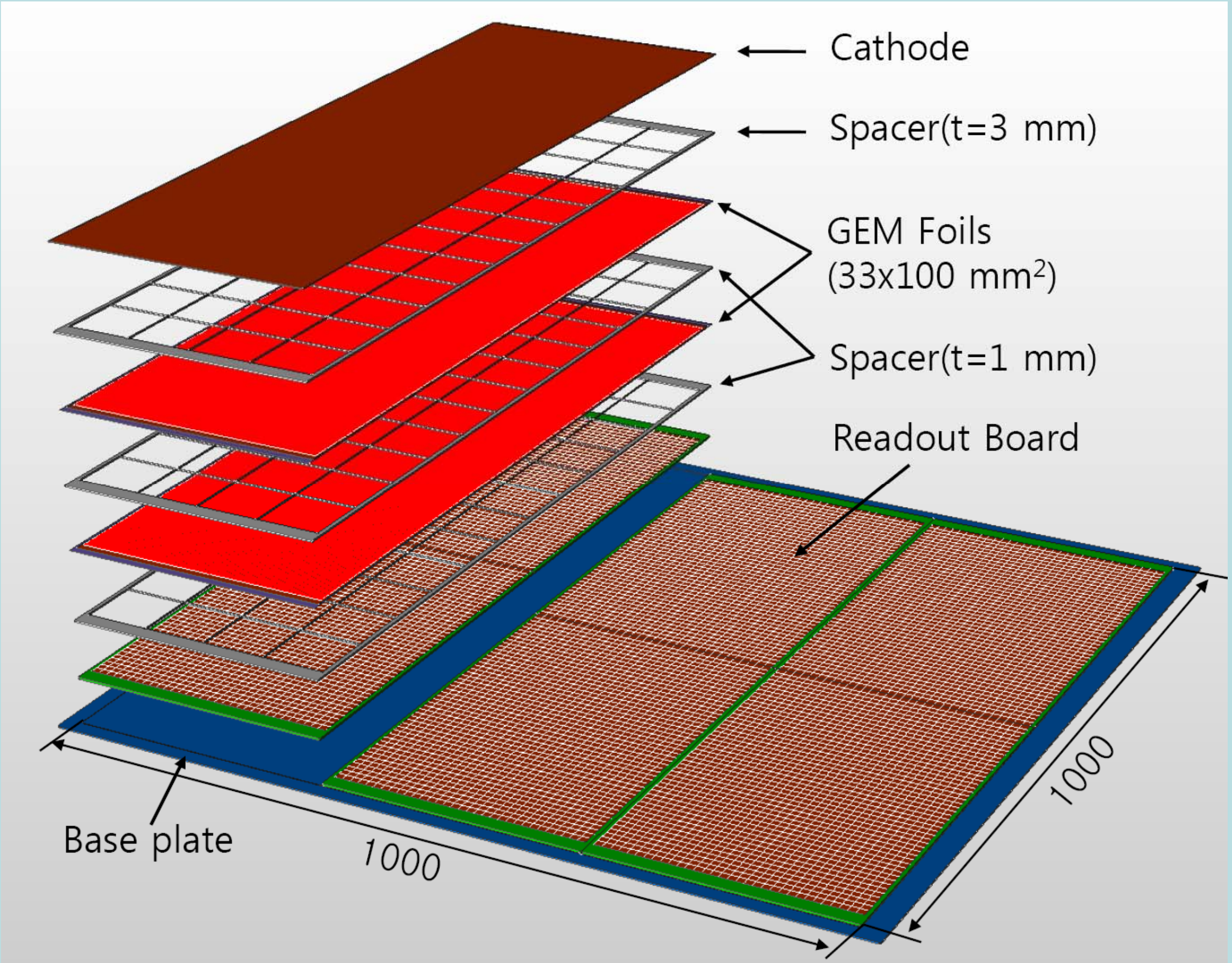
❖ Thickness: 1 mm

❖ Material : Epoxy glass (PERMAGLAS ME 730, Resarm)

→ Low dust emission

Future work / 1x1 m^2 large chamber

☞ Rui is preparing production of large GEM(33x100 cm^2) for this work.



GEM DHCAL Plans - I

- Jan. 2009 – Summer 2009
  - 30cmx30cm chamber
    - Construct a new chamber with optimal gas flow design
    - Characterize the chamber with sources and cosmic rays using 64 channel KPiX v7 at UTA
    - Characterize the chamber in particle beams
      - Responses, noise characteristics, efficiencies, gains, etc
  - 33cmx100cm unit chamber
    - **Finalize 33cmx100cm (32cmx96cm active area) large GEM foil silkscreen design**

GEM DHCAL Plans - II

- Spring 2009 – Late 2009
  - 33cmx100cm thin GEM unit chambers
    - Production and certification of 33cmx100cm foils
    - Characterization of 256 channel v8 KPiX chips
      - Available in late spring 2009
      - Use 30cmx30cm STP chamber
    - **Construction and characterization of 33cmx100cm thin GEM unit chamber**
- Late 2009 – Mid 2011
  - 33cmx100cm thin GEM unit chambers
    - Complete production of 15 33cmx100cm unit chambers
  - **Construct five 100cmx100cm GEM DHCAL planes**
    - Using DCAL or KPiX readout chips
  - **Beam test GEM DHCAL planes in the CALICE beam test stack together with RPC**

Summary

- Construct 30x30 cm^2 GEM chamber for DHCAL
- Calibration study on the KPiX system
- Beam/source test
- Chamber design for optimal gas flow and noise shielding
- Future plans with 1x1 m^2 large GEM

Thank you!