Application of MPGD to TPC for the ILC

LC TPC Collaboration

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DESY/FLC & KEK/IPNS

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Paris
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International Linear Collider (ILC)

Electron-positron collider of 500GeV

Physics goals of ILC :

Symmetry Breaking and Mass Generation:

Detailed study of Higgs Boson

most probably after its discovery at LHC.

Beyond the Standard Model:

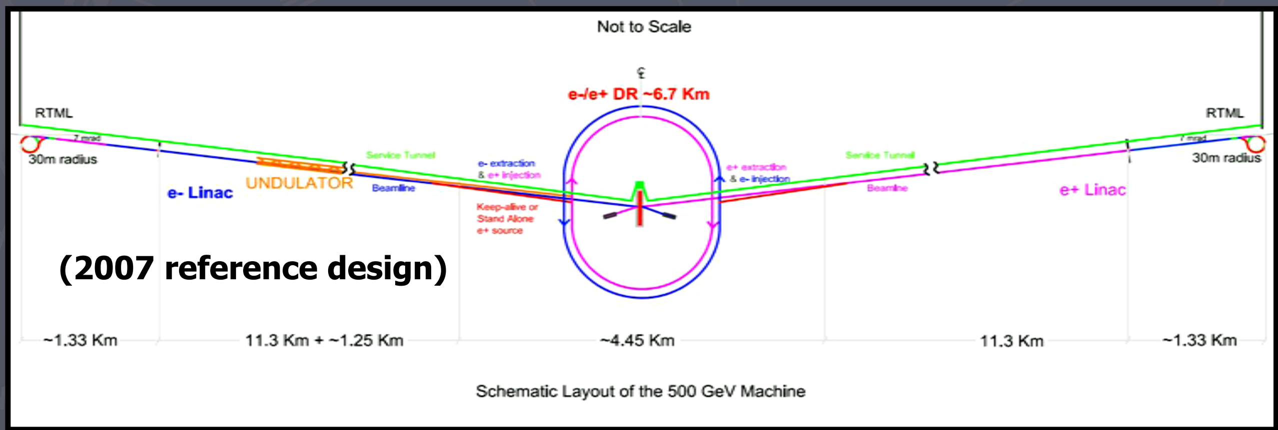
Supersymmetric particles (SUSY)

Extra dimension

???

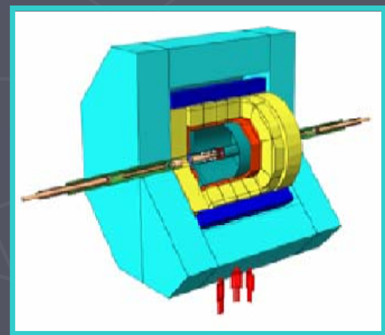
http://www.linearcollider.org/cms/?pid=1000437

31 km-long collider with two superconducting linacs



Schematic Layout of the 500 GeV Machine

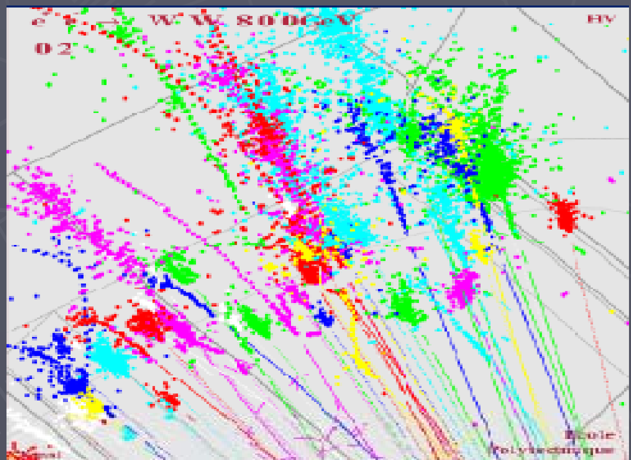
Detector at the collision point



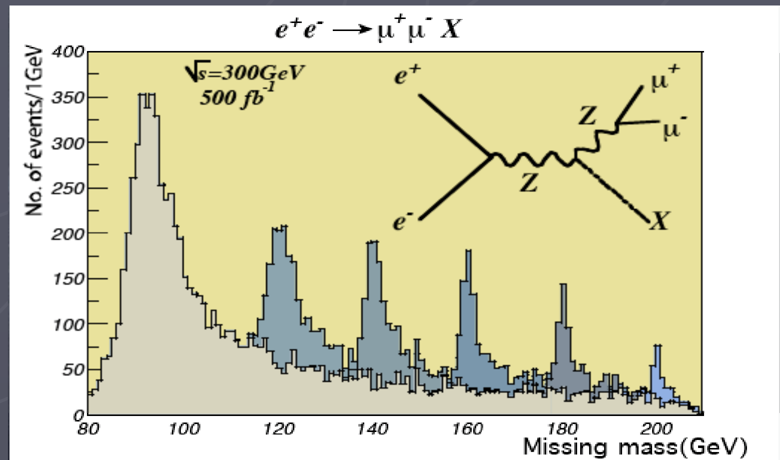
Tracking at ILC

Performance requirement for ILC trucker greatly exceeds the achievement of existing truckers such as of LHC:

- **Momentum resolution: $\sigma(1/pt) \leqq 5 \times 10^{-5}$ GeV^{-1}**
  → TPC: ≧ 200 position measurements along each track
  with the point resolution of $\sigma_{r\varphi}$~ 50 - 100μm at 3-4T (TPC)
  → Si-tracker: 5-6 position measurements with $\sigma_{r\varphi}$~ O(10)μm at 5T.
- **Very high (close to 100%) tracking efficiency down to low momentum for Particle Flow Algorism (PFA) (the new type of calorimetry)**
- **Minimum material of trucker (inside the EM calorimeter):**
- **Stand with beam backgrounds: Occupancy, Distortion due to Ion**



PFA: Matching energy deposits in calorimeter with tracks



Recoil mass measurement of Higgs

Momentum Resolution: What We Need to Acheive?

(My Old Slide)

1. $e^+e^- \rightarrow ZH \rightarrow (Z \rightarrow \mu\mu/ee) + X$:
   If $\delta M(\mu\mu/ee) << \Gamma z$、
   then the beam energy spraed dominate.
   → Most probabaly $\delta(1/p_t) \sim 1.0 - 0.5 \times 10^{-4}$

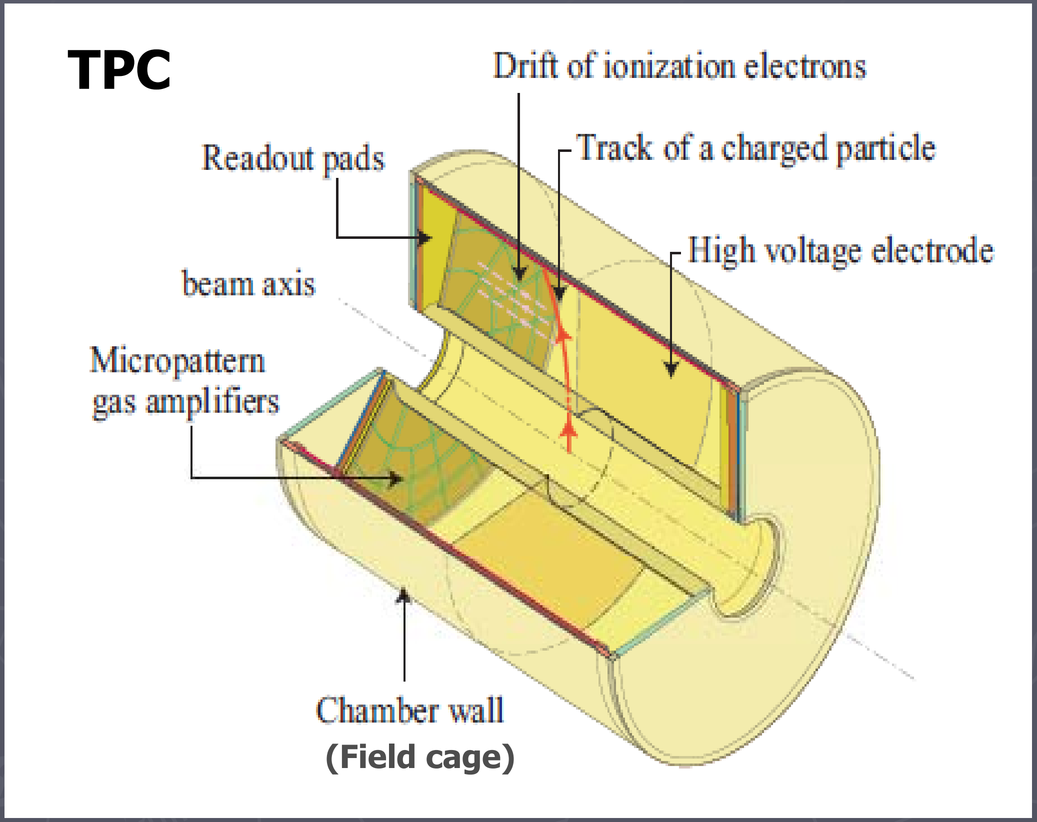
2. Slepton and the LSP masses though the end point measurement:
   σ_M (Momentum Resolution) ~ σ_M (Parent Mass)
   Only @ 1 ab^{-1} when $\delta(1/p_t) \sim 0.5 \times 10^{-4}$

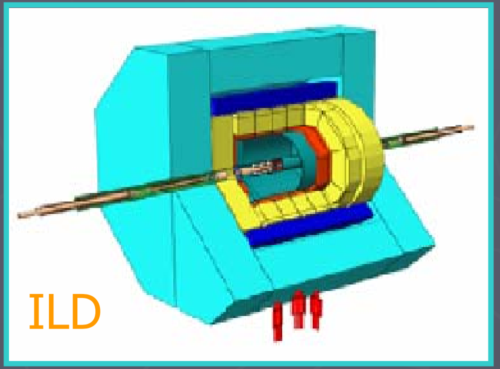
3. Rare decay: $e^+e^- \rightarrow ZH \rightarrow Z + (H \rightarrow \mu\mu)$:
   → $\delta(1/p_t) \sim 0.5 \times 10^{-4}$ sufficinet ?
   → Still need study one more time?

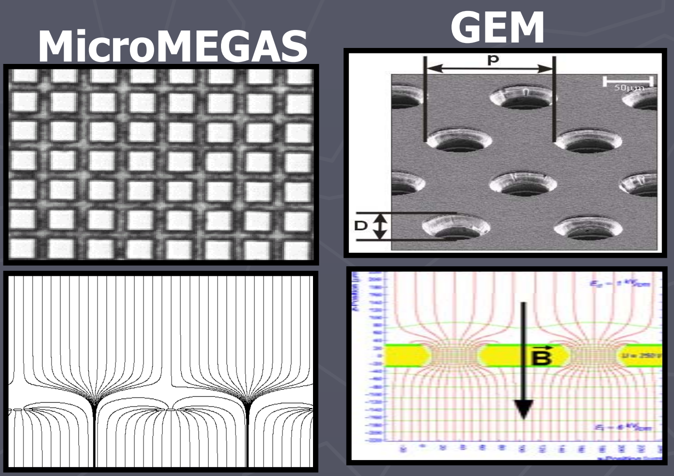
ILC TPC with Micro Pattern Gas Detectors

The traditional TPC with MWPC has the disadvantage of limited space resolution due to the E x B effect in high (3-4T) magnetic field. Also the structure to support many wires inevitably introduces significant dead regions

→ **MPGD TPC.**



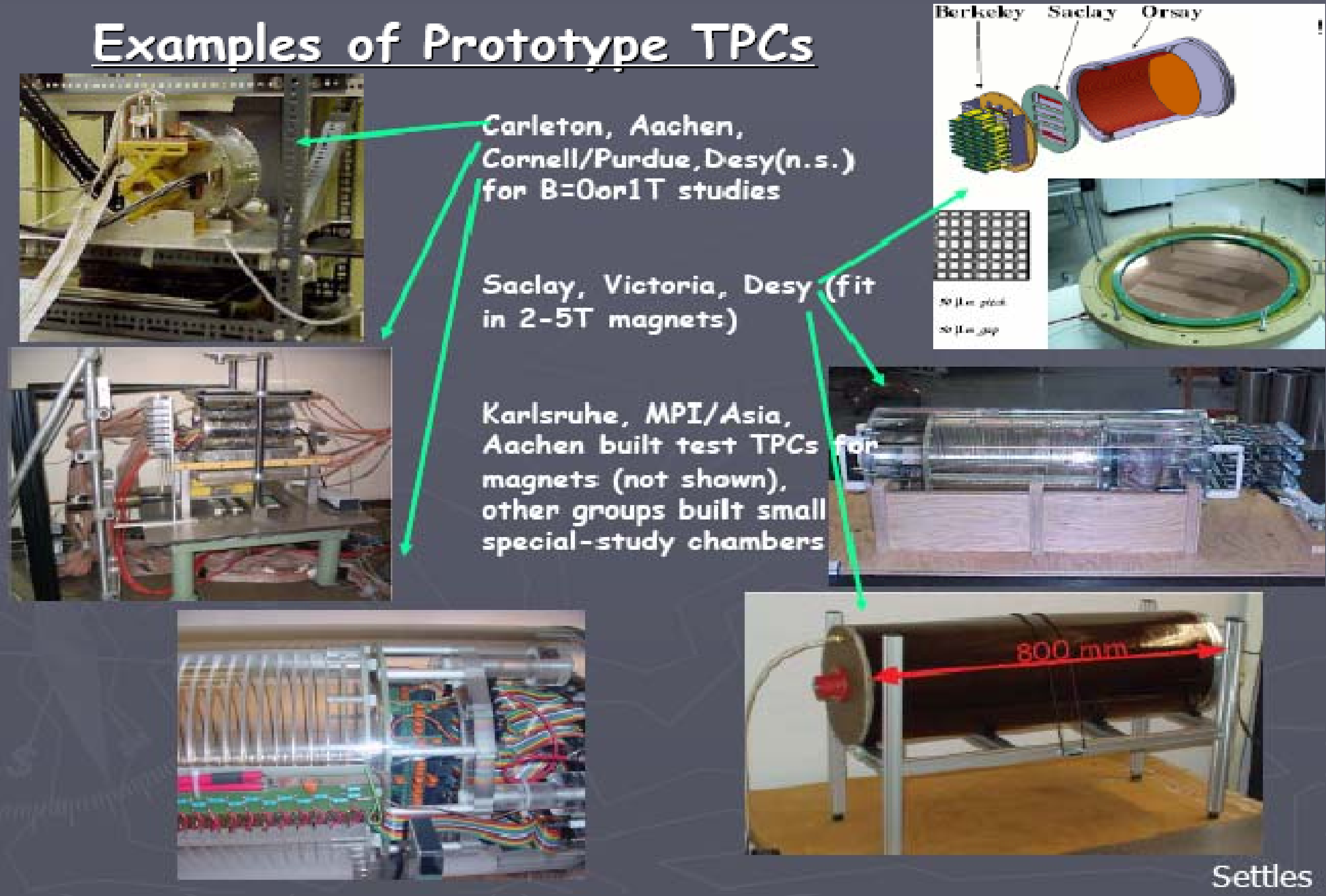




ILD TPC: **4 m in diameter and 4-5 m long**

Two gas amplifications with different readout schemes

Point Resolution of MPGD TPC with Various Small TPC Prototypes



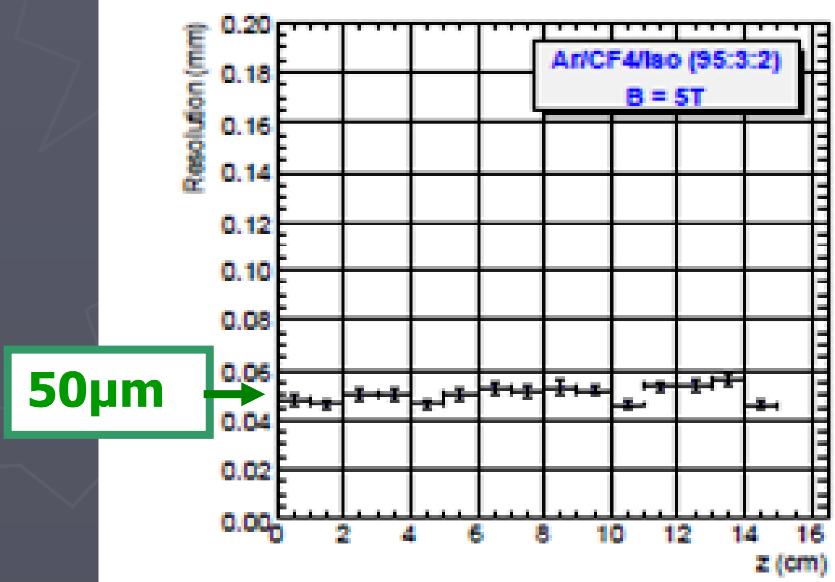
There are more ,,

Spatial Resolution of MPGD TPC:
The point resolution of $\sigma_{r\varphi}$~ 50-100μm at 3-5T

