Beam Test and Detector R&D

LCWT 09
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Apologies

I am supposed not to discuss R&D's themselves. But since I still do not know what I should talk. So I started with TPC R&D!

Detector R&D: Beam Test

Goal of R&D:

The detector with specifications given by Physics at ILC.
Criteria well defined at each step of R&D.

Need & goal of beam test:

Test/Demonstrate	new technology, new structure, new software.
Confirm/validate	speculation, simulation, theory
Compare/select	technologies, designs, software's.
Performance test	large scale prototype, combined test
Calibration	

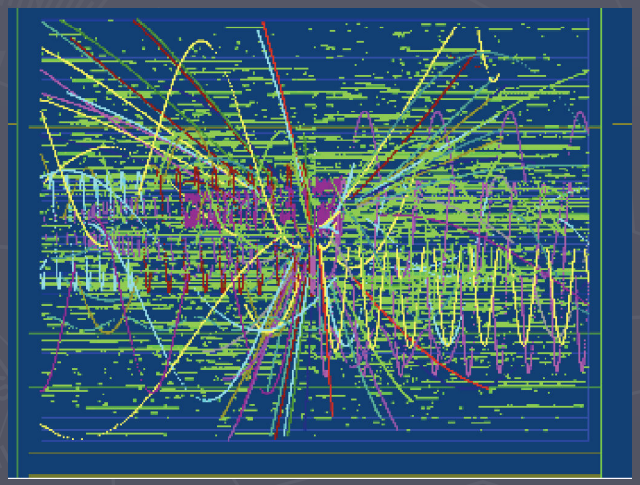
Starting from a simple case: TPC

TPC R&D: Simple Case

1. High Momentum resolution: (a) $\delta(1/pt) \leqq 5 \times 10^{-5}$
   → (b) ≧200 position measurements along each track with the point resolution of (c) $\sigma_{r\varphi} \sim < 100\mu m$ at 3-4T

   → from Wire TPC to MPGD TPC

2. High tracking efficiency down to low momentum in a high backgrounds at ILC for jet energy measurement.
3. Minimum material of trucker, in particular, for PFA (challenging!)
4. dE/dX



ttbar overlayed with 100BX of pair backgrounds

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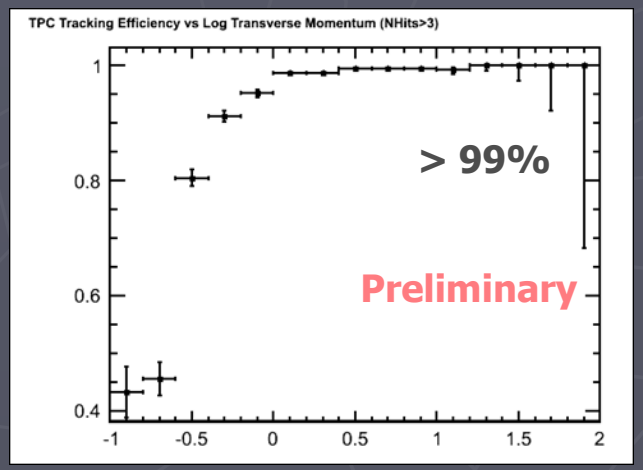


Tracking efficiency w pair background (S. Aplin & F. Gaede)

Demonstration Phase

From wire TPC to MPGD TPC:

1. Comparison of wire TPC and MPGD TPC: This stage we knew that the wire TPC has poor resolution due to ExB in high B → but comic ray test in 1,5T magnetic field and beam tests in 1T were dispensable.

2. Beam tests and the cosmic ray tests with many small TPCs prototypes to study stable operation and point resolution of MPGD TPC: learned a lot about the basic structure of MOGD TPC → GEM: signal spread in the induction gap, Micromegas: bulk structure, resistive anode readout etc.

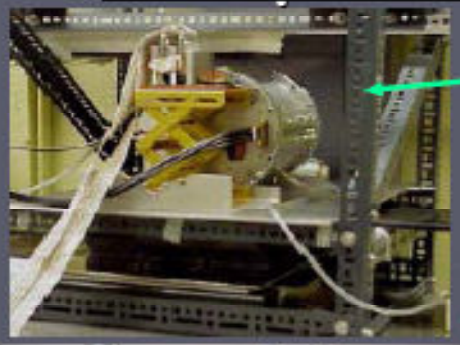
3. A full analytic formula of the point resolution of MPGD TPC "born from a beam test" giving a guidline for the point resolution of ILC TPC.

Some other issues (still remain even today!)

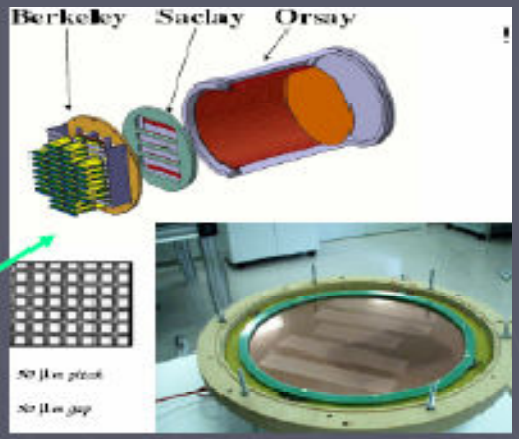
4. Search for the best gas for LC TPC
5. Ion feedback and gating- a simulation and (beam) tests.

