Scintillator strip calorimeter R&D

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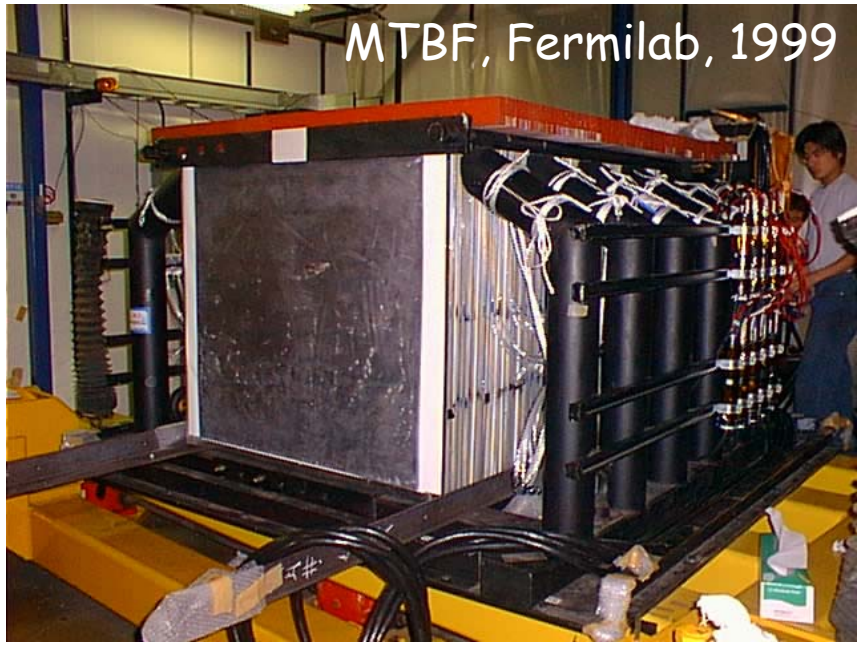
for GLDCAL and CALICE collaborations

Scintillator strip calorimeter

- Being studied by GLDCAL group
  - GLDCAL group: KEK, Kobe, Niigata, Shinshu, Tokyo, Tsukuba (Japan), KNU, SNU, SKKU (Korea), MSUIIT (Philippine), JINR (Russia)
- Can also be regarded as one of CALICE activities since Kobe and Shinshu became CALICE members in September 2006.

History of GLDCAL

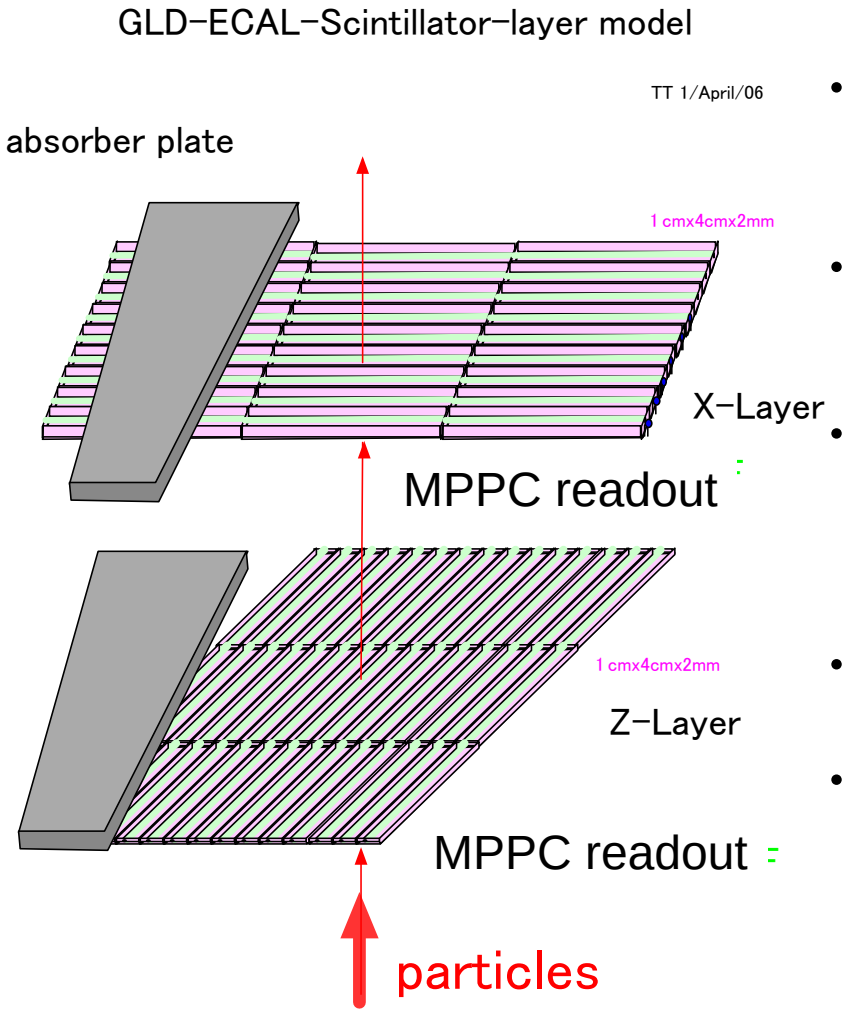
- Formerly called "JLCCAL"
- Have been working on scintillator-based calorimeter and its photon sensors.
- Study of lead/scintillatior compensating HCAL
  - A $1m^3$ test module, with ~300 PMTs
  - tested at KEK (1996-1998) and Fermilab (1999)
- Study of fine segmented lead/scintillator ECAL
  - Small tile ECAL (4cm x 4cm)
  - Strip array ECAL (1cm x 20cm)
  - Strip shower maximum detector (1cm x 20cm)
  - Readout with MAPMTs
  - Test modules tested at KEK (2002, 2004) and DESY (2003)



MTBF, Fermilab, 1999

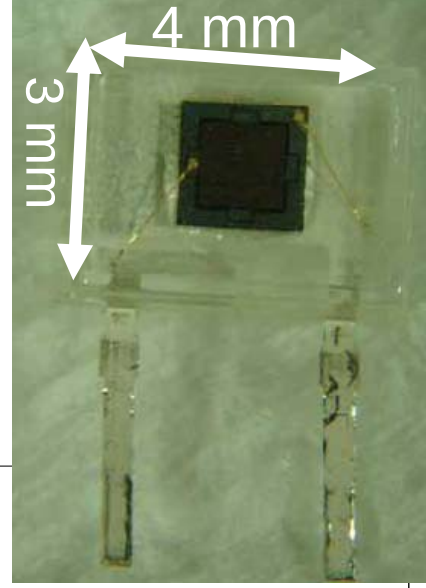
KEK, 2004

Concept of strip calorimeter

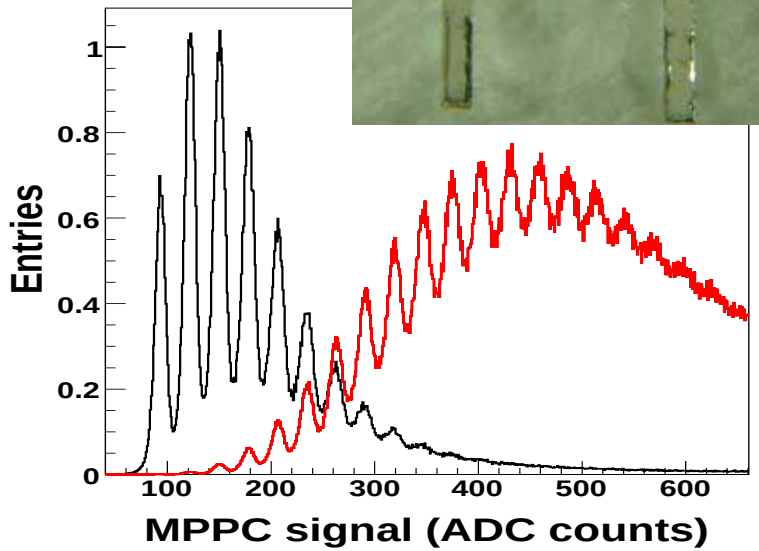


- Sampling calorimeter with
  - scintillator and W for ECAL
  - scintillator and Pb (Fe) for HCAL
- Realize fine granularity (effective segmentation ~1cm x 1cm) for PFA with strip structure
- Huge number of readout channels for a ILC detector
  - ~10Mch for ECAL,
  - ~4Mch for HCAL
- This is achieved by MPPC (or SiPM) readout
- Clustering algorithm for the strip structure is under development.