Demonstration for MicroMEGAS TPC with resistive anode
by Carleton TPC in DESY 5T magnet (M. Dixit et al., 2007)

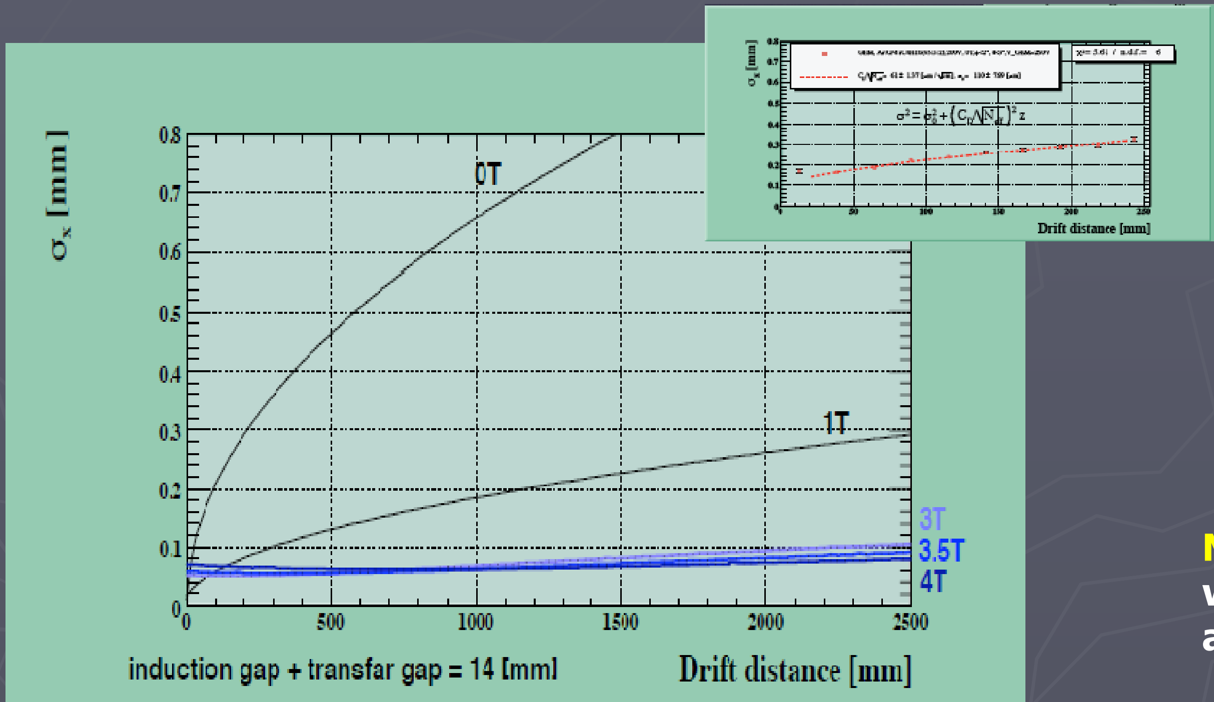
- 2 mm x 6mm pads + resistive anode
- The small diffusion constant (20 μm/cm$^{1/2}$) of Ar-CF4-Isobutene (95:3:2)
- 50μm (constant) resolution for the drift distance up to 16 cm
- Neff (at 0.5T) = 27-29.
- Still need to understand why 50 μm but not less.
- Cosmic rays

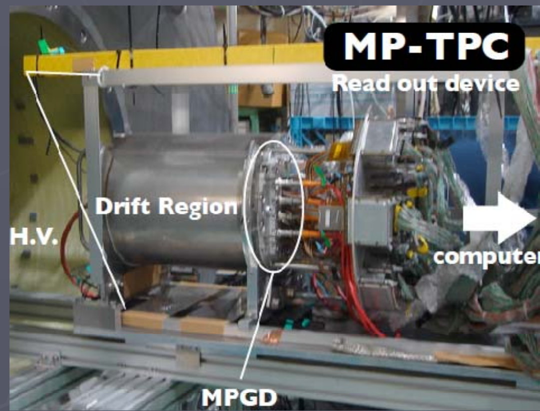
In DESY 5T solenoid



Spatial Resolution of MPGD TPC
The point resolution of $\sigma_{r\varphi}$~ 50 - 100μm at 3-5T

Measurements for three GEM TPC with narrow pads (1.17mm) using MP-TPC in 1T PCMAG at KEK (beam and cosmic rays (2005 ~) . Extrapolate the results to ILC TPC by a full analytic formula (next slide).





MP-TPC in its cosmic ray set up with 1T superconducting magnet at the KEK cryogenic center.

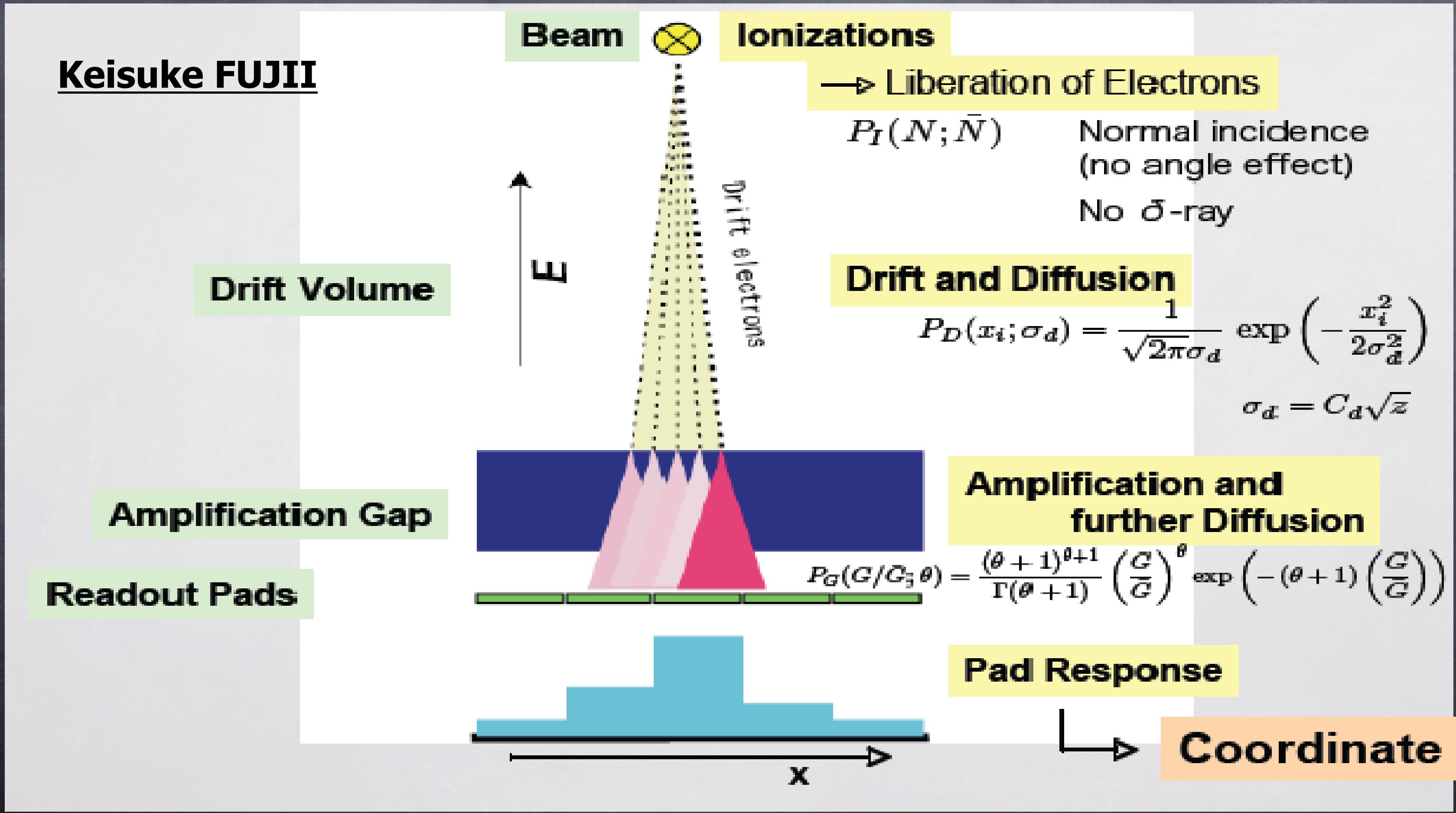
Extrapolation to I LC TPC from measurements at 0/1T by MP-TPC (θ=φ=0: no angular pad effect). Ar/CF4(3%)/isobutene (2%) at 200V/cm. The number of effective electrons Neff = 22. (R. Yonamine et. al. 2008)

(Measurements with DESY Midi-TPC in 5T magnet come soon but so far for P5. Also TU-TPC)

Spatial Resolution of MPGD TPC

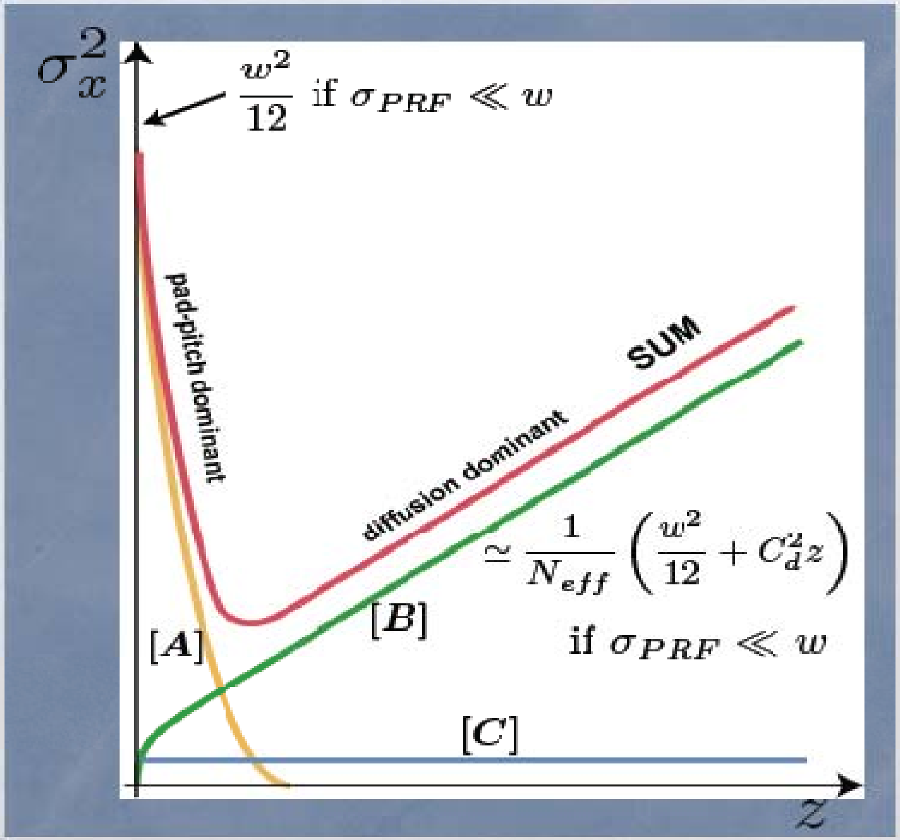
To understand the implication of the MP-TPC beam test results (2005-2006) at KEK-PS for different MPGDs, **a full analytic formula of spatial resolution of MPGS TPC** was derived including the effect of the gas gain fluctuation.

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



(The angular pad effect is still to be incorporated.)

Spatial Resolution of MPGD TPC: Analytic formula: Three components and Neff



[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:

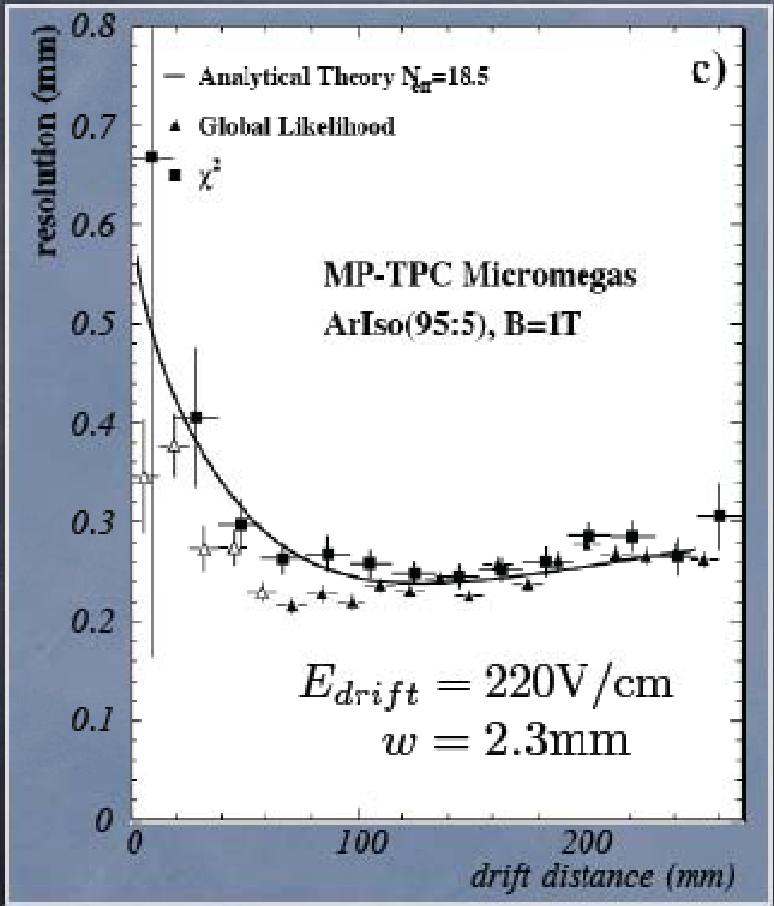
$$\sigma_{\bar{x}}^2 \simeq \frac{1}{N_{eff}}\left(\frac{w^2}{12} + C_d^2 z\right)$$

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

$$N_{eff} = \left[\left\langle \frac{1}{N} \right\rangle \left\langle \left(\frac{G}{\bar{G}}\right)^2 \right\rangle\right]^{-1} = \frac{1}{\langle \frac{1}{N} \rangle}\left(\frac{1+\theta}{2+\theta}\right) < \langle N \rangle$$

Spatial Resolution of MPGD TPC

A Comparison with Measurement with MP-TPC Prototype



- Theory reproduces the data well
- Underestimation in the data of σ_x at short drift distance due to track bias
- Global likelihood method eliminates S-shape systematics at short distance when possible

MP-TPC collaboration (Carleton Univ.-CDC group-DESY-MPI-LAL Orsay-CEA Saclay)