Experiences for Stable Operation of MPGD TPC in Various Small Prototypes in LC TPC Collaboration

Examples of Prototype TPCs

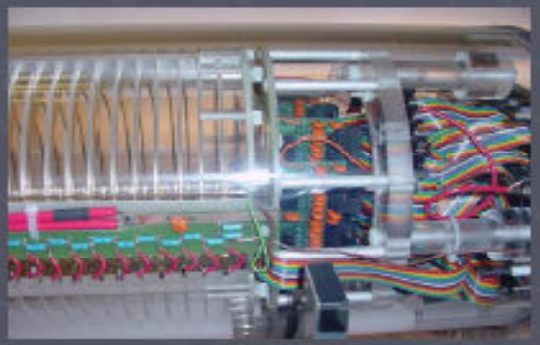


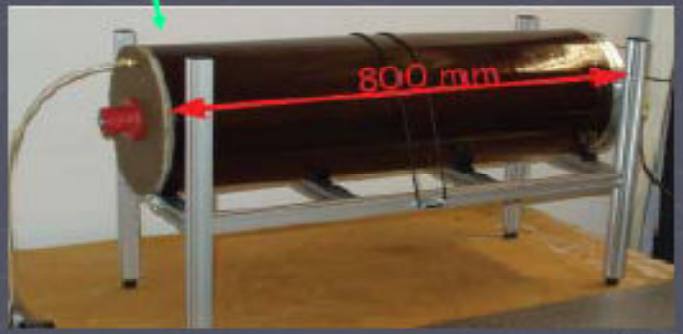
Carleton, Aachen, Cornell/Purdue, Desy(n.s.) for B=0or1T studies



Saclay, Victoria, Desy (fit in 2-5T magnets)

Karlsruhe, MPI/Asia, Aachen built test TPCs for magnets (not shown), other groups built small special-study chambers