Why MPPC ?



- MPPC stands for Multi-Pixel Photon Counter, being developed by HPK in collaboration with our community.
- Pros
  - Low cost (in future)
  - Very compact
  - Sensitive to the light with wavelength ~ 400 nm
  - High PDE (15~20% for 1600 pix)
  - Insensitive to magnetic field
  - High gain (10^5~10^6)
  - Operational at V_{bias}=70~80 V
  - Good timing resolution
  - Superior photon counting capability
- Cons
  - Thermal noise rate (100kHz~300kHz)
    - Set threshold at ~1.5 p.e.
  - Response is non-linear due to limited number of pixels (saturation effect)
    - We currently have 1600 pix MPPC with sensitive area 1mm^2
    - Correction may be adapted at some level, but
    - MPPC with more pixels (N_{pix} > 5000) is desired → pressure to HPK
  - Sensitive to temperature change
    - ΔGain / ΔT = 2~4 % / C^o , to be improved in future
  - Cross-talk between pixels



Time line of our R&D

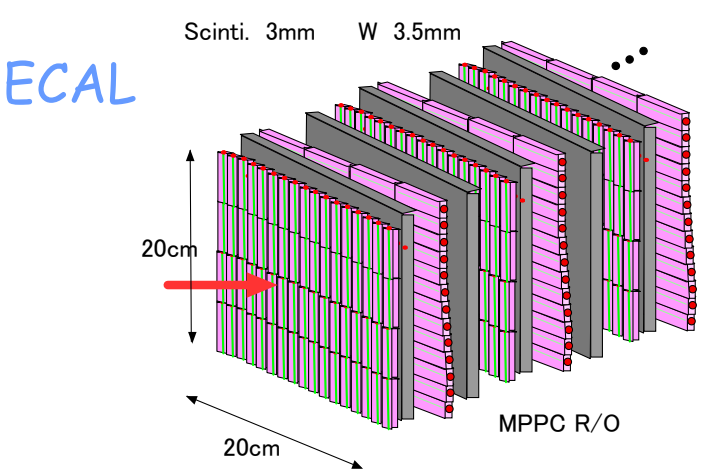
2005 2006 2007 2008 2009 2010 2011 ...

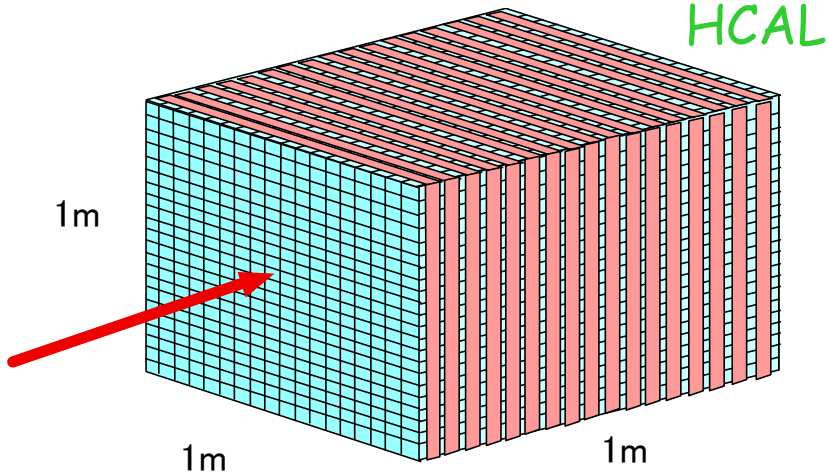
JSPS grant for ILC detector

JSPS grant for ECAL R&D

(JSPS: Japan Society for the Promotion of Science)

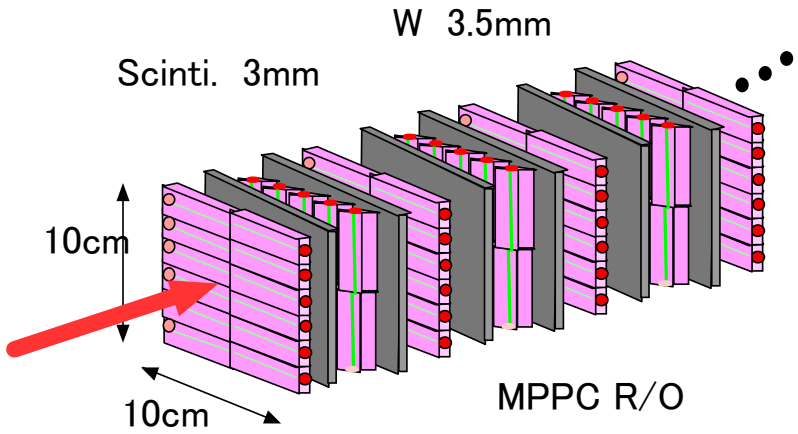
BT@DESY BT@Fermilab BT@Fermilab





ECAL Beam Tests at DESY

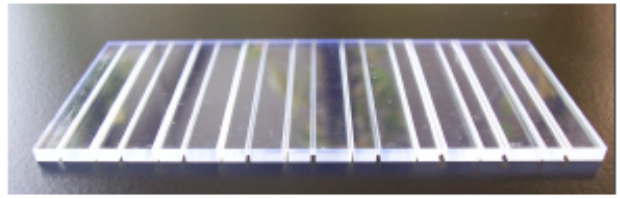
DESY BT (Feb-Mar 2007)



26 layers ~ 500 channels:
1600-pix MPPCs will be used.

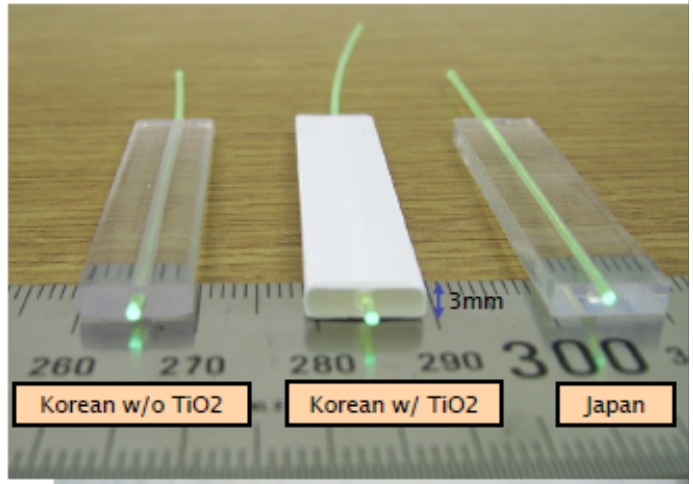
- First beam test of scintillator strip ECAL with MPPC readout
- Performance for1-6 GeV e+
  - Energy resolution
  - Response linearity
  - Position resolution
- Experience of multi-channel (~500ch) MPPC readout
- Test 3 different strip types
- Introduction of
  - LED gain monitoring system
  - Temperature monitoring system
- Thrash out all the pros and cons