Spatial Resolution of MPGD TPC
Neff

The charge center

$$\bar{x} = \frac{\sum_{i=1}^{N} G_i x_i}{\sum_{i=1}^{N} G_i} = \tilde{x} + \frac{\sum_{i=1}^{N} G_i \Delta x_i}{\sum_{i=1}^{N} G_i}$$

i	Subscript of i-th electron in a e-cluster
x_i	= $\tilde{x}$ + Δx_i
$\tilde{x}$	Initial position of the e-cluster
G_i	Gas gain for i-th electron

Probability to measure $\tilde{x}$ at $\bar{x}$

$$P(\bar{x};\tilde{x}) = \sum_{N=1}^{\infty} P_I(N;\bar{N}) \prod_{i=1}^{N} \left(\int d\Delta x_i P_D(\Delta x_i;\sigma_d) \int d\left(\frac{G_i}{\bar{G}}\right) P_G\left(\frac{G_i}{\bar{G}};\theta\right) \right) \times \delta\left(\bar{x} - \tilde{x} - \frac{\sum_{i=1}^{N} G_i \Delta x_i}{\sum_{i=1}^{N} G_i}\right)$$

Probability function to ionize i-th electron ($P_I(N;\bar{N})$)

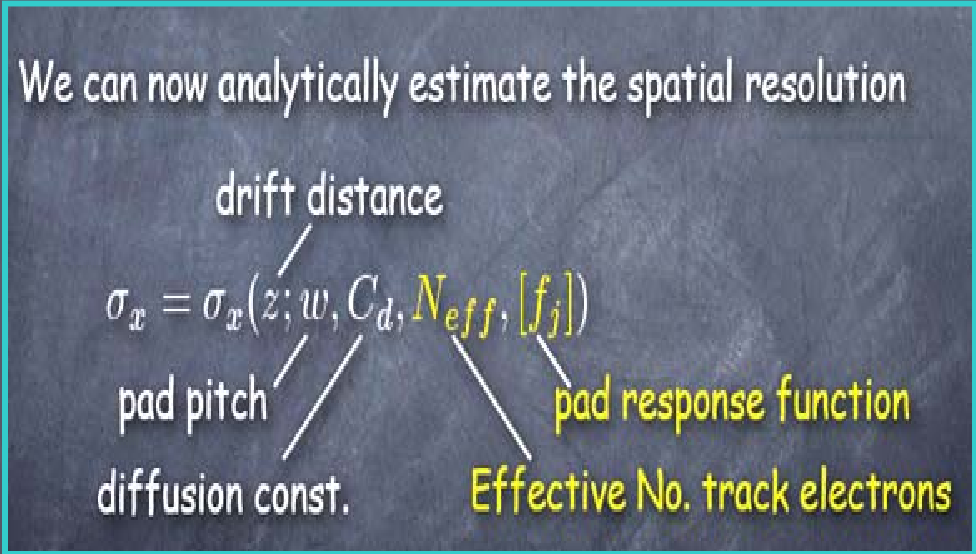
Probability function for i-th electron to diffuse by Δx_i ($P_D(\Delta x_i;\sigma_d)$)

Dispersion of the charge center

$$\sigma_{\bar{x}}^2 = \int d\bar{x} P(\bar{x};\tilde{x})(\bar{x}-\tilde{x})^2 \simeq \sigma_d \left\langle \frac{1}{N} \right\rangle \left\langle \left(\frac{G}{\bar{G}}\right)^2 \right\rangle \equiv \sigma_d^2 \frac{1}{N_{eff}} \neq \sigma_d^2 \frac{1}{\langle N \rangle}$$

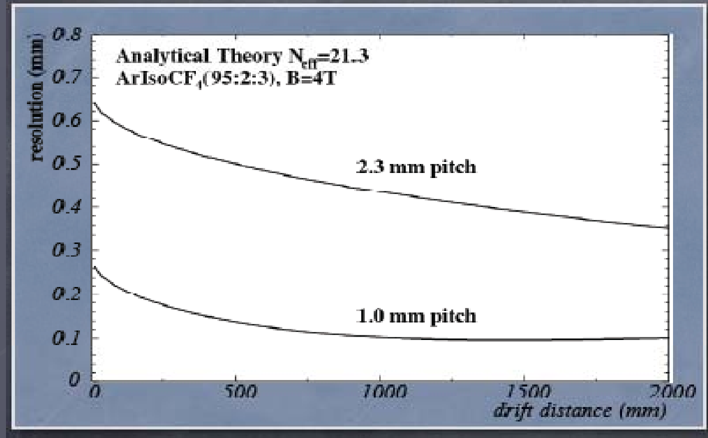
Neff ~ 20-30 while N ~ 70 for 6mm long pad.

Spatial Resolution of MPGD TPC
Three Candidates for ILC TPC



One of the conclusion s :

MicroMEGAS needs resistive anode to spread charge over pads



- Theoretical basis for how to improve the spatial resolution!

  Possible improvement of theory: angle effects

Conclusion: Three candidates

GEM + narrow pad readout:
Defocusing + narrow (1mm) pads

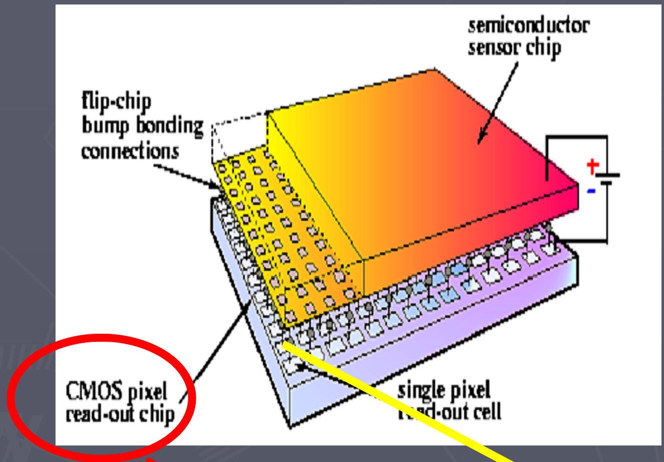
MicroMEGAS + resistive anode:
With wider pads

Digital TPC:
MicroMEGAS/GEM+ Timepix
Free from the gas gain fluctuation
More (+60%) primary electrons.

Digital TPC: Silicon Pixel Readout of MPGD TPC

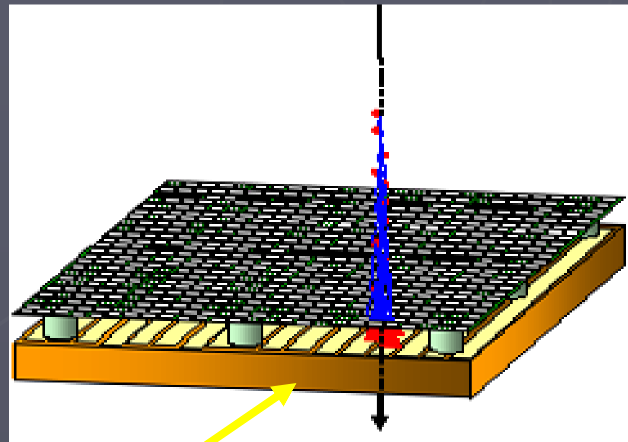
Universities of Freiburg and Bonn
CEA- Saclay, CERN and NIKHEF

Silicon Pixel Detector
(Silicon pixel + CMOS pixel read chip)



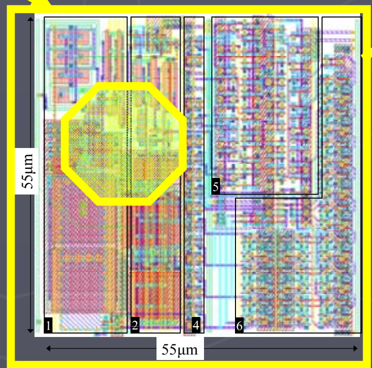
+

MicroMEGAS detector
(MicroMEGAS + Readout pads)



Timepix chip
256x256 pixels.
Pixel: 55x55 μm²
Active surface: 14x14 mm²
On/off readout.
Hit Time information.

Available Nov 2006



Timepix
(one pixel)

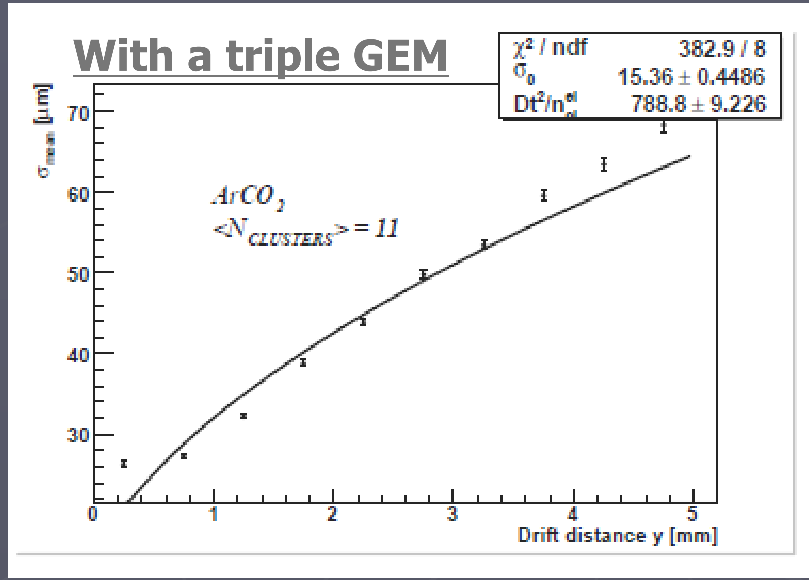
Replace the readout pad plane by the CMPS pixel chip

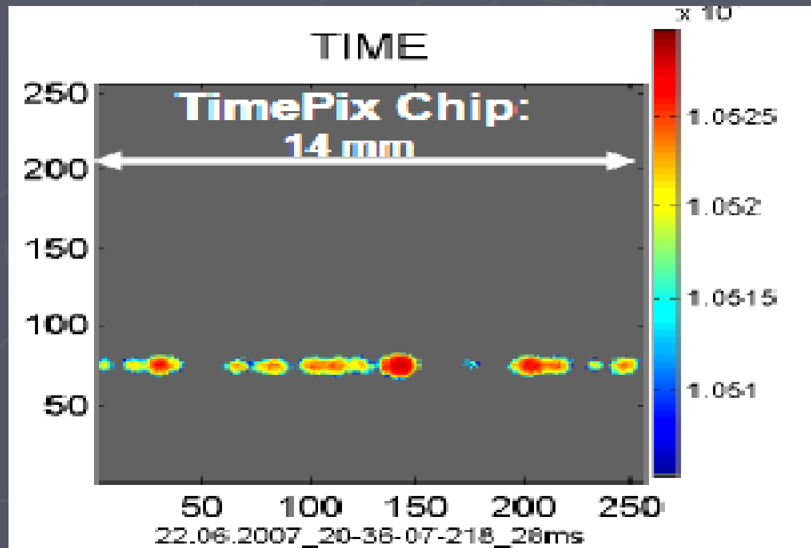
"Digital TPC"

Signal spread of Micro-MEGAS : O(10 μm) < 55 μm

Silicon Pixel Readout for TPC

- **From Medipix to Timepix chip in 2006** (CERN): 256x256 pixels of 55x55μm² with a preamp, a discriminator and a counter to measure hit time.
- **Robust operation with triple GEM** in 2006. Detailed beam test at DESY in 2007. GEM+Timepix sees "bubbles" which show the size of signal spread of GEM and may contain more than one primary electrons.
- Detection efficiency of primary electrons is an issue to apply to TPC at ILC. (The rapid deterioration of the position resolution as drift distance increases.)
- It is very attractive with its powerful graphic capability.

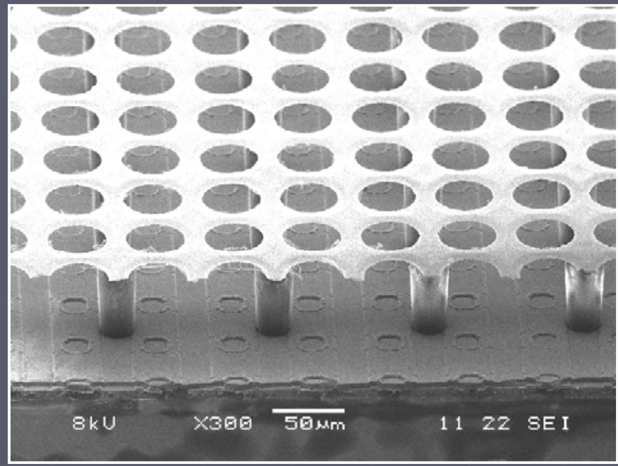




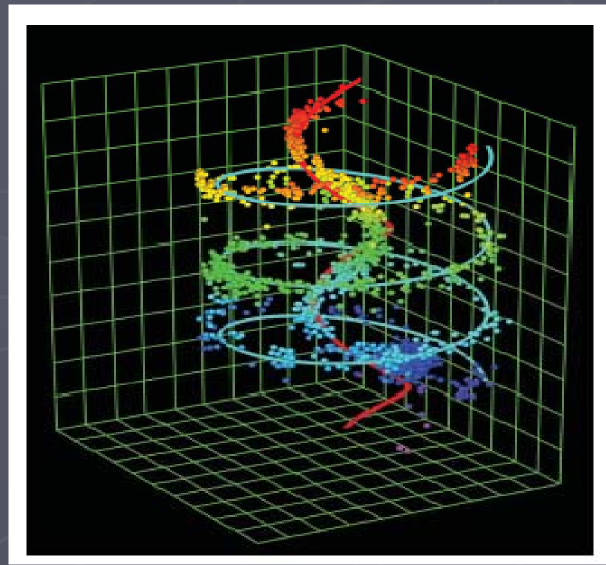
Results of DESY beam test
of Triple GEM +Timepix (Freiberg + Bonn)

Silicon Pixel Readout for a TPC

- **Ingrid MicroMEGAS Timepix:** Integrated grid, i.e., MicroMEGAS mesh on the top of the CMOS chip.
- **To prevent discharge (in particular in Ar-based gases) to kill the chip**, a discharge protection of high-resistive ($\sim 10^{11}$) Ω·cm **amorphous Si layer (3→ 20 μm thick)** on top of CMOS chip was processed. Now also SiN protection.
- Good energy resolution of Ingrid devices
- Ion backflow of a few per-mil level at high field ratio.
- Still need a higher gain (a few 1,000?).
- MicroMEGAS + TimePix can be **a true digital TPC avoiding the effect of the gain fluctuation,** possibly improving the spatial resolution by a few 10 %.
- Need silicon trough hole and 3D chip technology to implement high speed DAQ.