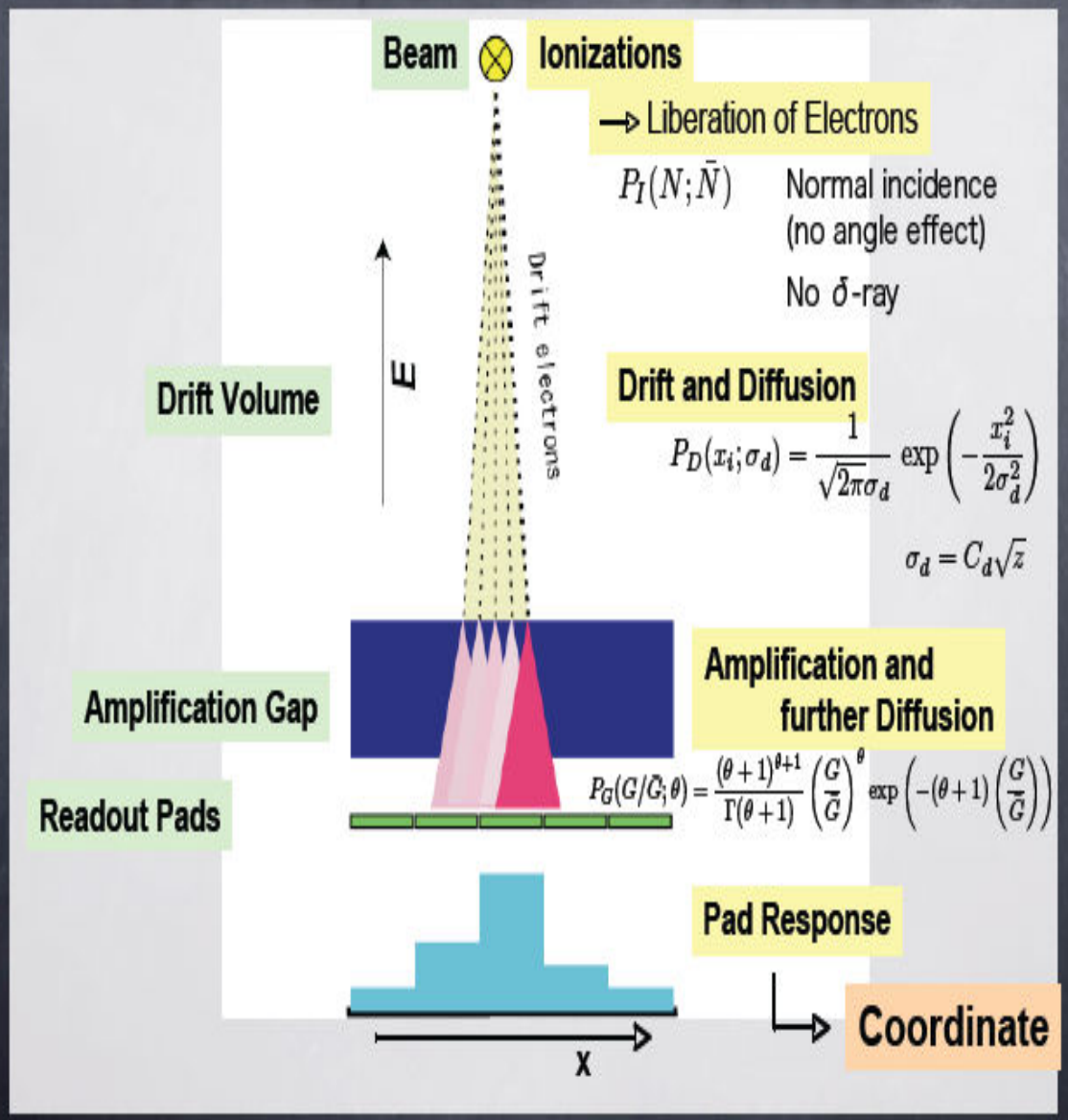




Settles

There are more ,, and d they are still in operation

Fundamental Processes



The fundamental process is known!

TPC Gas: Gas physics
- No. of primary electrons
- Fluctuation of ionization
- Attachment
- Diffusion
- Drift velocity
- (Aging)

Drift: Filed cage/Magnet
- E & B field
- Distortions (ExB)

Gas amplification: MPGD
- MicroMEGAS or GEM
- Gain fluctuation
- Ion backflow

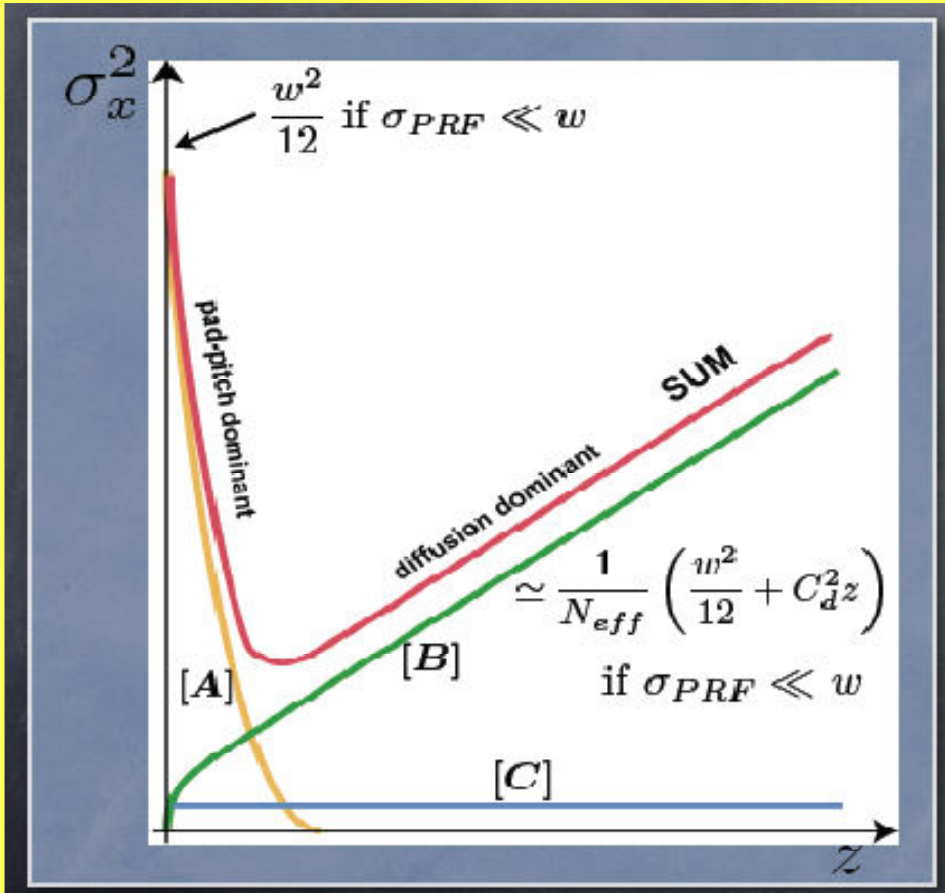
Position measurement:
- Conductive pad
- Resistive anode pads
- Pixels

Low noise electronics:
- Analog/digital

http://www-jlc.kek.jp/subg/cdc/lib/DOC/TPCSchool/200801/Fujii_Keisuke/TPCfundamentals-1.pdf (42MB)

Spatial Resolution of MPGD TPC:

Full Analytic Calculation



[A] Purely geometric term (S-shape systematics from finite pad pitch): rapidly disappears as Z increases

[B] Diffusion, gas gain fluctuation & finite pad pitch term: scales as $1/N_{eff}$, for delta-fun like PRF asymptotically:

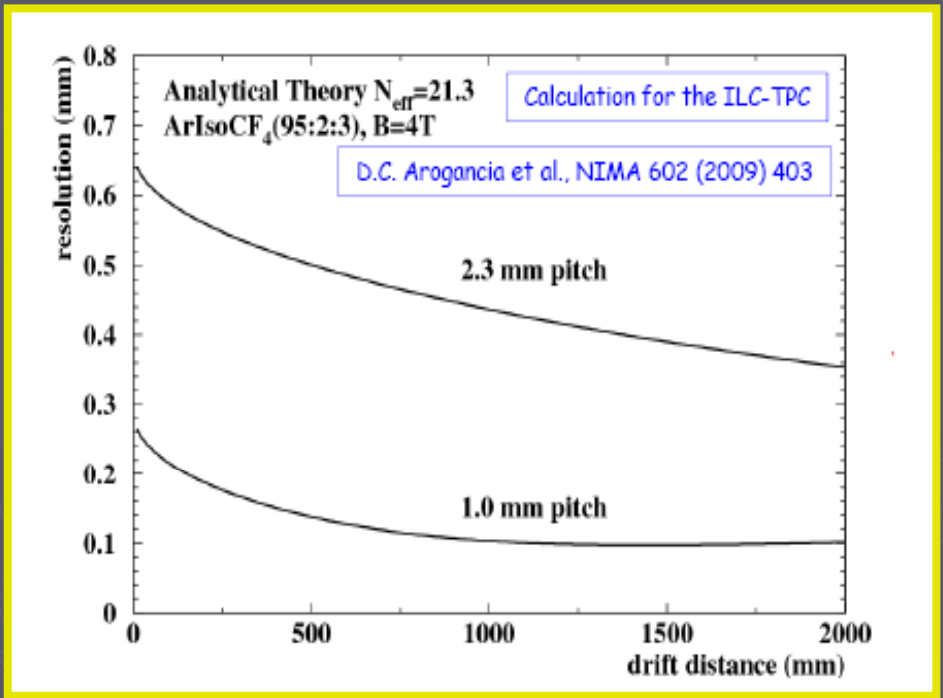
$$\sigma_{\bar{x}}^2 \simeq \frac{1}{N_{eff}}\left(\frac{w^2}{12} + C_d^2 z\right)$$

[C] Electronic noise term: Z-independent, scales as $\langle 1/N^2 \rangle$

K may be dependent of the amplification scheme. If *K* is small, then Neff can be close to 35. in the case of GEM, Neff seems to be 20-25.

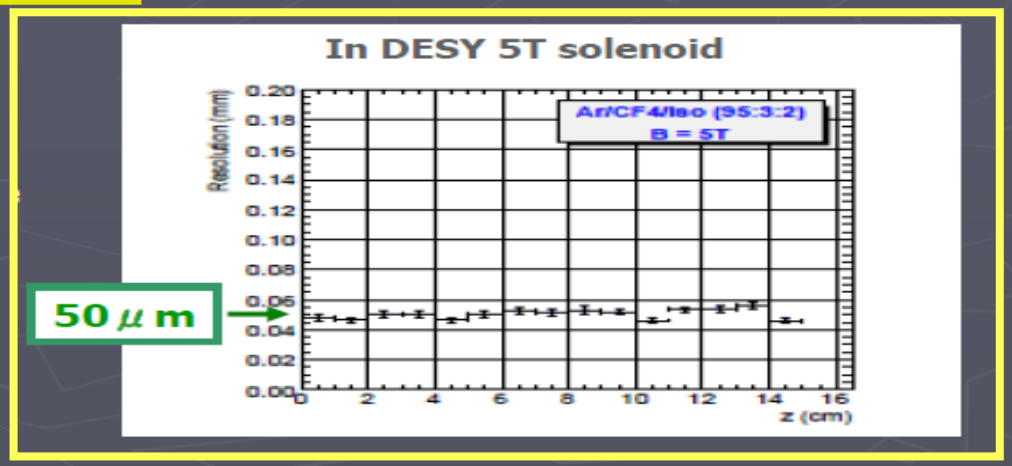
D.C Arogancia et at., arXiv: 0705.2210v1 [hep-ex] 15 May 2007.
Talks at ILC TPC School at Beijing, Jan. 2008:
http://www.hep.tsinghua.edu.cn/talks/TPCSchool2008/