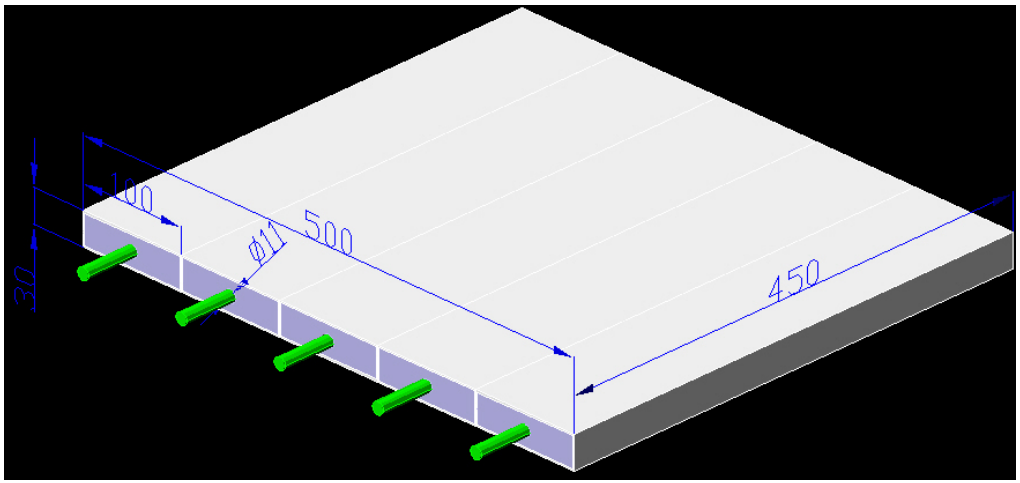
scintillator

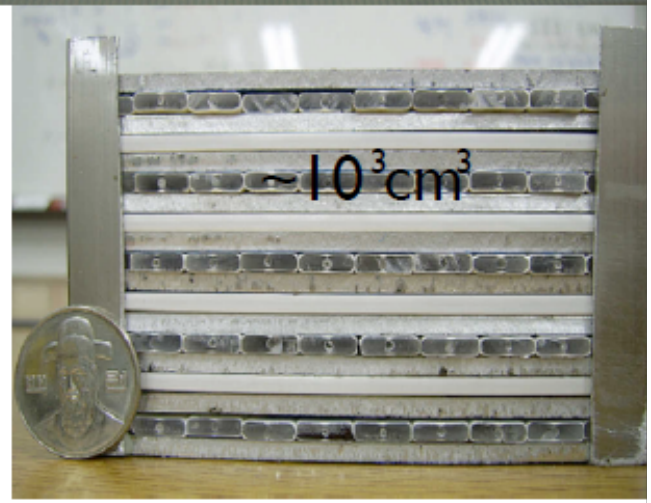


- KURARAY : Mega strip plate
- KNU (Kyungpook National U.) extruded and covered by TiO2

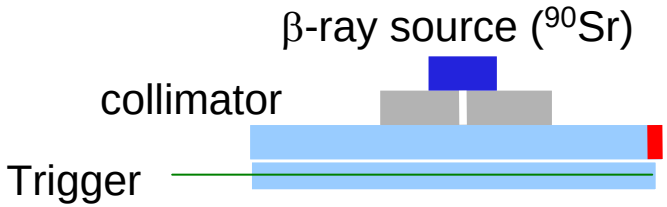
(Extruded Mega-strip under development)







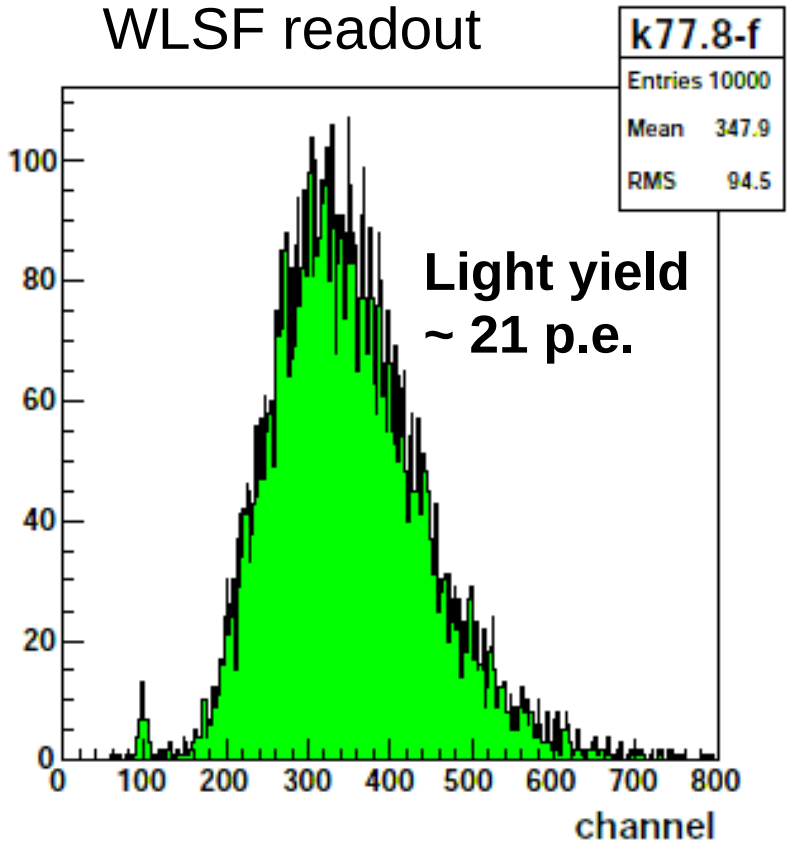
Signal from scintillator strips (@Shinshu-U)