"Ingrid" + a-Si protection



5 cm^3 Digital TPC with MicroMEGAS
Two electron tracks from ^{90}Sr source

DIGITAL TPC : The Ultimate Resolution

(1) Detect all drift electrons individually with microscopic pixels, and

(2) Measure position of each primary electron digitally, so that there is no deterioration due to the gas gain f luctuation, with the necessary precision (50 micron)

→ With Narrow signal spread O(10micron) of MicroMEGAS , "MicroMEGAS + Timepix" seems to be preferable:

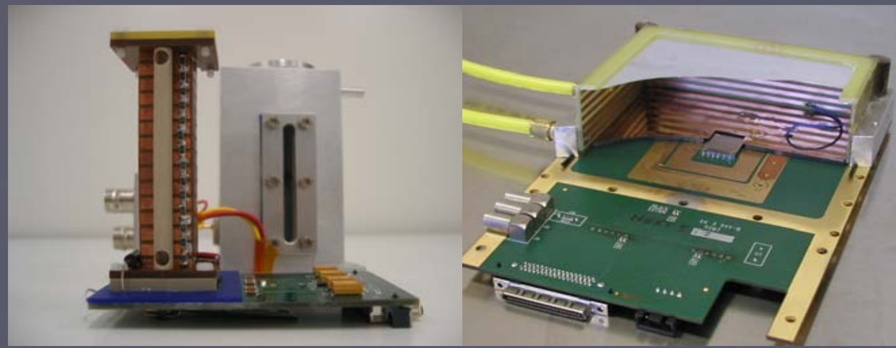
To beat out the analog readout Of MPGD TPC in term of position resolution, need high single electron detection efficiency:

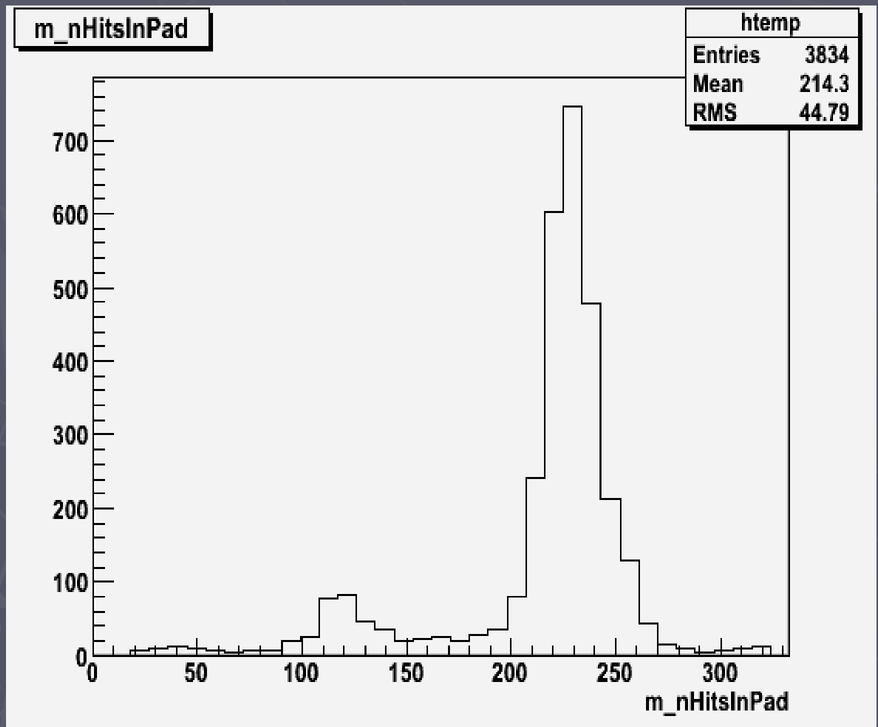
→ High detection efficiency at the chip level (shown: next slide)
→ No geometrical dead space in the real TPC application
→ the silicon through hole to route the signal to the back of TimePix, and 3D chip technology for high speed data readout.
→ Need demonstration of tracking!

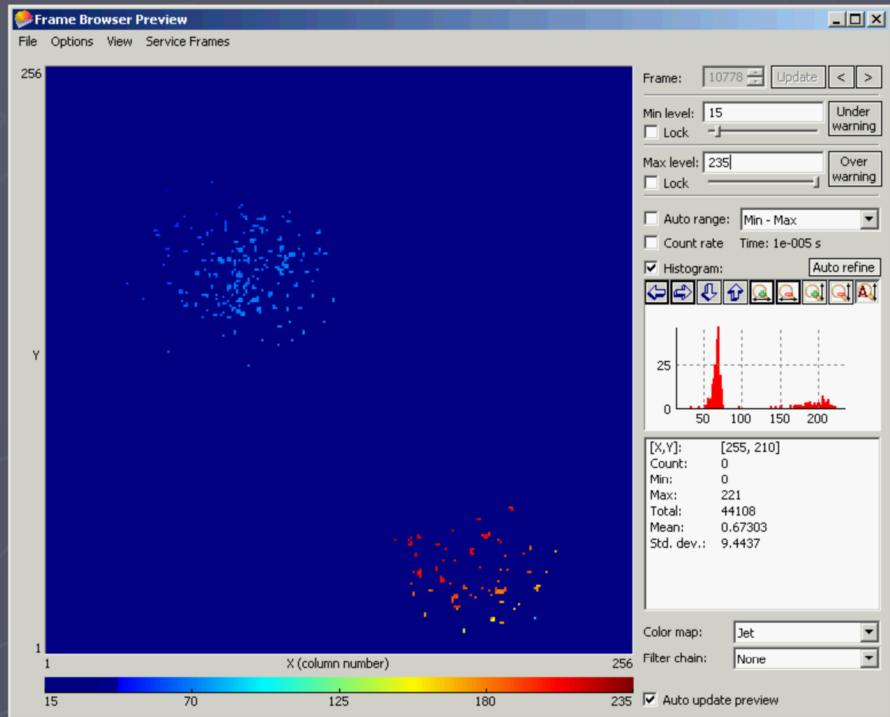
DIGITAL TPC : The Ultimate Resolution
MicroMEGAS + Timepx

Measure electrons from an X-ray conversion and count them and study the fluctuations (Nikhef-Saclay)

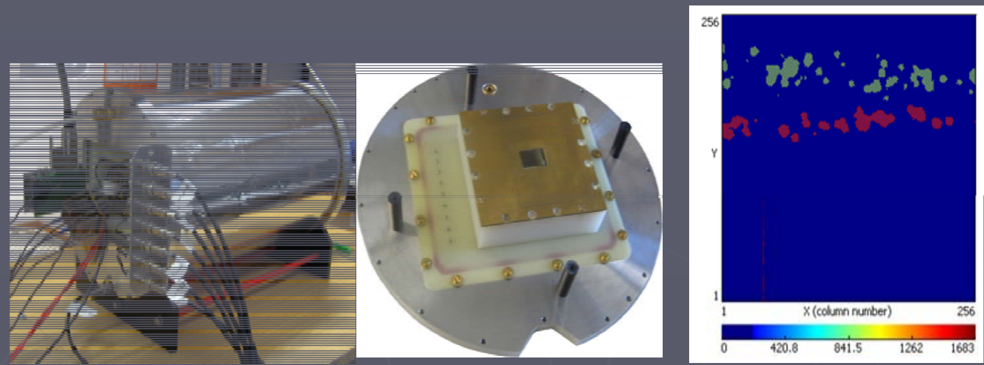
→ Single electron efficiency is in fact very high.





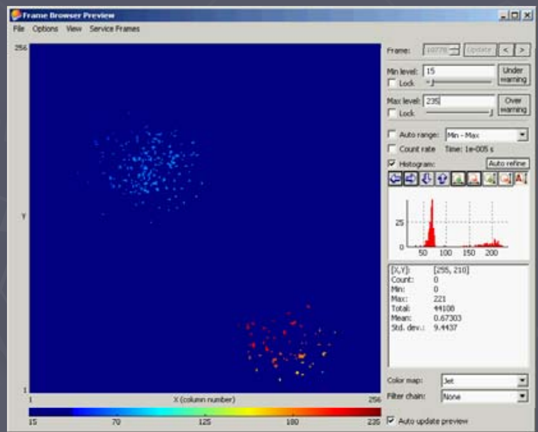


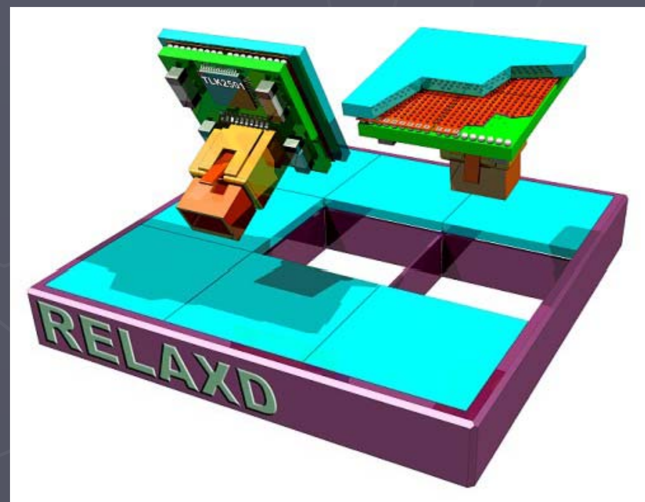
Silicon Pixel Readout for TPC: Many Plans



Small TPC to test triple GEM+Timepix (Bonn)
(Beta rays)

RELAXD Quad Board Project
with through-Si via & 5Gb
readout (NIKHEF)





A mini TPC at Saclay-NIKHEF
(Fe55 Source)

(Also LP1 detector modules with Timepix chips)

Of Course, There Are Other, Ordinary Issues of TPC

TPC gas: (Under study at a few places such as DESY, KEK,,)

Ar/CF4(3%)/Isobutene (T2K cocktail)
No attachment, ok both for Micromegas and GEM
P5
May be more ?

Beam background: (Recently by A. Vogel/DESY)

Beam beamstrahlung (photon and electron pairs).
But the occupancy in TPC much les than 1% (A. Vogel)

Tracking in non-uniform magnetic field: (Settles & Wiedenmann)

Correction can be done when the field is mapped
down to O(1G) as in the case of ALEF.

Ion back-drift and ion disks:

A detailed simulation underway (Bonn)
GEM gating (Saga/CCD group)

,,,,,,,

Gas for ILC TPC

Low diffusion at high magnetic field (large $\omega\tau$).
Sufficient primary electrons.
Small electron attachment.
(the drift region and the amplification region)
Reasonable drift velocity at an acceptable drift field.
Gating condition (when we use the GEM gating).
Neutron background with less or no hydrogen (quencher)
Stable operation of MPGD.
Long term stability of TPC (aging and corrosion)

Some works underway

The intensive gas (gain) study for MicroMEGAS (Saclay)
Ar/CF_4 gas study for GEM (the LC TPC group)
P5 study by DESY group with 5T magnet.

TPC Gas: Ar-CF4 Gas Mixture

Small transverse diffusion with the large ωτ@ high magnetic field

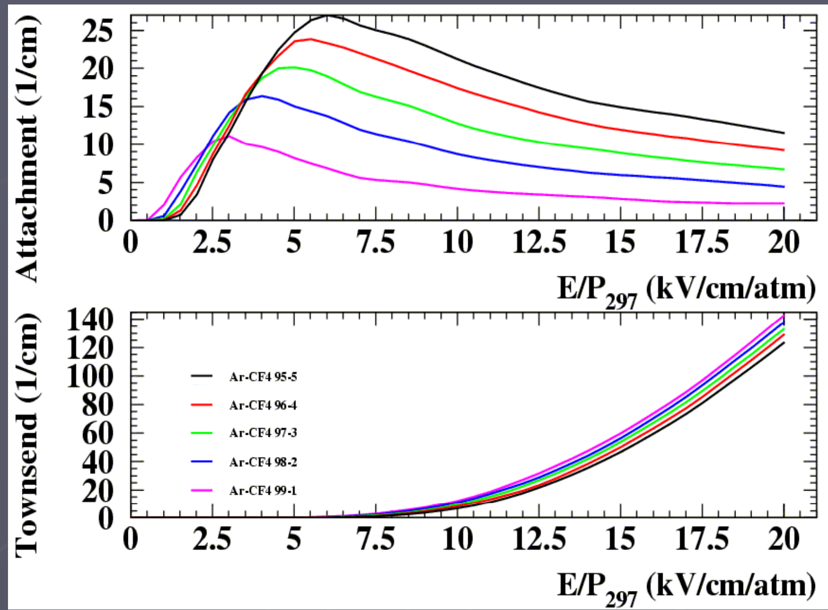
Large electron attachment for E > a several 100V/cm   -> The question if GEM works?

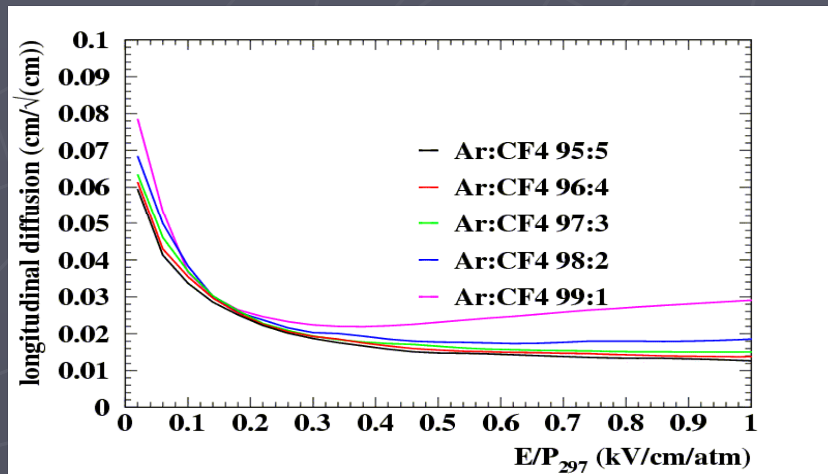
Need some quencher (Isobutene)   both for MicroMEGAS (unstable operation) and GEM (very low gain)

(1) MicroMEGAS: Nice result@5T (M. Dixit et. al. 2007)

(2) GEM: Known to work with Isobutene (T2K 2006)

This measurement with MP-TPC is to confirm (2) and measure Neff.

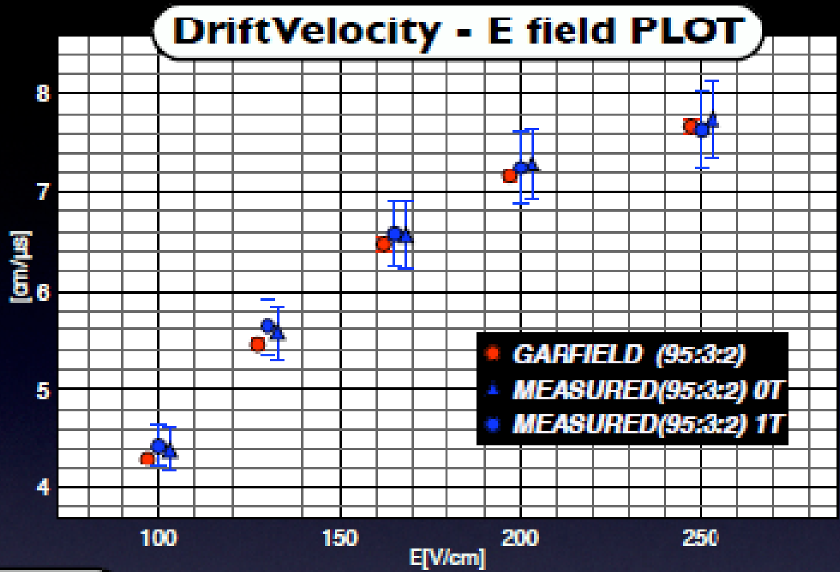


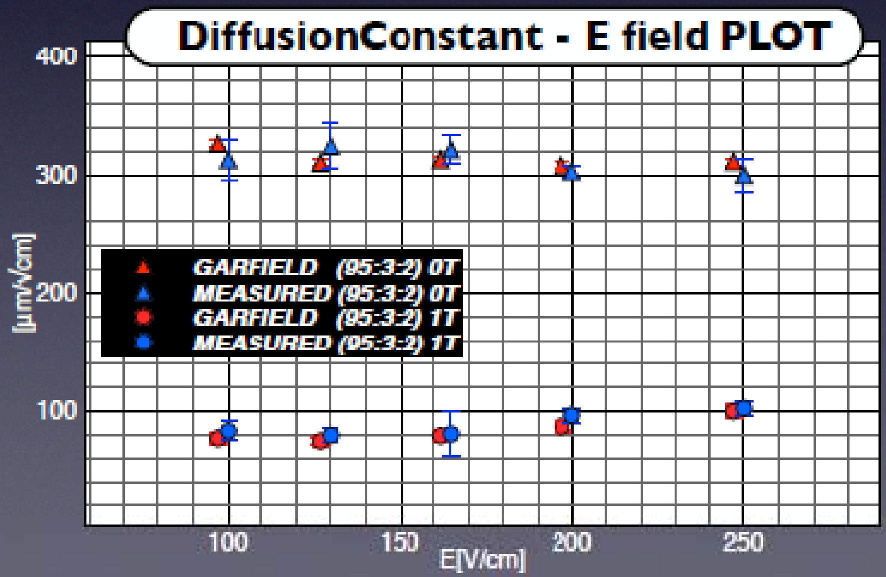


Result Summary

Gas: Ar-CF4-isoC4H10(95:3:2)