Position resolution: MaicroMEGAS

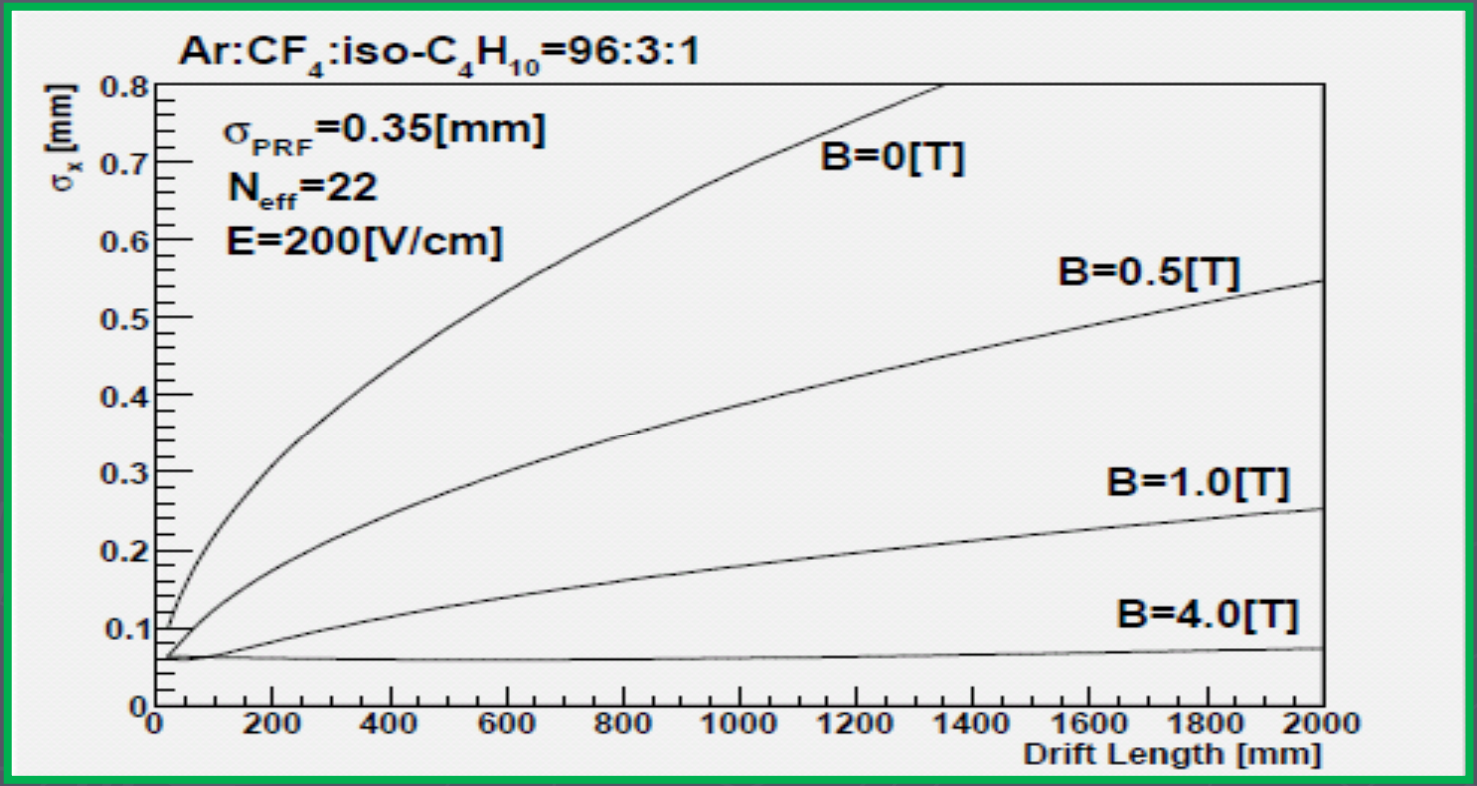


MicroMEGAS :
RMS (avalanche) on pads = 15µm
-→ need resistive anode
Not sufficient resolution for normal pads

MicroMEGAS with resistive anode:
Pads of 2mm x 6mm
B=5T
Neff = around 24-25



Position Resolution: GEM TPC
Analytic formula of position resolution



GEM

RMS (avalanche) on pads= 350μm (Adjustable)
Neff around 20 for 1mm x 6mm pads
If Neff < 20 → No GEM TPC fro ILC!

Options of MPGD for ILC TPC

Based on the studies with small MPGD TPC Prototypes

Analog TPC: Immediate options if the current ILC schedule

(1) Multi layer GEM + Narrow (1mm wide) pad readout:
- Defocusing by multilayer GEM
- Narrow (1mm) pads → Larger readout channels
- Effective No. of electrons (Neff):