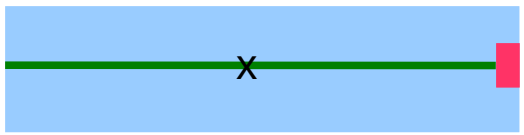


Strip size : 1 cm x 4.5 cm x 3 mm
covered with reflector film

Bias voltage : V_0 + 2.1 V
Temperature : 25 °C

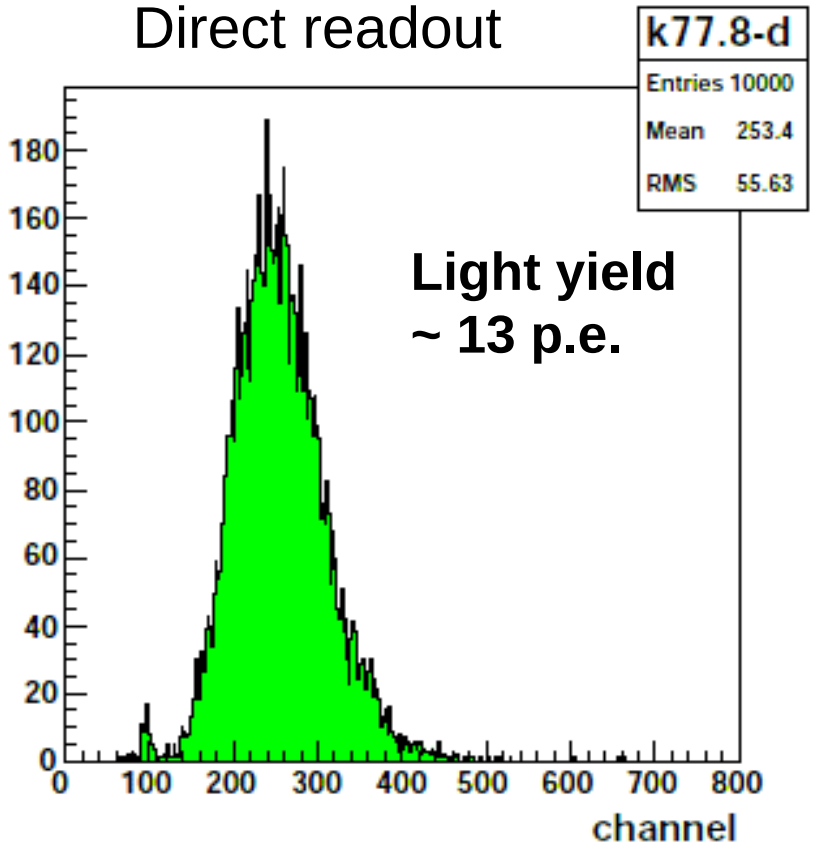
WLSF readout

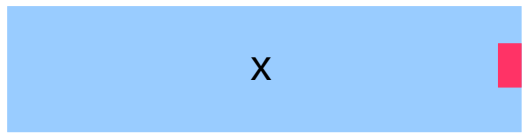




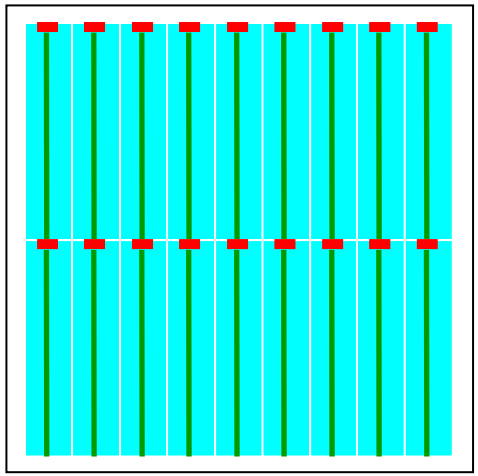
WLSF diameter : 1 mm

Direct readout

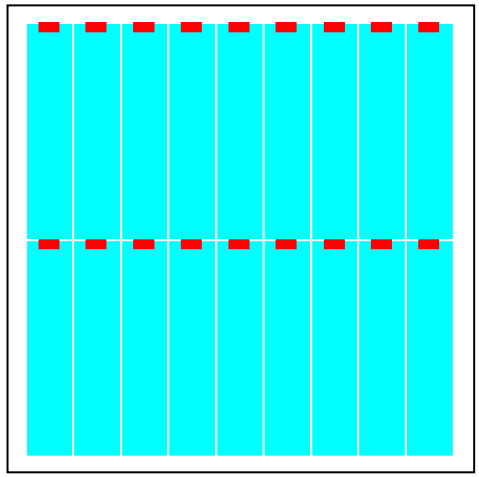




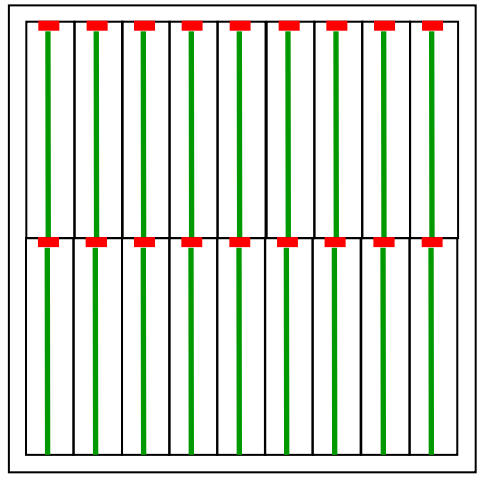
3 Types of Modules



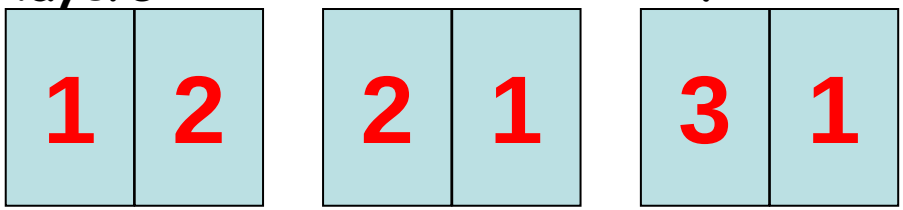
1. Mega-strips,