ドリフト速度とディフュージョン係数について
シミュレーションによる結果と共にプロットした。





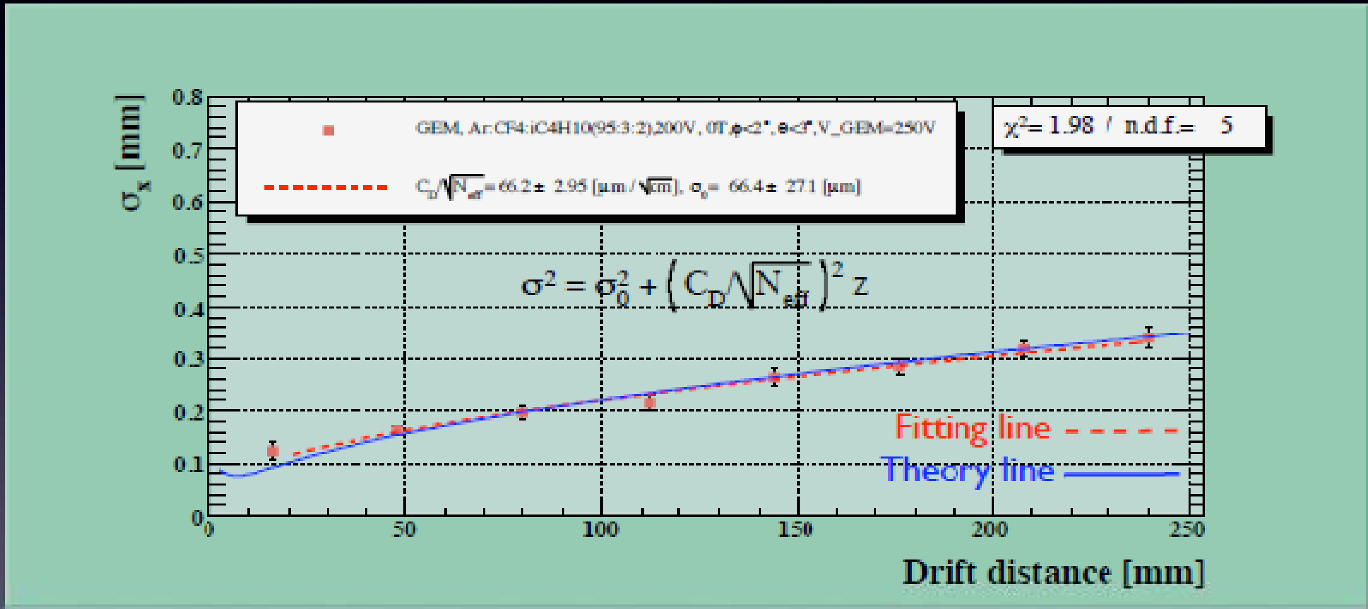
今回の結果を見る限り、garfieldシミュレーション
測定結果をうまく再現する。

Attachment

amplification region

増幅部分のみのアタッチメントを調べるのは難しいので、Neffを求めて、P5等の結果と比較を行う。

NeffはResolutionの結果をフィッティングすることによって得られる。



Ar-CF4-isoC4H10(95:3:2) E=200[V/cm] B=0[T]

測定データ

$$C_D = 303 \pm 5$$

$$\frac{C_D}{\sqrt{N_{eff}}} = 66 \pm 3$$

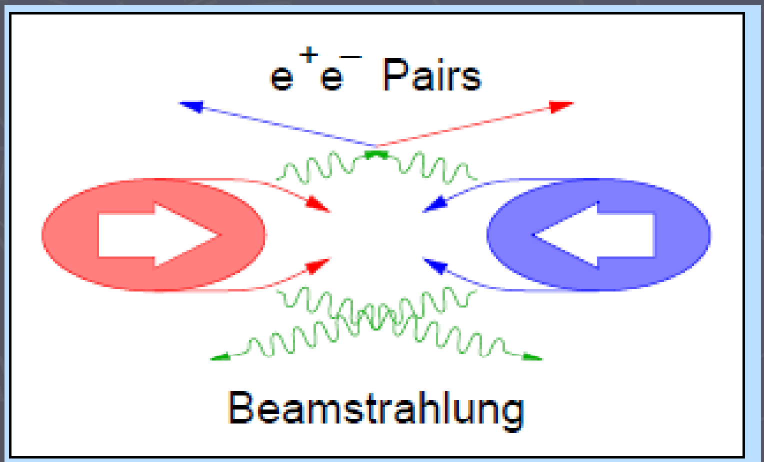
} Neff ~ 21 ± 2 (※P5 ~22)

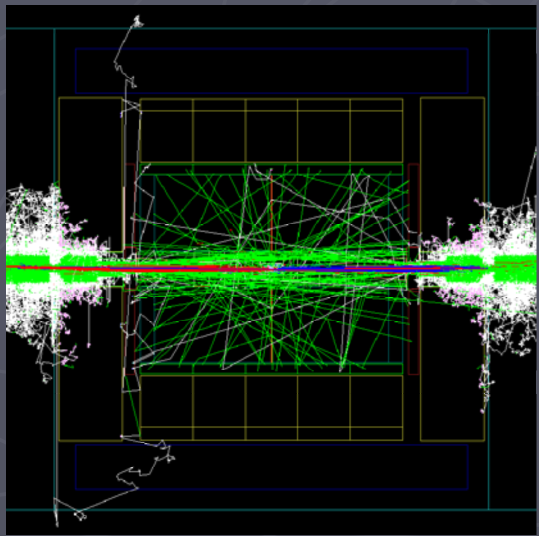
A. Vogel

Beam Backgrounds for TPC at ILC

- The ILC has the novel problem of beamstrahlung.
- High luminosity is essential for measurements.
- tiny bunch size is required (x: 500 nm, y: 5 nm) bunches have a very high
- electric space charge
- particles are deflected and can emit photons ("beamstrahlung").

- Beamstrahlung photons can scatter to e+e– pairs.
- 105 particles per BX for ILC beam parameters energies in the GeV range.
- Strongly focused in the forward direction but sometimes also large polar
- angles.
- Pairs: a major source of detector backgrounds!

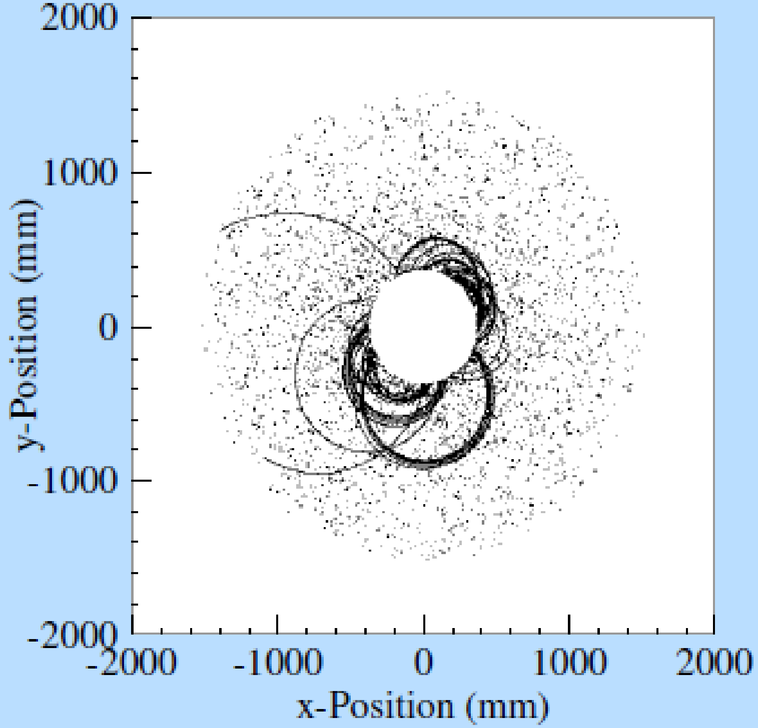




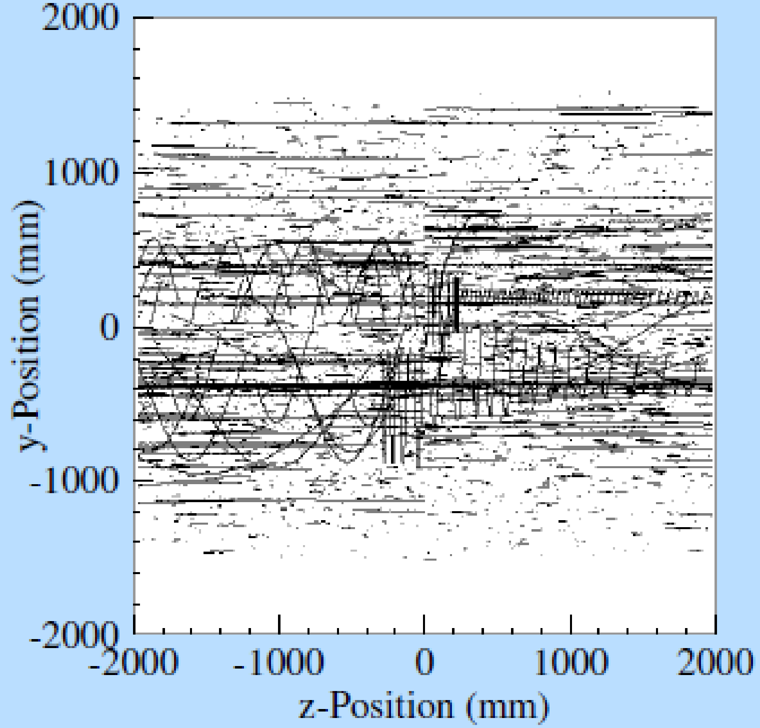
Beam Backgrounds for TPC at ILC

TPC – Spatial Distribution of Hits

Mokka hits in the TPC (overlay of 100 BX)



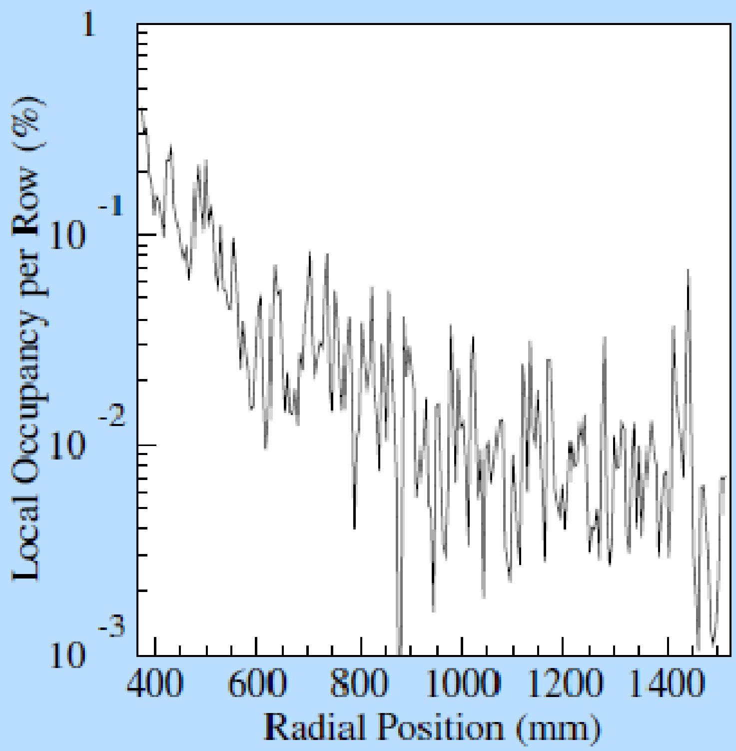
Front view



Side view

TPC – Occupancy

- highest occupancies at small radii
- overall value stays very well below 1 %
- outside-in tracking always possible
- n-p scattering gives negligible contribution
- backgrounds will be no problem for the TPC

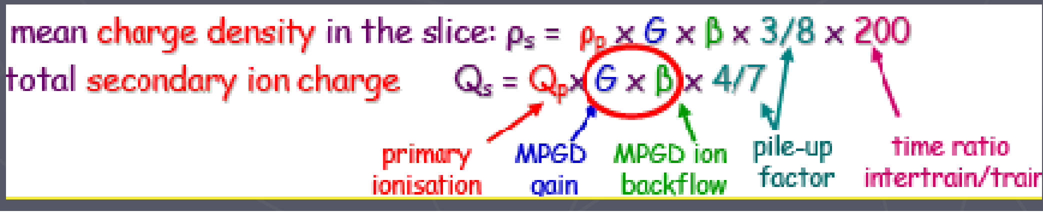


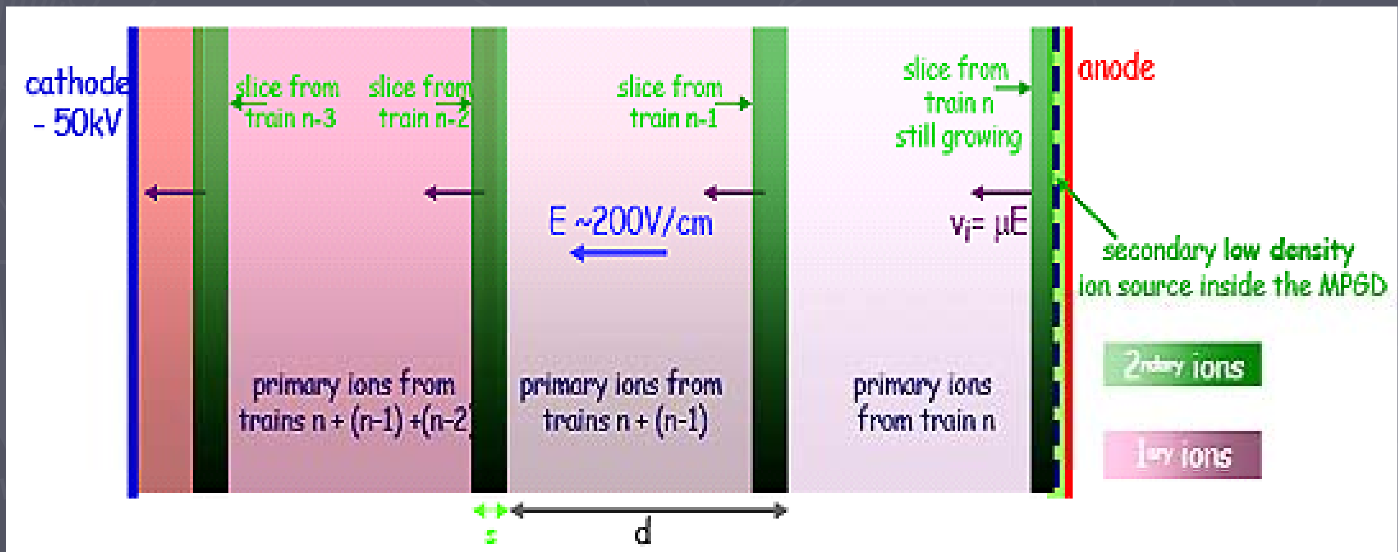
Overlay of 100 BX

Ion Feedback and Gating

V. Lepeltier,
TILC08 March 2008
Sendai

- Ions in the TPC drift volume, if its density is high, introduce the distortion.
- Two sources of ions; primarily ions and feed back ions from the amplification region.
- The collection time of ions is slow: 600ms for the drift filed of 200V/cm compared to the electron drift time of about 40 micro sec.
- If the ion feedback ration is height, the feed back ions build up the a few ion slices in the TPC drift volume.
- G x β is the key factor for the secondary ions. If > 1, we need an ion gating device.