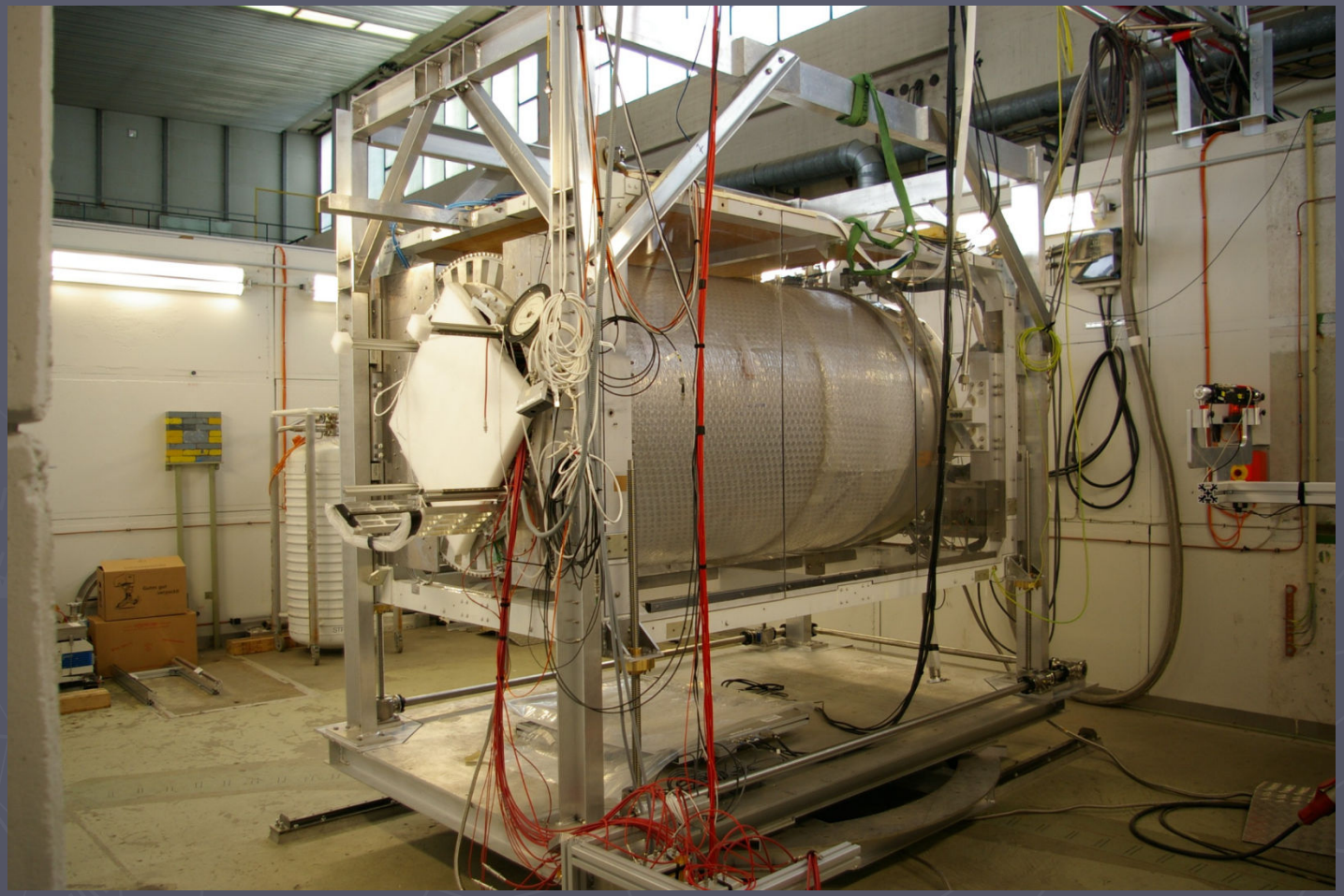
(2) MicroMEGAS + Resistive anode pad (2-3mm wide)
- Widening signal by resistive anode
- Wider pads → Less readout channels
- Neff:

Digital TPC:

(3) Ingrid-MicroMEGAS + Timepix: Digital TPC
- Digital → Free from the gas gain fluctuation
  - More information from primary electrons and
  - Thus better position resolution (to be demonstrated)

(4) Multilayer GEM + Timepix: More an analog TPC?
- Need to improve the efficiency for primary electrons

TPC Large Prototype Beam Test



TPC Large Prototype Beam Test at DESY :

Goals

- Study, in practice, design and fabrication of all components of MPGD TPC in larger scale; a field cage, an endplate, detector modules, front-end electronics and field mapping of non uniform magnetic field.

- Demonstrate full-volume trucking in non-uniform magnetic field, trying to provide a proof for the momentum resolution at LC TPC: R&D goal (1-a)

- Demonstrate dE/dX capability of MPGD TPC.
- Study effects of detector boundaries.

- Develop methods and software for (tracking,) alignment, calibration, and corrections.

(Beijing tracker review, Jan 2007)

Measurement of Momentum Resolution
LP

Two steps:

(1) $\sigma_{r\varphi}$: OK also at LP1 : Present status

← MPGD TPC
← Gas of low diffusion (high $\omega\tau$) : Ar:CF4:Isobutene (T2K gas)

(2) Momentum resolution: More difficult

← Non uniformity of PCMAG magnetic field (in purpose → ILC)
← Distortion of other sources: Field cage, endplate
← Distortion due to ion feedback (Ion disks)

→ Tracking Software for the non uniform magnetic field (Urgent!)

But also, eventually comparison/selection of technologies

TPC Large Prototype Beam Test (LP2) from 2011

Current Plan

2010 Continue LP1 test at DESY

2011 LP2: Move to a high momentum hadron beam:

← Limitation using electron beam to measure momentum.

→ Options of magnet

Move the current PCMAG

Find a proper high filed magnet accommodates current LP1 TPC (Solenoid preferable).

→ Build also a new field cage with a laser track calibration

→ With TPC "Advanced Endplate" (need resources!)

TPC Large Prototype Beam Test (LP2)
Some issues

Momentum measurement :

A standard high momentum hadron beam line: where?