WLSF readout,
13 layers

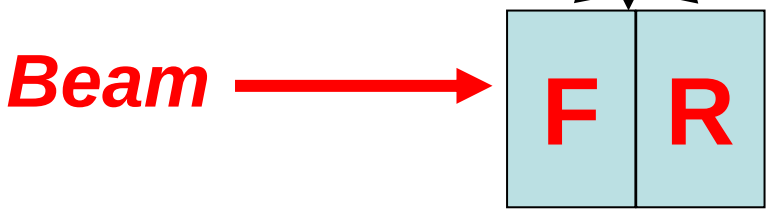


2. Mega-strips,
Direct readout,
13 layers



3. Extruded strips covered by TiO_2,
WLSF readout,
13 layers (KNU)

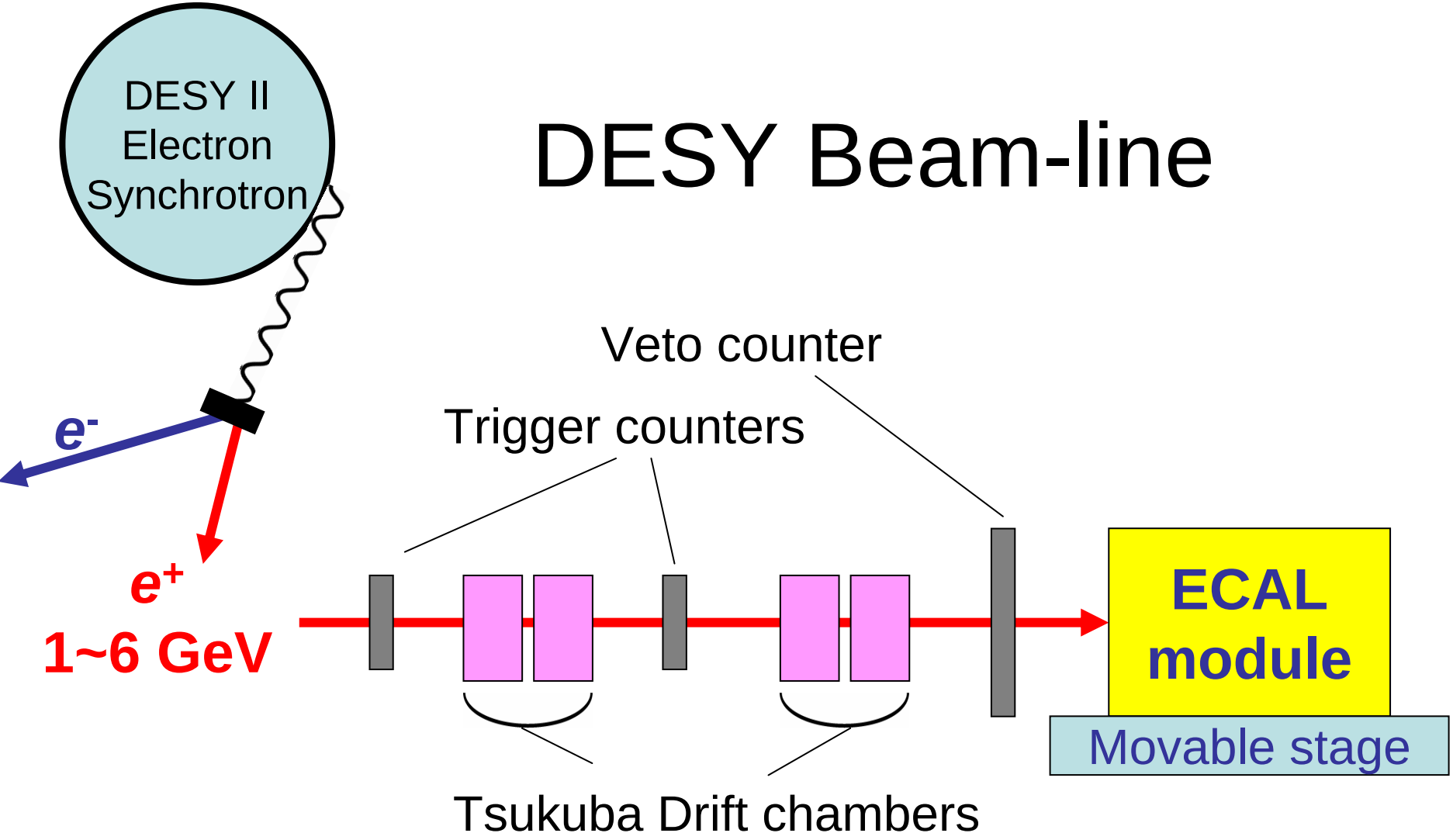




13 + 13 layers

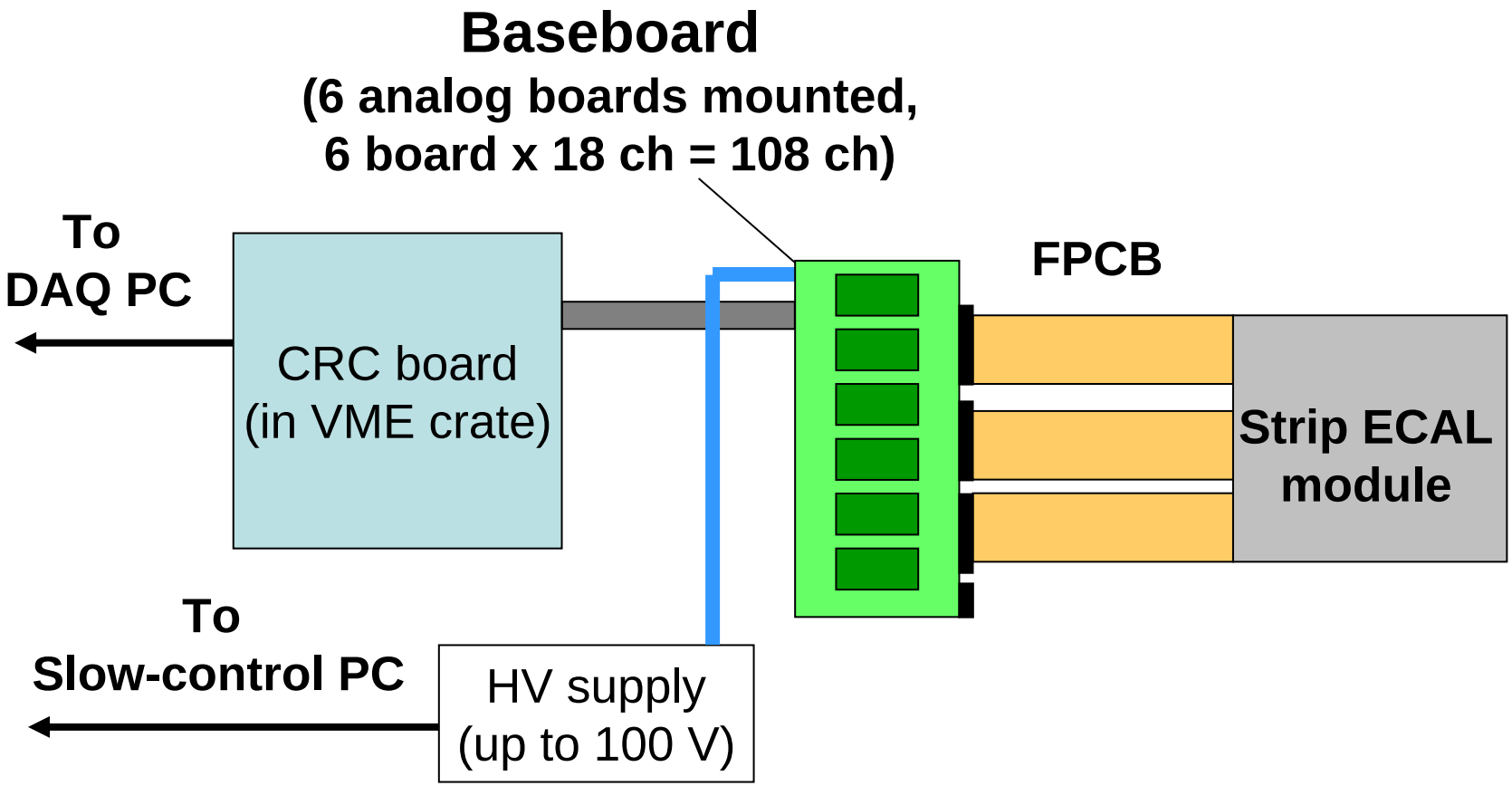
We will examine 3 different combinations of the modules.

DESY Beam-line



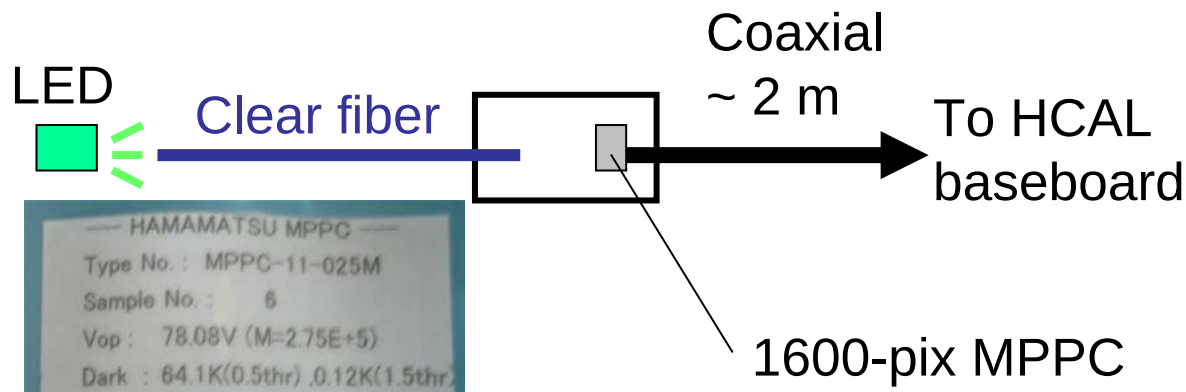
- Position scan with a movable stage
- Positron incident position determined with drift chambers.