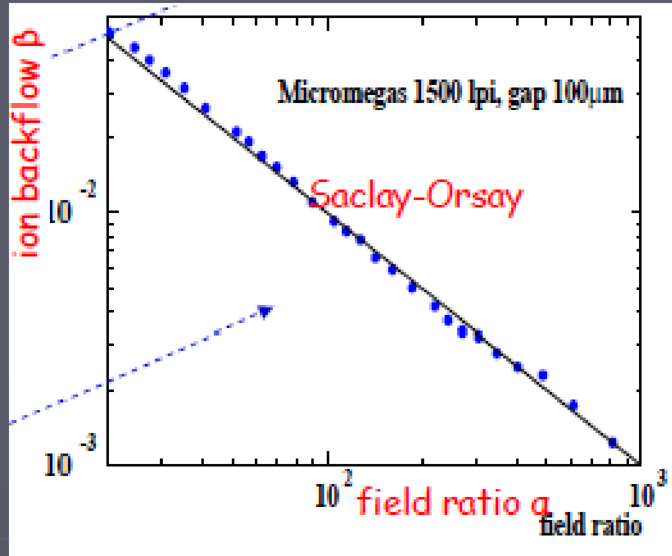




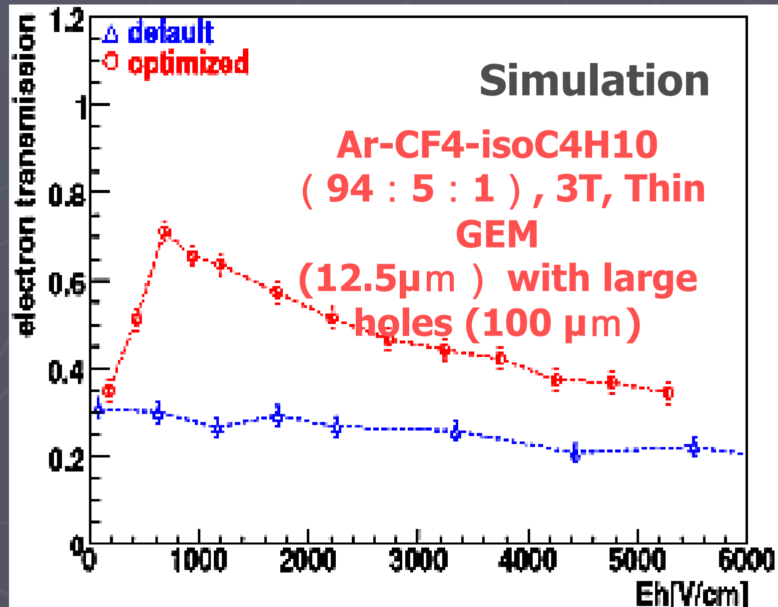
Detailed simulation underway using Marlin TPC (Bonn)

Ions in the ILC-TPC

- The ion feedback ratios of MicroMEGAS and triple GEM is O(0.1) %. If the gas gain of the MPGD system is < 1,000, the total amount of the feed back ions is in the same order of the primary ions but still the mean charge density in the slices may be 200 times of that of primary ions.
- Urgently need to study the level of distortion by a full simulation such as Marlin TPC.
- The wire gating is very efficient but introduces a mechanical complication and a small distortion around the wires.
- GEM gating can stop the feed back ions but the electron transmission may be 70 % at the best, and thus introduces a degradation of the spatial resolution.
- A questions: operate the MPGD with low gas gain (500), or, install a gating device?
- We has been working on a simulation and measurements of electron transmission of gating GEM. Soon also on the GEM gating itself.



Ion feedback ratio MicroMREGAS



Electron transmission of gating GEM (Saga/CDC group)

TPC Large Prototype (LP) Beam Test at DESY by LC TPC Collaboration using EUDET Facility

Goals

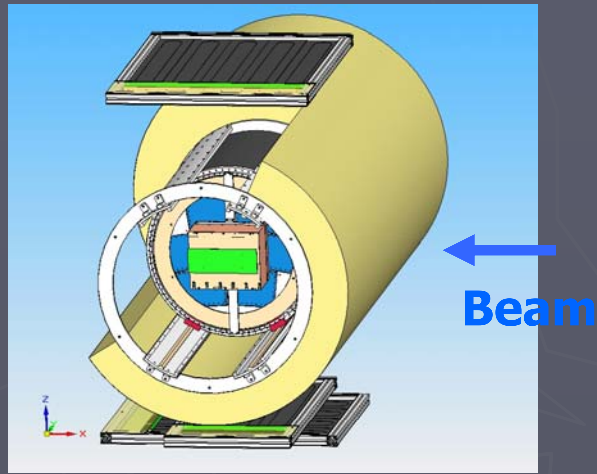
- Study, in practice, design and fabrication of all components of MPGD TPC in larger scale; field cage, endplate, detector modules, front-end electronics and field mapping of non uniform magnetic field. (But not yet the engineering stage.)

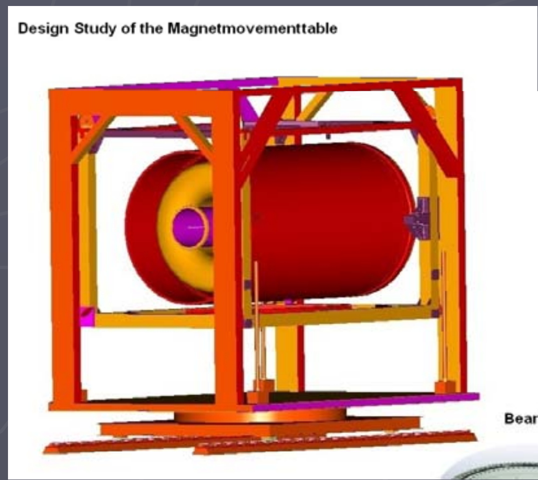
- **Demonstrate full-volume trucking in non-uniform magnetic field, trying to provide a proof for the momentum resolution at LC TPC.**

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

- **Develop methods and software for alignment, calibration, and corrections.**

(Beijing tracker review, Jan 2007)





LC TPC Large Prototype Beam Test at DESY
LC TPC Collaboration with EUDET Facility

Pixel beam telescope (EUDET)

Si strip detector (EUDET/SiLC)

Magnet: PCMAG (LC TPC/KEK,CERN)

Field cage & All Mechanics (EUDET: DESY)

Endplate (LC TPC/Cornell)

Test beam (DESY)

Gas system (EUDET:DESY)

Different MPGD Detector Modules (LC TPC: CDC group; Saclay & Carleton; NIKEHF Bonn etc)

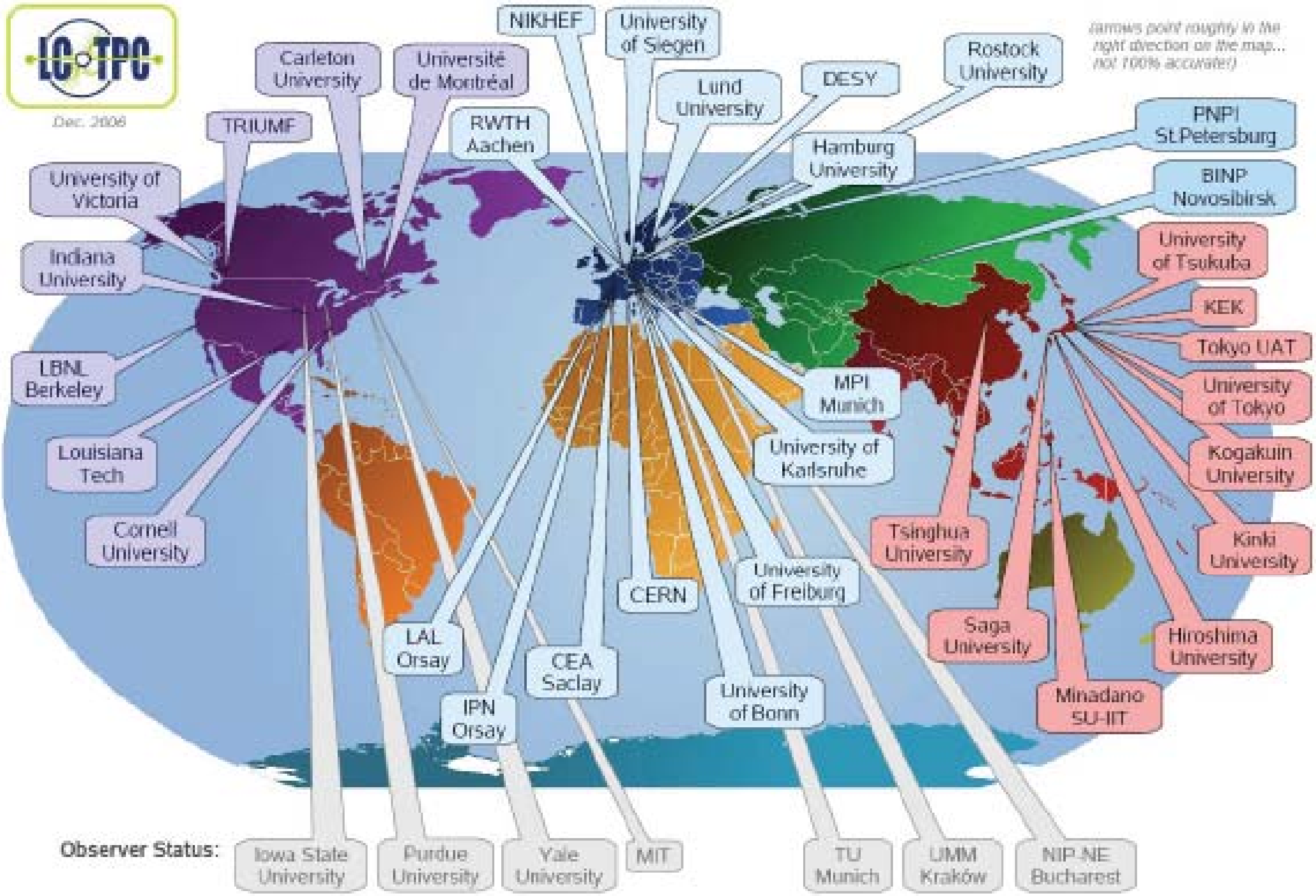
DAQ & Monitoring (EUDET)

Cosmic trigger (LC TPC/KEK, Saclay)

Two types of Readout electronics (EUDET:CERN, Lund & LC TPC: CDC group, Saclay)

Software development (EUDET & LC TPC)

LCTPC Collaboration



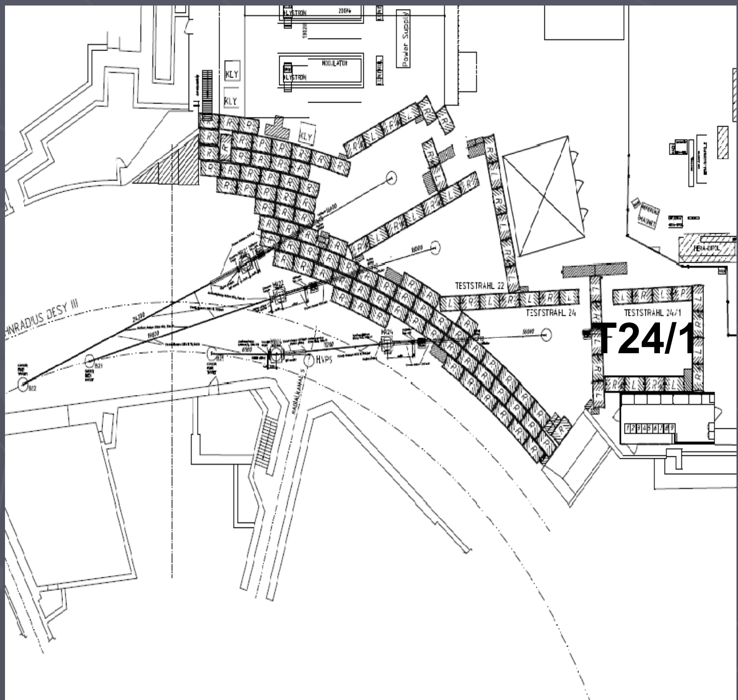
DESY II Test Beam Line

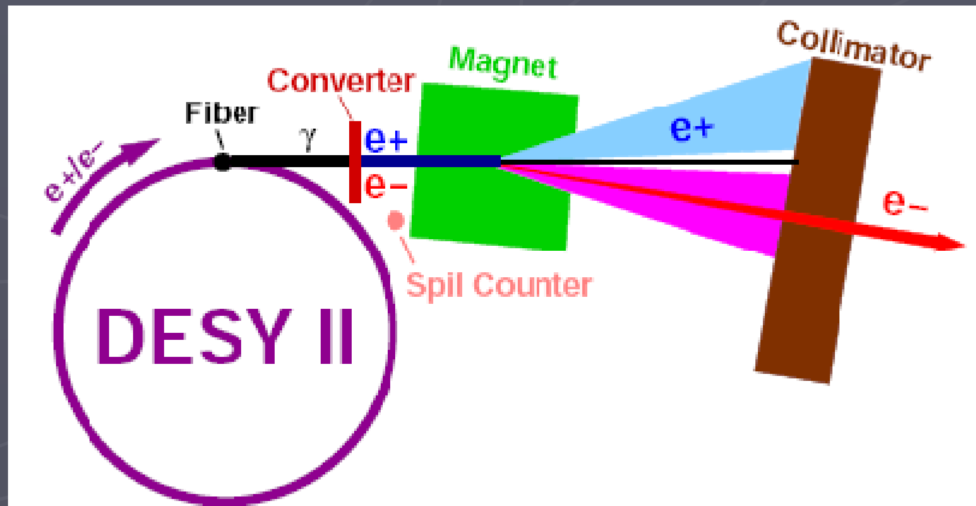
Converted bremsstrahlung electron from C-fiber targets of DESY II.
Electron energy: 1 - < 6.5 GeV/c.

The test beam should be available from mid August in this year.

Silicon-pixel beam telescope by EUDET.

Rates	Target	
Energy	3mm Cu	1mm Cu
1 GeV	~330 Hz	~ 220Hz
2 GeV	~500 Hz	~330 Hz
3 GeV	~1000 Hz	~660 Hz
5 GeV	~500 Hz	~330 Hz
6 GeV	~250 Hz	~160 Hz

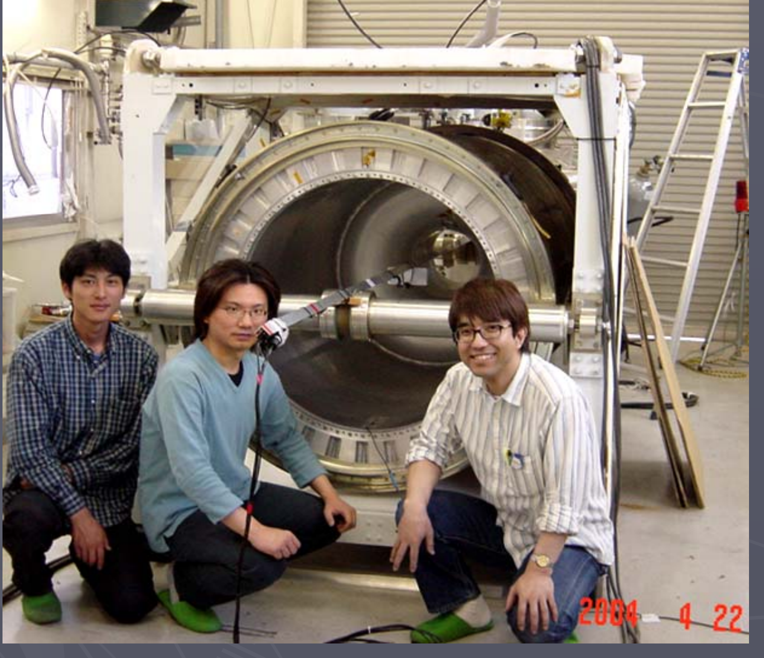


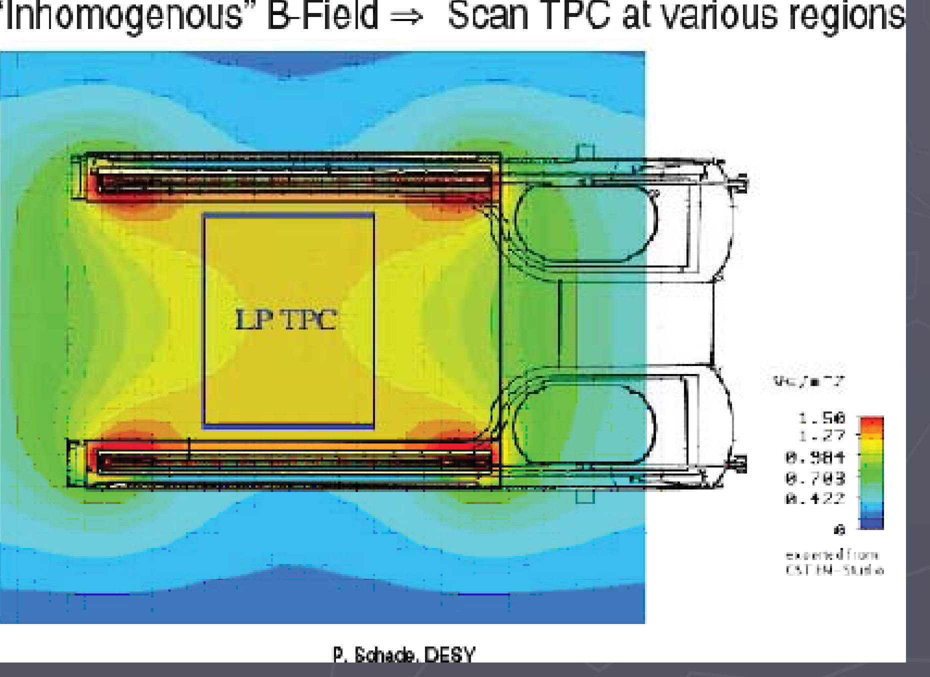


Superconducting Magnet: PCMAG

KEK

PCMAG is a Persistent Current, superconducting MAGnet with thin (0.2X0) coil and wall. It has no yoke. PCMAG was used in MP-TPC beam tests at KEK PS in 2004-200, and moved to DESY in Dec 2006 for LP1 beam test. The magnet has been tested and mapped at DESY in 2006-2007 under the cooperation of DESY, KEK and CERN groups. A new transfer tube is expected in April for safer operation, but PCMAG is essentially ready.