Liquid He supply & He gas recovery for PCMAG → Modify PCMAG with cryo-coolers

Double track separation (Jet environment)

In principle we may simulate the situation from single track parameters.

Base line shift (proper tune of readout electronics and MPGD system)

Ion issue -> simulation in the fisrt

Bunch structure

Back grounds and Ion disks → by a laser sauce

Power pulsing and cooling ("Advanced endplate")

→ Pad plane with readout electronics may be tested in lab.

Actually many things can be done in lab. Or by simulation based on the basic parameters checked also by beam tests.

Calorimeter R&D
More technology options

Goals of R&D:

Demonstrate feasibility of (Particle Flow Approach) calorimeter for ILC
Well defined already? Do we need a proof for PFA?

Goals of beam Test:

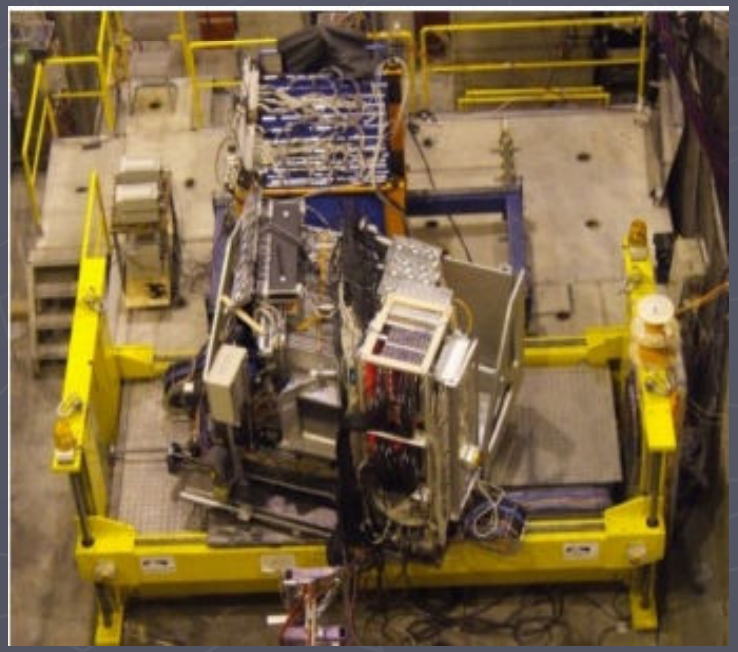
Establish technology: basic performance of calorimeter
Tune the reconstruction algorithms
Validate/tune Monte Carlo models

Many detector options: → CALICE

PFA calorimeter: EM calorimeter
- CALICE Si-W ECAL
- SiD Si-W ECAL
- CALICE Scintillator-W ECAL
- CALICE MAPS Digital ECAL

PFA Calorimeter: HCAL
- CALICE Scintillator Analog HCAL (AHCAL)
- CALICE RPC Digital HCAL (DHCAL)
- CALICE MicroMegas DHCAL
- CALICE GEM DHCAL
- CALICE RPC Semi-Digital HCAL (sDHCAL)

Dream calorimeters



Calorimeter R&D
More technology options

(Lei Xia/ANL HEP

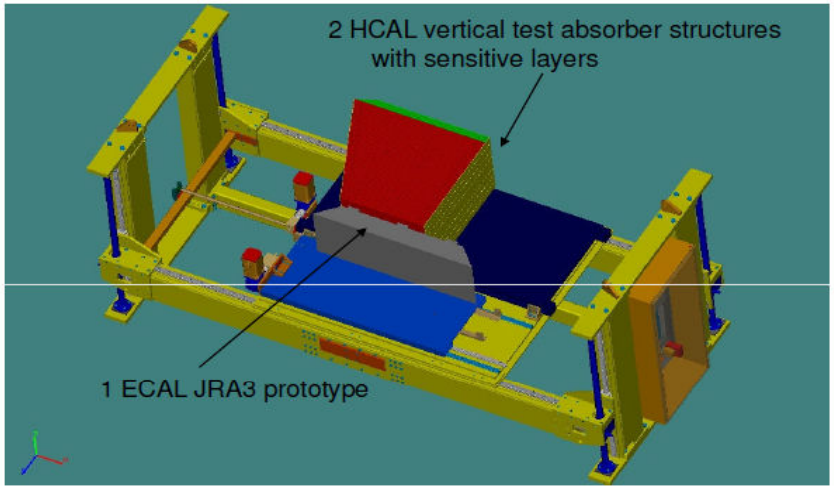
Summary

R&D effort	Sensor/readout /layer test	Small module	Large module
CALICE SiW ECal	2010 – 2012		2010: combined test with DHCal 2012: technical prototype
SiD SiW ECal	?		2010
CALICE ScW ECal	2010 – 2012		
CALICE MAPS ECal	2010 – 2011		2012
CALICE AHCal	2009 – 2010	2010 – 2011	(technical prototype) (current AHCal layers with W)
CALICE RPC DHCal	2010		2010 (1m^3 prototype)
CALICE MicroMegas DHCal	Yes		("technical prototype")
CALICE GEM DHCal	2009 – 2010		2010 – 2011 (5 x 1m^2)
CALICE RPC SDHCal	2010		Later 2010 (part of "technical prototype")
Fiber Dual Readout (DREAM)			2010 –
Totally Active Dual Readout	Yes	(Yes)	(Yes)