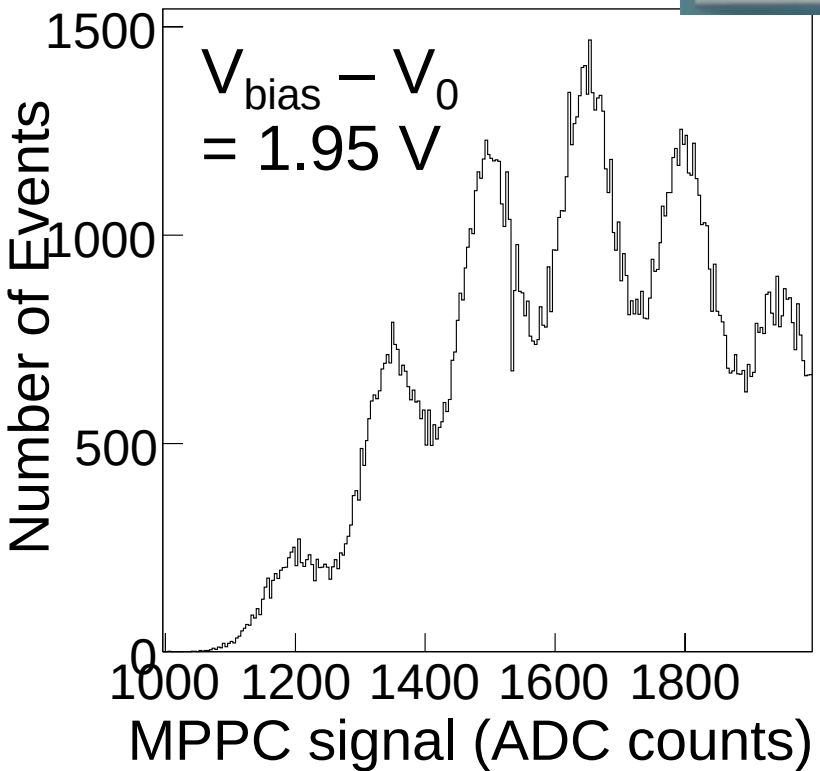
Readout Electronics
(developed by CALICE electronics group)

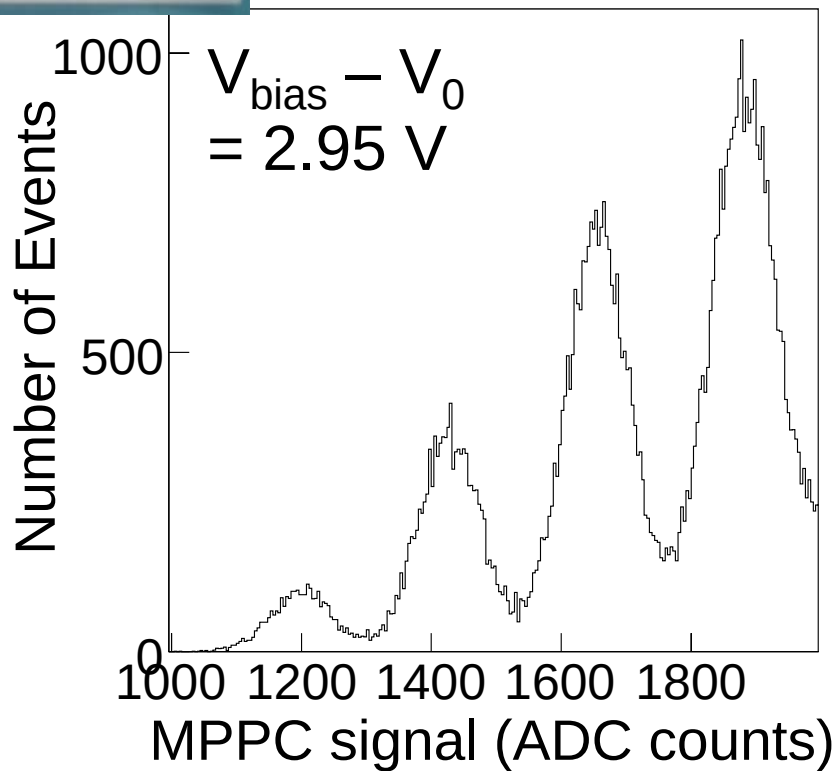


MPPC signal with CALICE electronics

(checked at DESY)