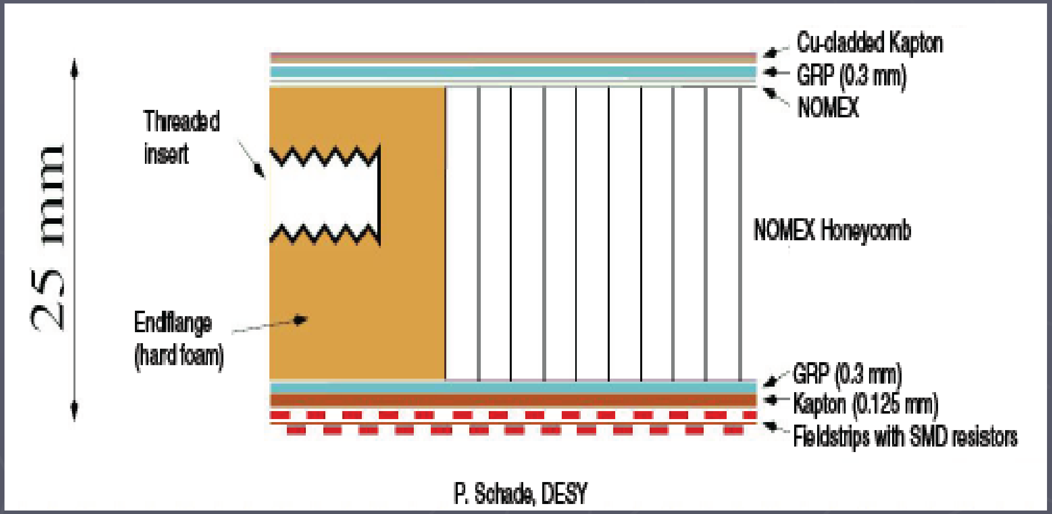


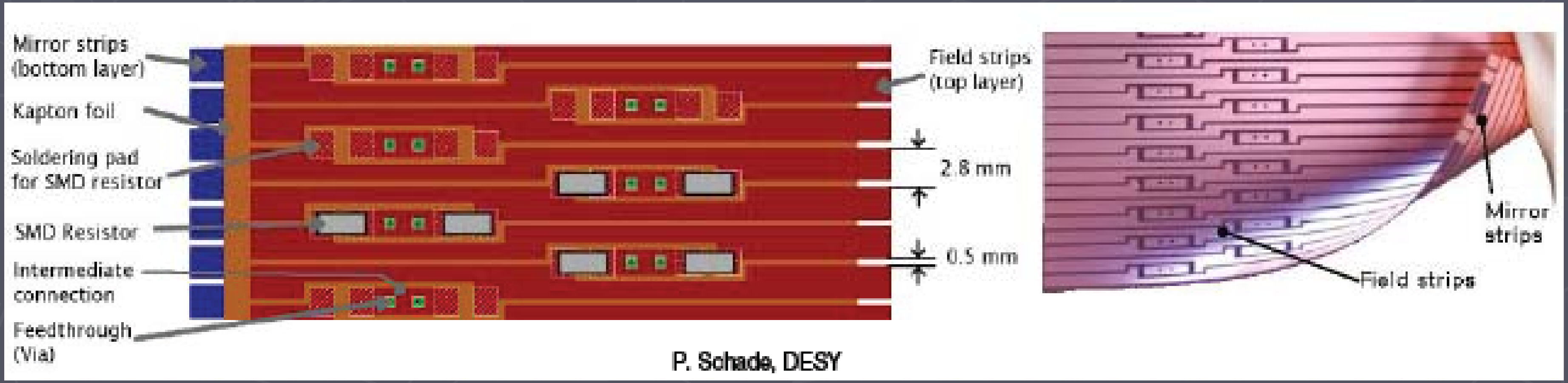
Coil diameter: 1.0 m, length: 1.3 m, weight: 460 kg, central magnetic filed: up to 1.2T, liq. He capacity and life time: 240L and max. 10 days, Operational current: 430A (1T), filed decay time: > 1 year, Transparency: 0.2X.

DESY
Univ. Hamburg

Field Cage

- Field cage: 750 mm in diameter
  610mm long.
- Cu (35 μm thick) strips and its mirror strips on one Kapton film.
- **The light weight composite structure of Nomex hone-comb with glass fiber layers.**
- Max. drift field: 320V/cm (21kV)
- Field uniformity: $\delta E/E \leqq 10^{-4}$
- **Divider chain with SMD resistors inside the field cage.**

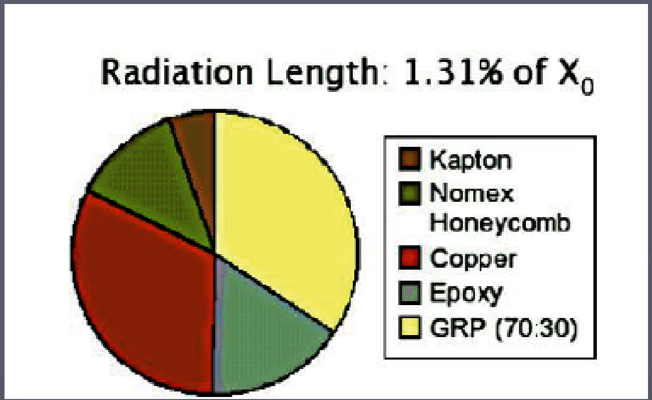




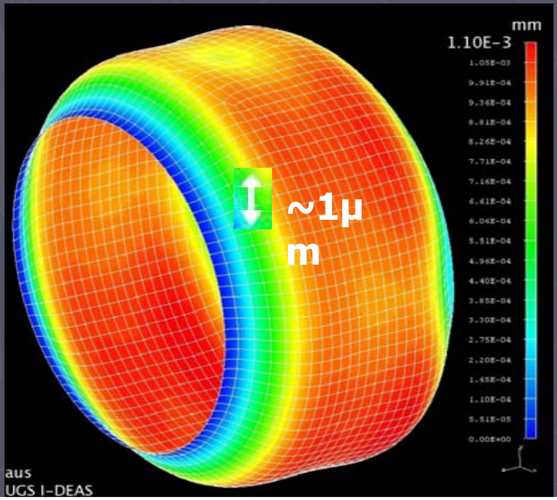
LP TPC Field Cage

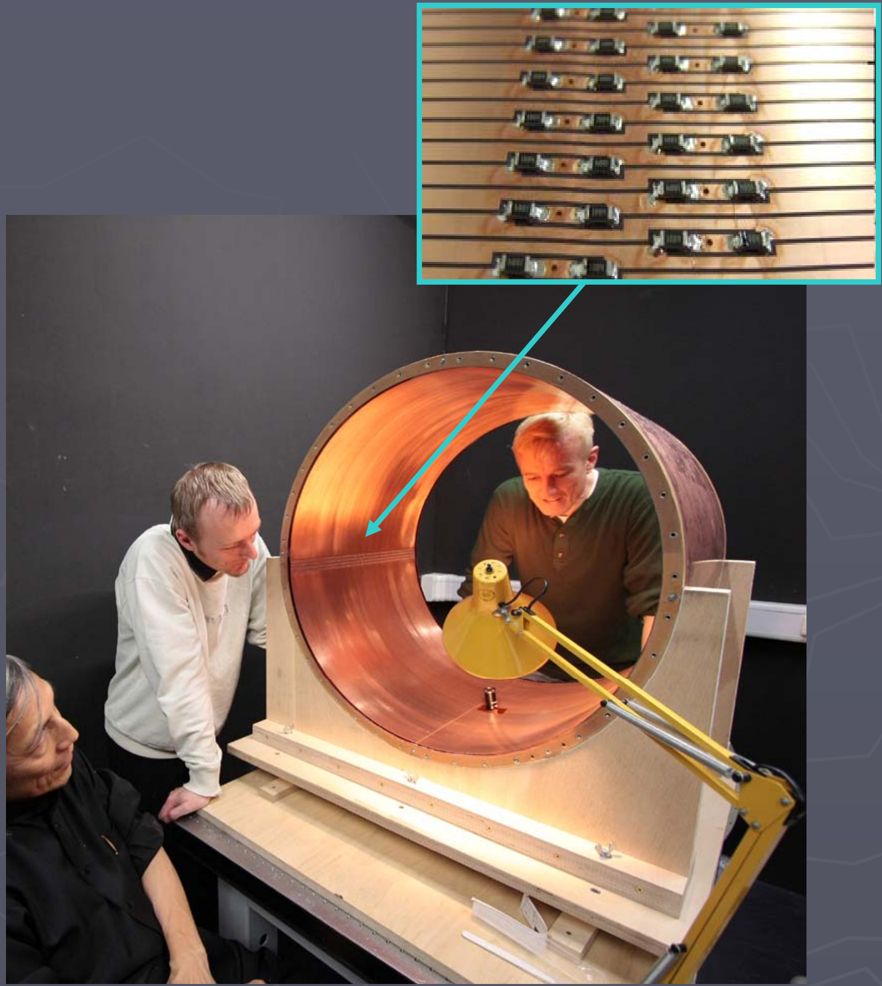
DESY
Univ. Hamburg

Material budget of field cage. Two layers of Cu strips (35μm) contribute.



Field cage is also the gas container: Deformation for "100mb" gas pressure & 5kg point load. Nominal operation pressure: 6mb.





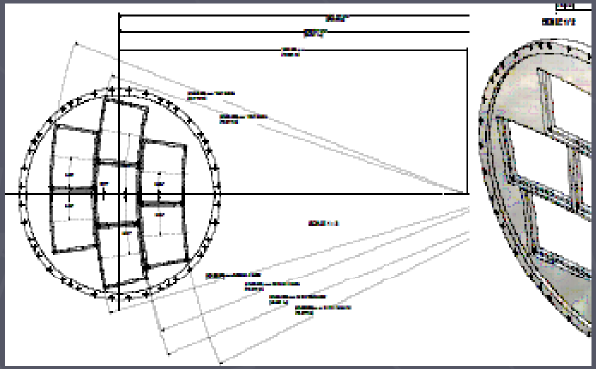
After Initial inspection at DESY, filed cage is to be assembled with the endplates and cathode plane for pressure

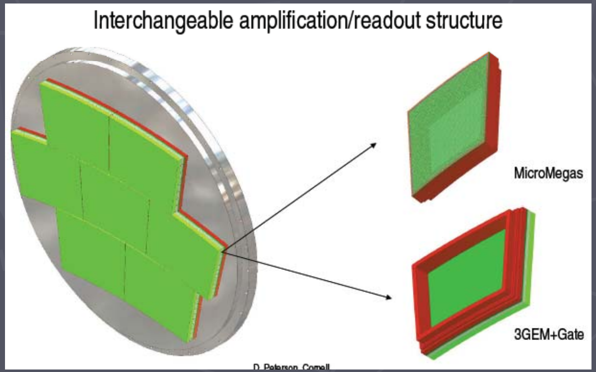
TPC Endplate

Cornell University

LP1 endplate made of Al, accommodates 7 detector modules. The diameter of the endplate is about 770 mm.

The shape and size of the detector module was decided to simulate one at LC TPC of the size of GEM widely available. All 7 detector modules have the same outer shape so that they are interchangeable on the endplate. However, we do not plan to mix the detector modules of different MPGD since they are normally in different operation conditions (such as the voltage applied to their front face). The endplate is designed at Cornell Univ. The endplate has arrived at DESY. Need design R&D for a light structure.





Detector Modules

Three types of MPGD detector modules are being prepared:

(1) MicroMEGAS with resistive anode: one module without resistive anode is already at DESY for the LP beam test commissioning in November. The second module has been fabricated with a resistive foil at CERN. A few fabrication methods of resistive anode are under trial.

(2) Double GEM (100 μm thick) with a gating GEM readout by narrow (1 mm wide) pads: 4 modules should be ready at the beginning of 2008.