Immediate future | Further away

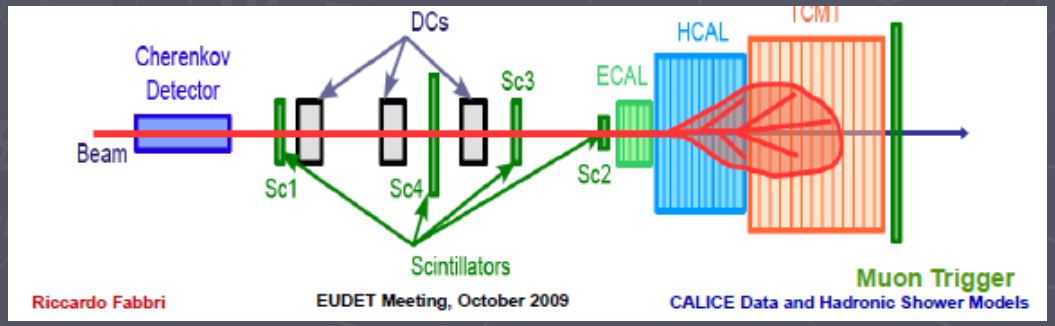
Calorimeter: Large Module Test

Future HCAL project



- Mechanical structure assembled together with ECAL for test beam experiment
- Test in magnetic filed also under discussion

31.08.2009 Erika Garutti - HCAL status report 24/24



basically, or else?

PFA Calorimeter: How Do We Test It?

Combined detector become very large.

Dieter Schla t er

Particle Flow Algorithm

Jet energy resolution: Goal σ_E/E = 3 – 4 %

Simulations for ILD and SiD

M. Thomson
ALCPG 2009

E_{JET}	σ_E/E (rms$_{90}$)	
	ILD	SiD
45 GeV	3.7 %	5.5 %
100 GeV	2.9 %	4.1 %
180 GeV	3.0 %	4.1 %
250 GeV	3.1 %	4.8 %

At 3 TeV ?

ILD B=3.5 T, absorber = 6 λ_I

500GeV	4.1 %

CLIC_ILD B=4 T, absorber = 8 λ_I

500GeV	3.5 %

Looks promising ! How can one test this with data?

Dieter Schlatter - 21.10.09 32

→ **The issue of Combined test**

Vertex R&D: Beam Test

Marcel Vos, Carlos Marinas

Characterization using infra-red laser and gamma-sources in laboratory yields very valuable information.

But

TB is useful for measurement of response to MIPs, spatial resolution, time structure, two-track resolution, Lorentz angle, ...

Also: don't forget psychology, collaboration building, etc.

Vertex/Si tracker R&D: Beam Test

Marcel Vos, Carlos Marinas

Test beam:

- Simple test beam EUDET telescope in high energy beams ?

Bunch structure

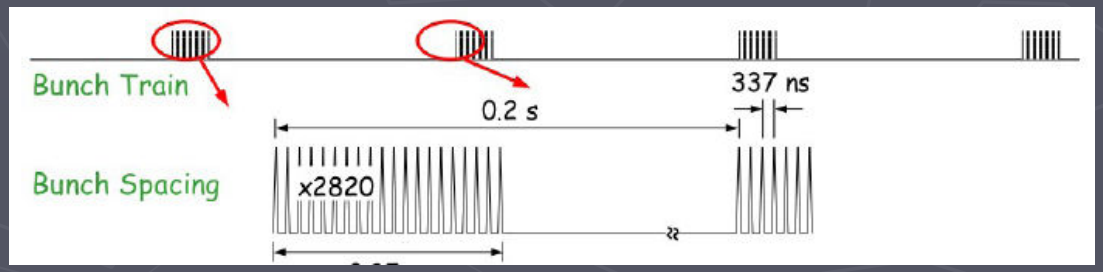
- Needed to test pulsed power/readout scenarios.
- Can we find a (cheap) workaround?

Magnet :

"Jet environment"

Combined test

- Silicon-TPC (DESY, EUDET MEMO 2007-28)
- Silicon-alignment system
- Full VTX-tracker slice (in magnetic field)
- VTX-Tracker-Calorimeter (Particle Flow TB)



Duplicated Conclusion: Issues to be answered

Test beam: Where? How long? Do we get support?

Bunch structure: (a) Do we really need it? , (b) If so how and where?

New Magnet : (a) Field? (b) Dipole or solenoid? (c) Which?

"Jet environment" (a) Do we really need it?

Combined test (a) Can we afford it? (b) what do we study? (c) How?

- Silicon-TPC (DESY, EUDET MEMO 2007-28)
- Silicon-alignment system
- Full VTX-tracker slice (in magnetic field)
- VTX-Tracker-Calorimeter (Particle Flow TB) : Issue of resource