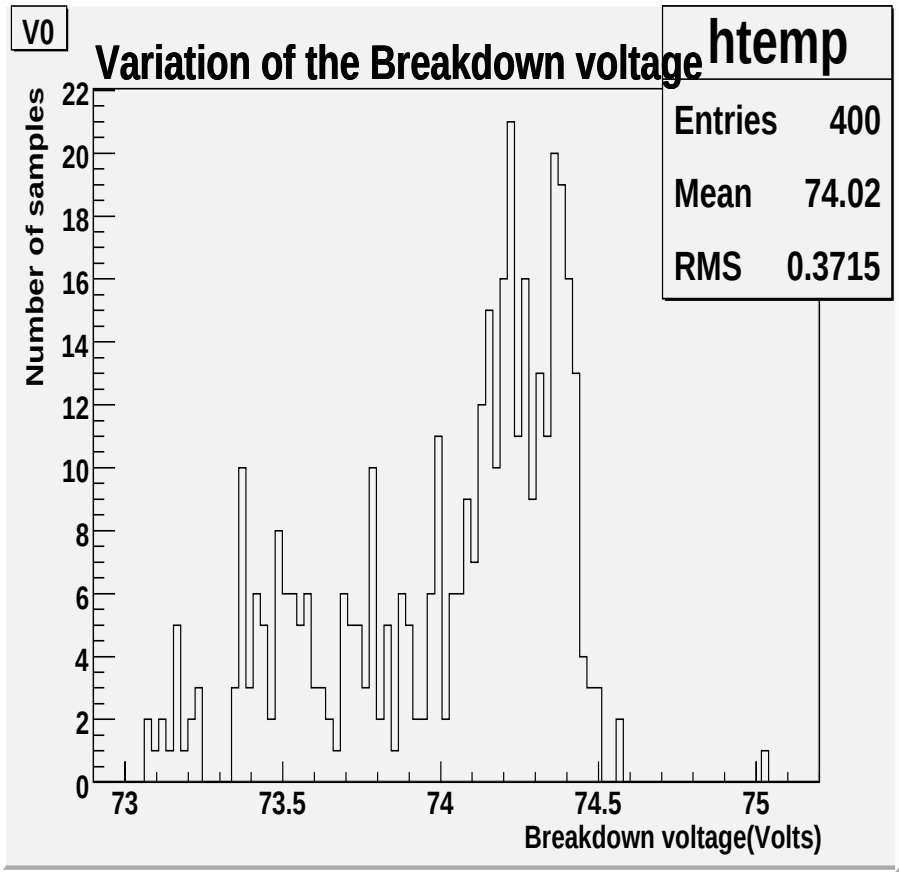


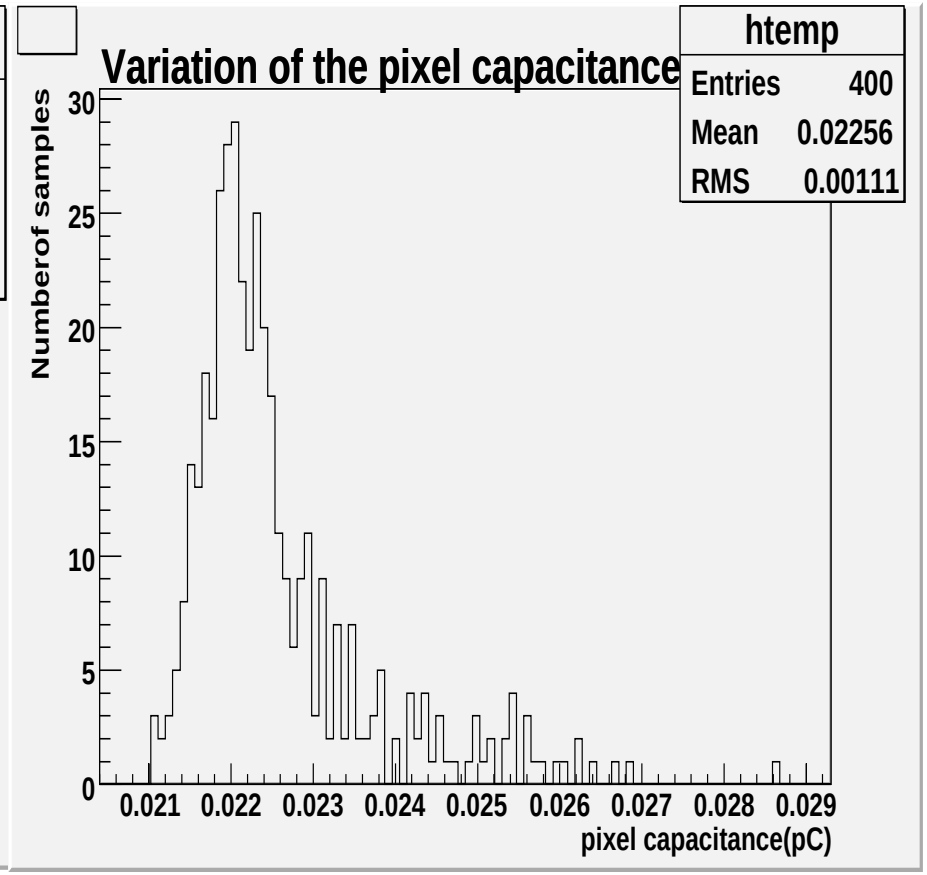




Very preliminary results of 400 MPPCs: Breakdown Voltage, Pixel capacity

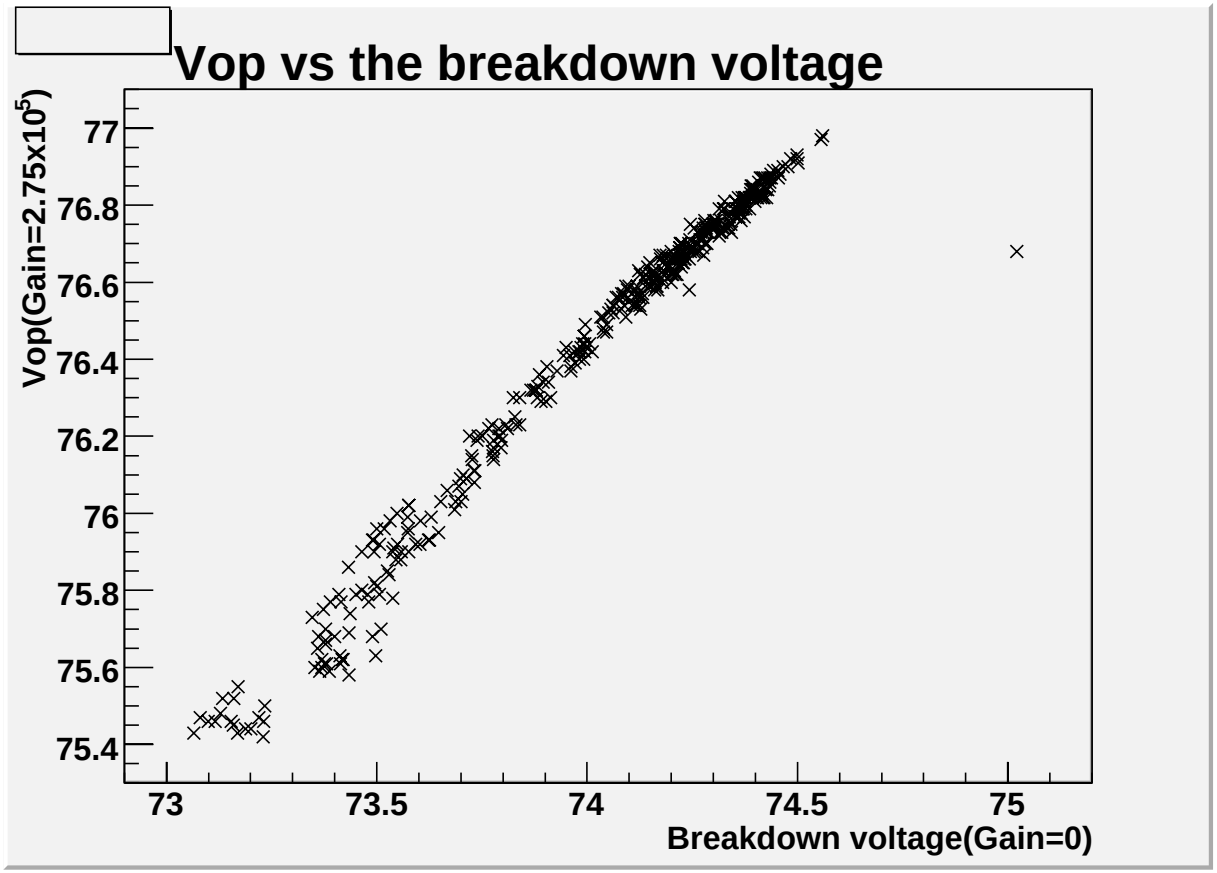
Gain = $C \times (V_{bias} - V_{breakdown})$





(measured at Shinshu-U)

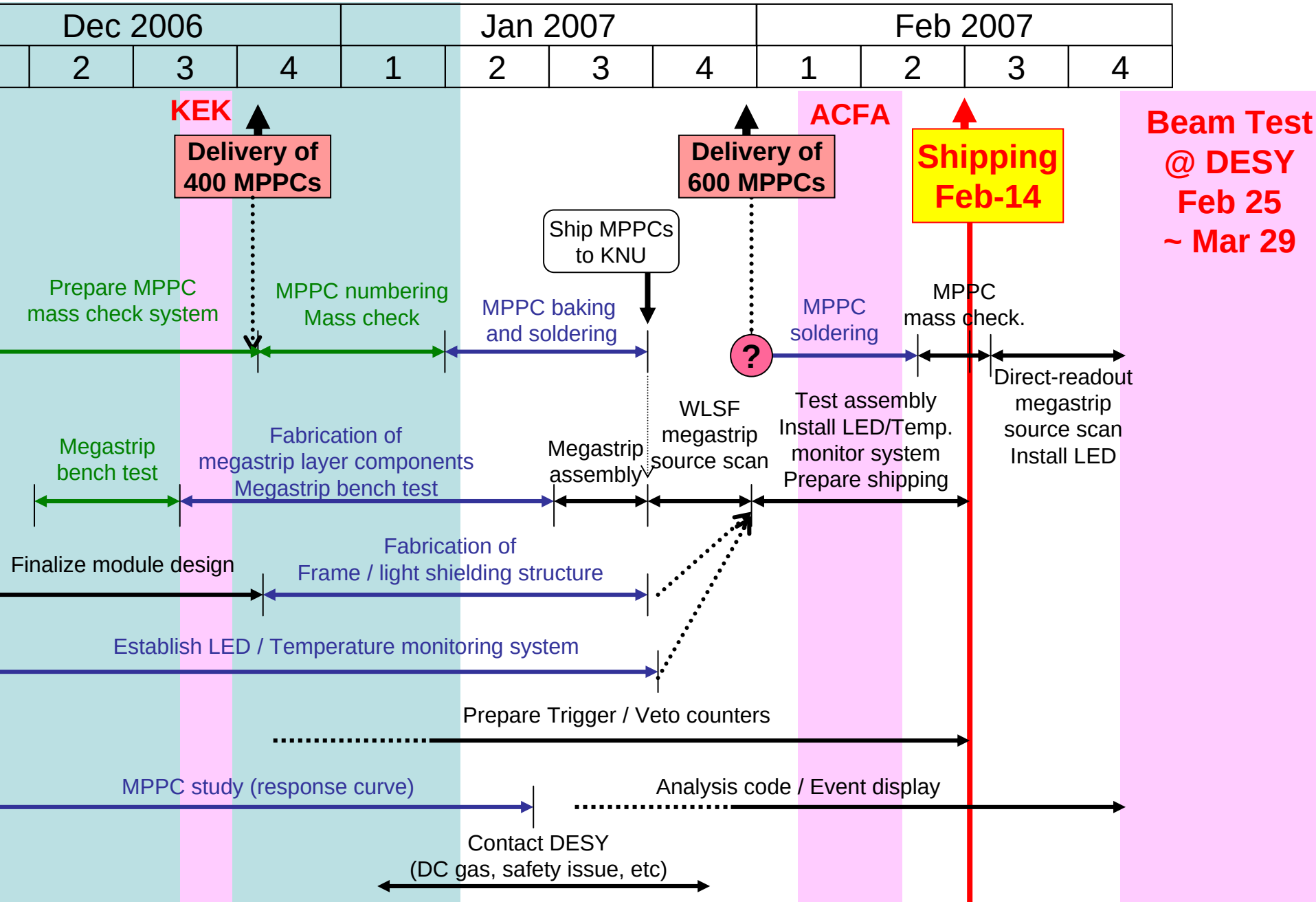
Very preliminary results of 400 MPPCs: Comparison with HPK data sheet



- V_{op} = bias voltage @ Gain = 2.75 x 10^5 given by HPK.

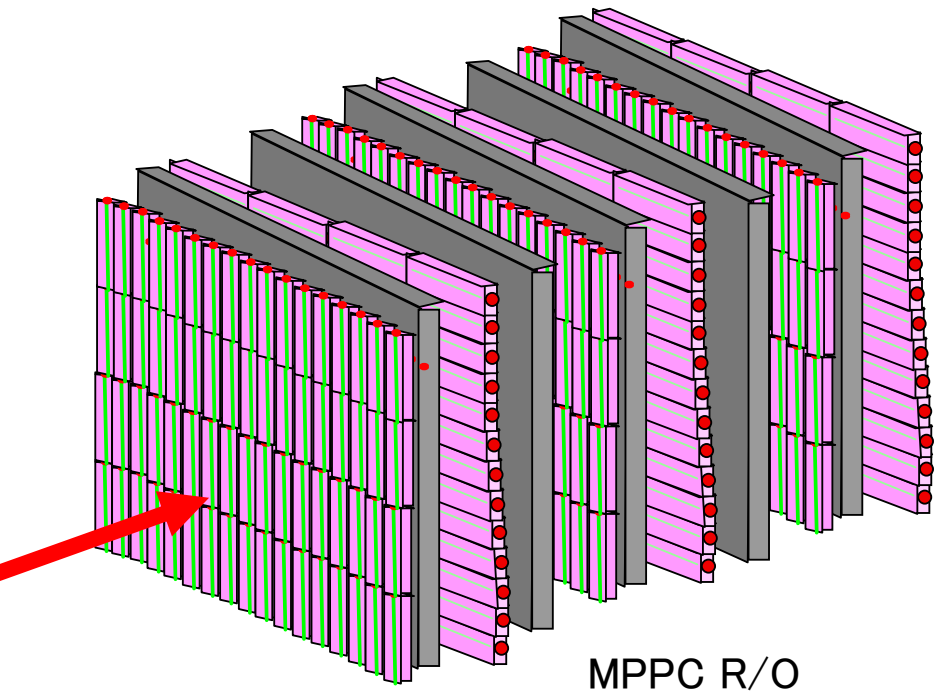
Our result is consistent with the HPK data sheet.

Schedule toward the SC-ECAL Beam Test @ DESY



ECAL Beam Test at Fermilab

FNAL BT (2007-)



- Extend the test module (x4 in cross-section)
- Performance for higher energy particles
  - E=4-120 GeV
  - Particle=e, μ, π ,p
- Standalone test
- Combined test with CALICE HCAL

Scintillator Strip HCAL

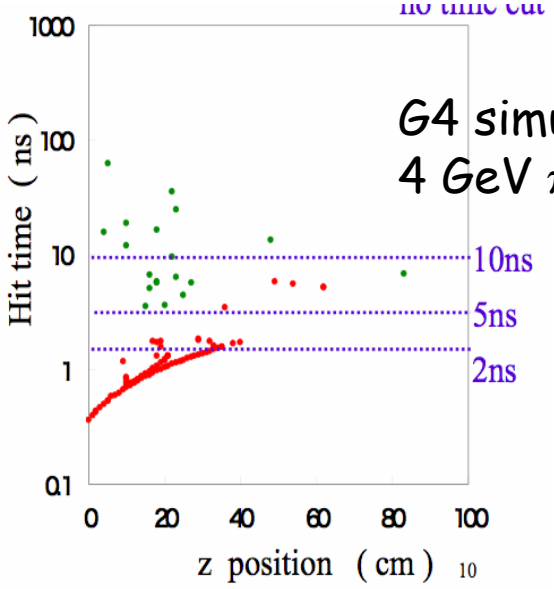
- BT of $1m^3$ HCAL module is the next project after the ECAL BT: (funded)
- Detailed plan still to be discussed.
- Expect/hope much closer collaboration with CALICE AHCAL group ➔ the next generation HCAL prototype ?

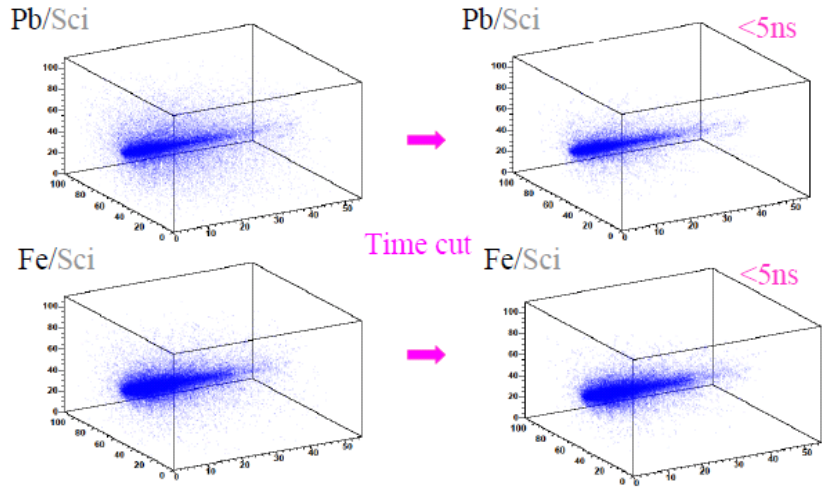
Comments on Fermilab TB facility

- Our experience of MTBF in 1999
  - No Cherenkov counters. Only SRD (synchrotron radiation detector) could be used for electron ID.
  - We had to bring our own drift chambers to measure the incident position.
  - Suffered from electric noise in the PMT signals, whose origin could not be identified.
  - Suffered from multi-particle events due materials in the beam.
- Now we have
  - Gas Cherenkov counters and beamline TOF for particle ID
  - Tracking with MWPCs, a pixel station, and SciFi detectors.
  - Less material in the beam.

  Great improvements. Thanks a lot !!
- For stable MPPC operation
  - Hope stable temperature at the experimental hall: MPPC is sensitive to temperature
  - Hope to have less electric noise than our 1999 TB.

Neutral hadrons in hadronic jets





- Hadronic jets have slow components due to neutral hadrons. The slow components are
  - necessary for compensation (better energy resolution),
  - but, unnecessary for PFA (separation of particles)
- Very interesting if we can test HCAL module with tagged neutral hadrons (n, K_L,…) at the new MCenter beamline.

Summary

- Scintillator strip calorimeter is being studied
  - ECAL TB at DESY (2007) and Fermilab (2007-)
  - HCAL TB after that, (2009- ?)
- High energy TB is made at Fermilab, but
- Low energy TB facilities (DESY, KEK, IHEP, etc.) are also very useful for test of detector components.