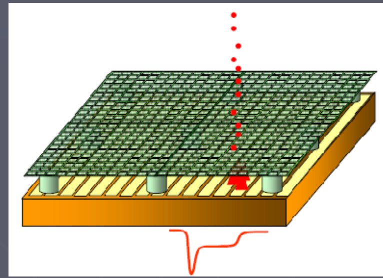
(3) Detector modules with 4 - 8 Timepix chips with MicroMEGAS/GEM (three GEM):

- **Triple GEM modules (being discussed at Bonn):**
- **Dummy detector modules:**

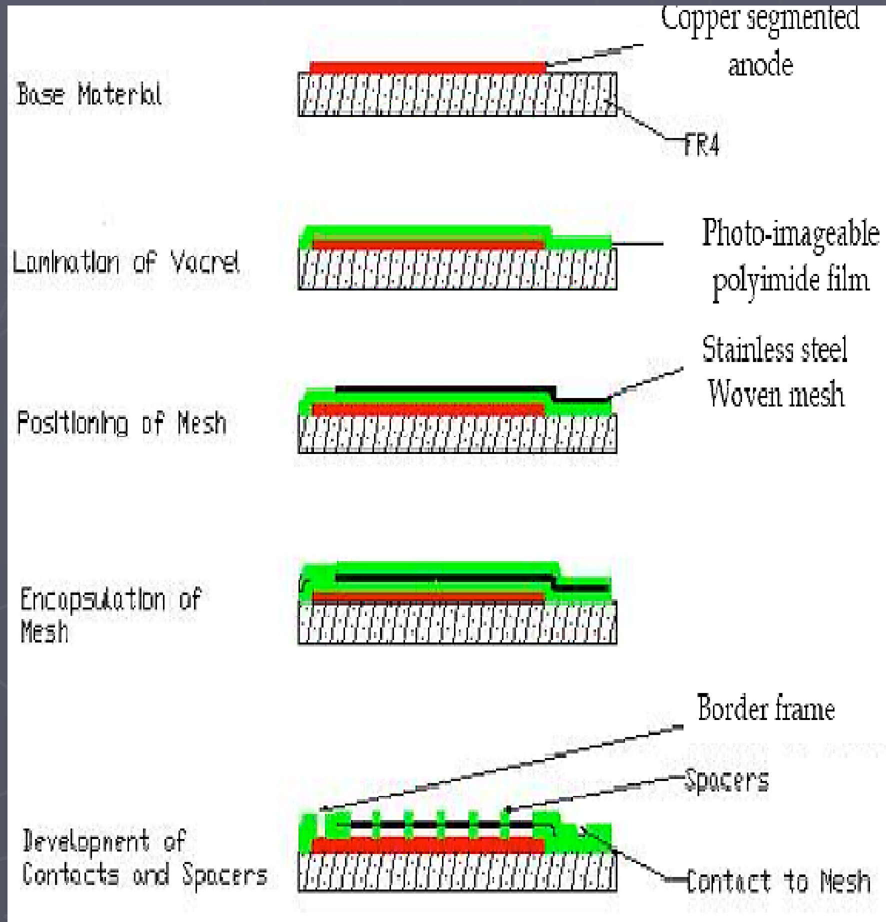
Detector Module: MicroMEGAS with Resistive Anode

Saclay, Carleton

(1) MicroMEGAS detector by the "bulk" technology (2004):



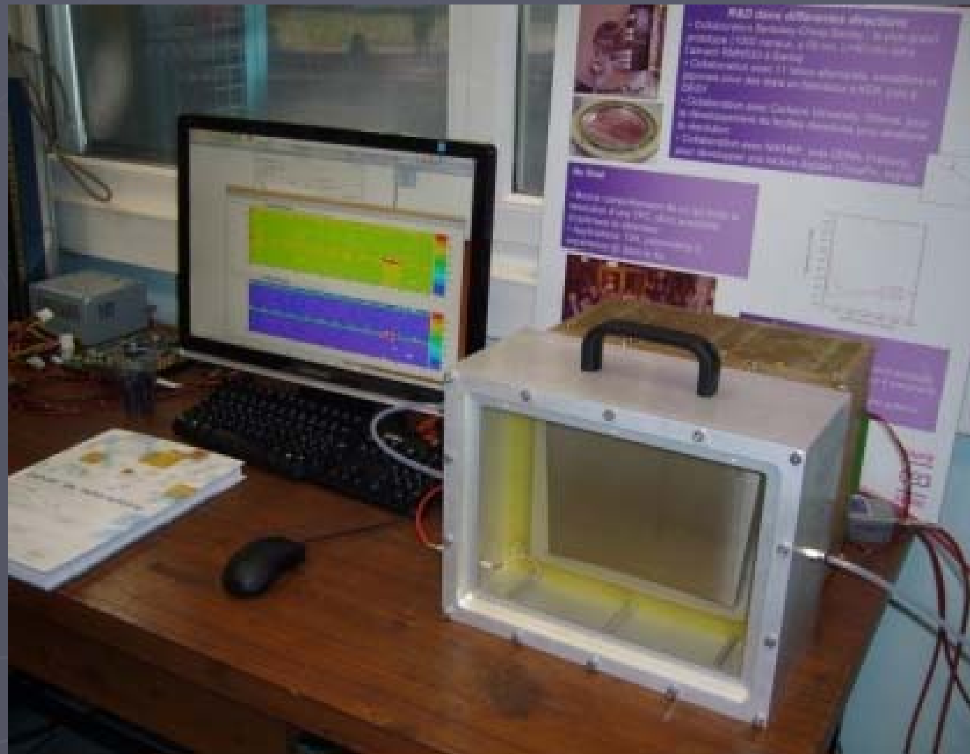
Mesh fixed by the pillars themselves :
No frame needed :
fully efficient surface
Very robust : closed for > 20 μ dust
Used by the T2K TPC under construction



The First Module of Bulk MicroMEGAS Detector for LP Commissioning (without resistive foil)

The second module with a resistive carbon-loaded kapton foil have been produced at CERN. (Rui de Oliveira)

MicorMEGAS module :
24 rows x 72 pads.
Av. Pad size: 3.2 x 7mm^2

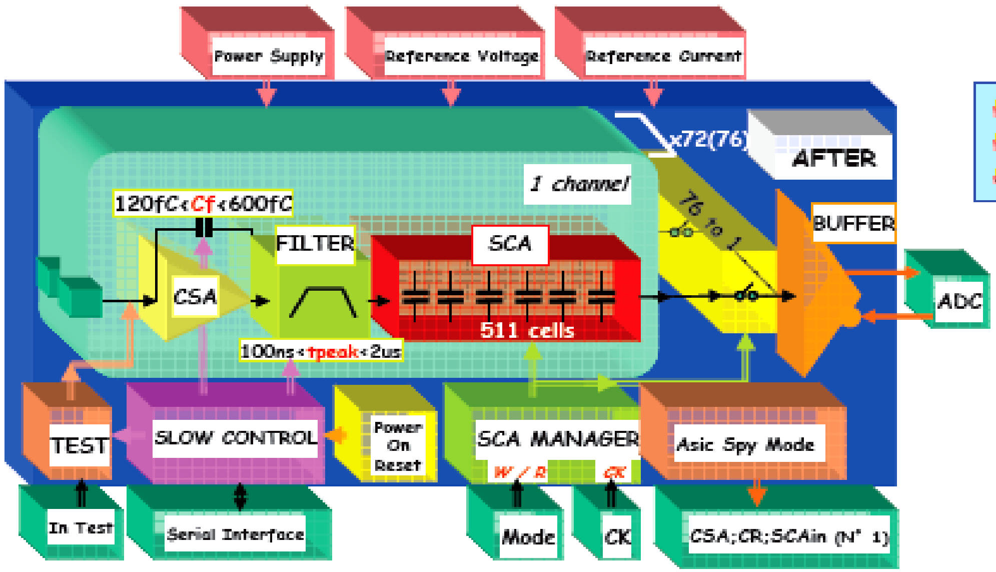


Tests in gas were performed at Saclay. One faulty pad had to be disconnected.

TPC Readout Electronics: After Electronics

Saclay

AFTER Main Features



- No zero suppress.
- No auto triggering.
- No selective readout.

Main features:

- **Input Current Polarity:** positive **or** negative
- **72** Analog Channels
- **4** Gains: 120fC, 240fC, 360fC & 600fC
- **16** Peaking Time values: (100ns to 2µs)
- **511 analog memory cells / Channel:**
  Fwrite: 1MHz-50MHz; Fread: 20MHz

- **Slow Control**
- **Power on reset**
- **Test mode:**
  calibration or test **[channel/channel]**
  functional **[72 channels in one step]**
- **Spy mode on channel 1:**
  CSA, CR or filter out

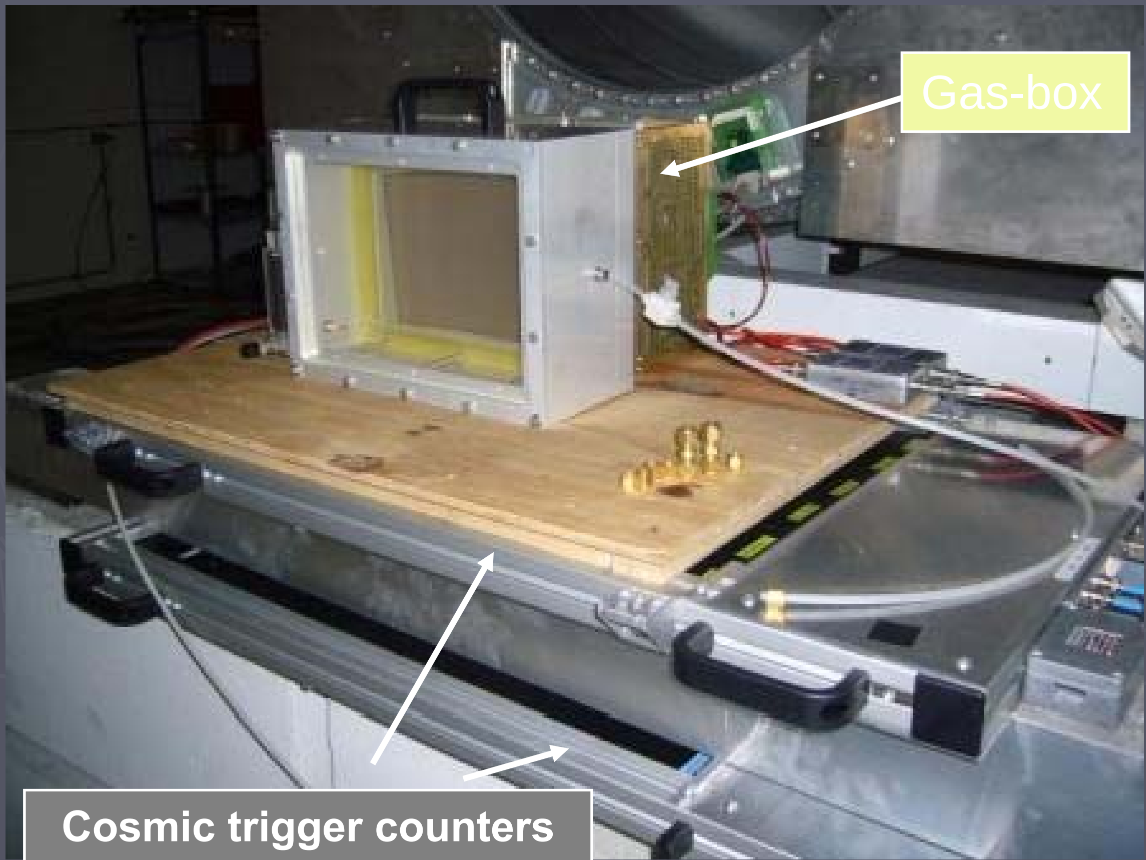
LCTPC meeting Oct. 10, 2007 *E. DELAGNES* 4

The amplifier is quite similar to PCA16. A good system for prototype tests.
Need idea and work for the long drift for LC TPC, i.e., the long capacitor array.

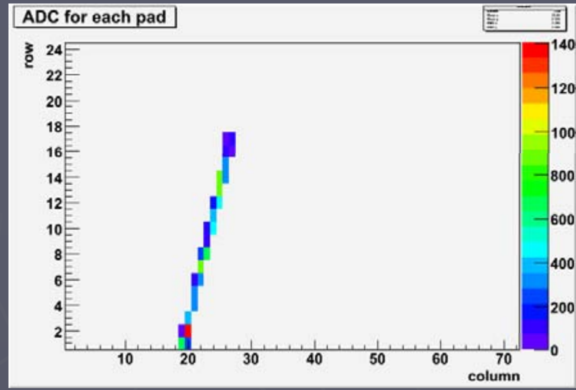
Mechanical support of the electronics

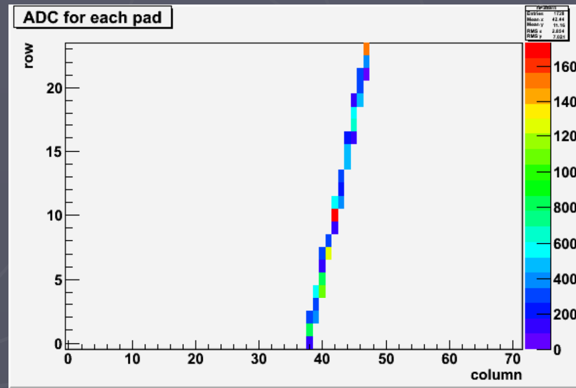
Shielding, Faraday cage, flat cables, gasbox…

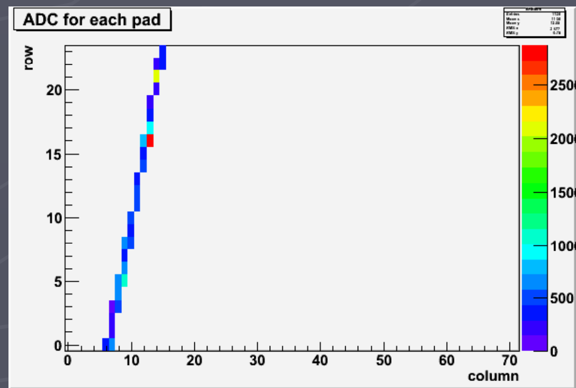
In-situ TEST of the First Module with Cosmic Rays at DESY T24/1



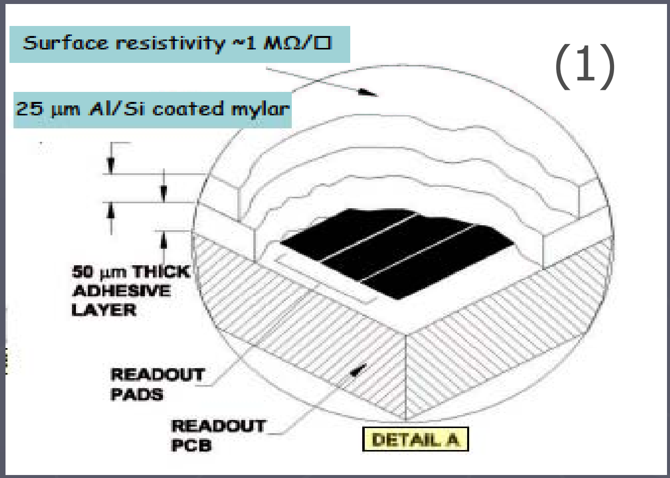
Cosmic trigger counters readout by MPPCs.







Different Technique of Resistive Anode for Bulk MicroMEGAS Modules



(1) Carbon-loaded kapton:
An old technique first tested in Carleton, using a Dupont film 1 MOhm/sq. Improvements of the resistive foil and apply to bulk. First results promising. One panel has recently produced.

(2) Prepreg+ screen printing:
This has been tried at CERN. Two prototypes of 10x10 cm2 (2 and 8 M Ohm/sq) have been tried at Saclay. There is not clear evidence that they are spark protected. Will be applied to the CERN panel.

(3) Plasma deposition of thin layer of SiO2/SiN (N. Wyrsch, Neuchatel) :
Used for SiTPC. Preliminary tests underway. Will make two small bulk detectors 12x14 cm2 with different resistively. Then make one bulk module with this resistive layer.

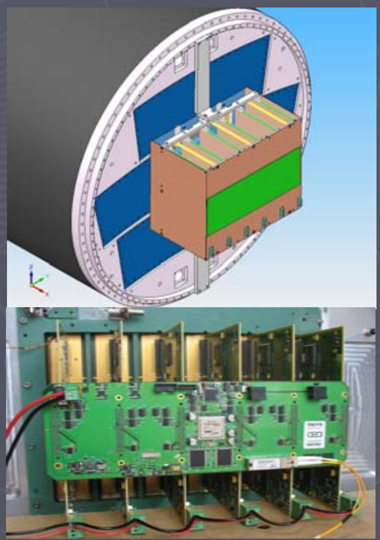
(3) Initially difficult but now improved.

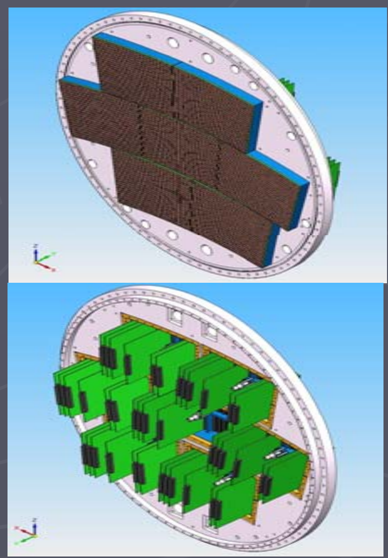
Schedule for MicroMEGAS Module

Take beam data with the first MicroMEGAS module in PCMAG starting November 2008.
Then other detector modules (different PCBs) in 2009.

Start R&D for electronics on a mezzanine PCB to be ready in early 2010:
- R&D to optimize protection & compactness
- Development to test AFTER chips at the wafer level
- New card design
- Start cooling and integration studies

Make 7 fully equipped modules (250 Watts) in 2010.





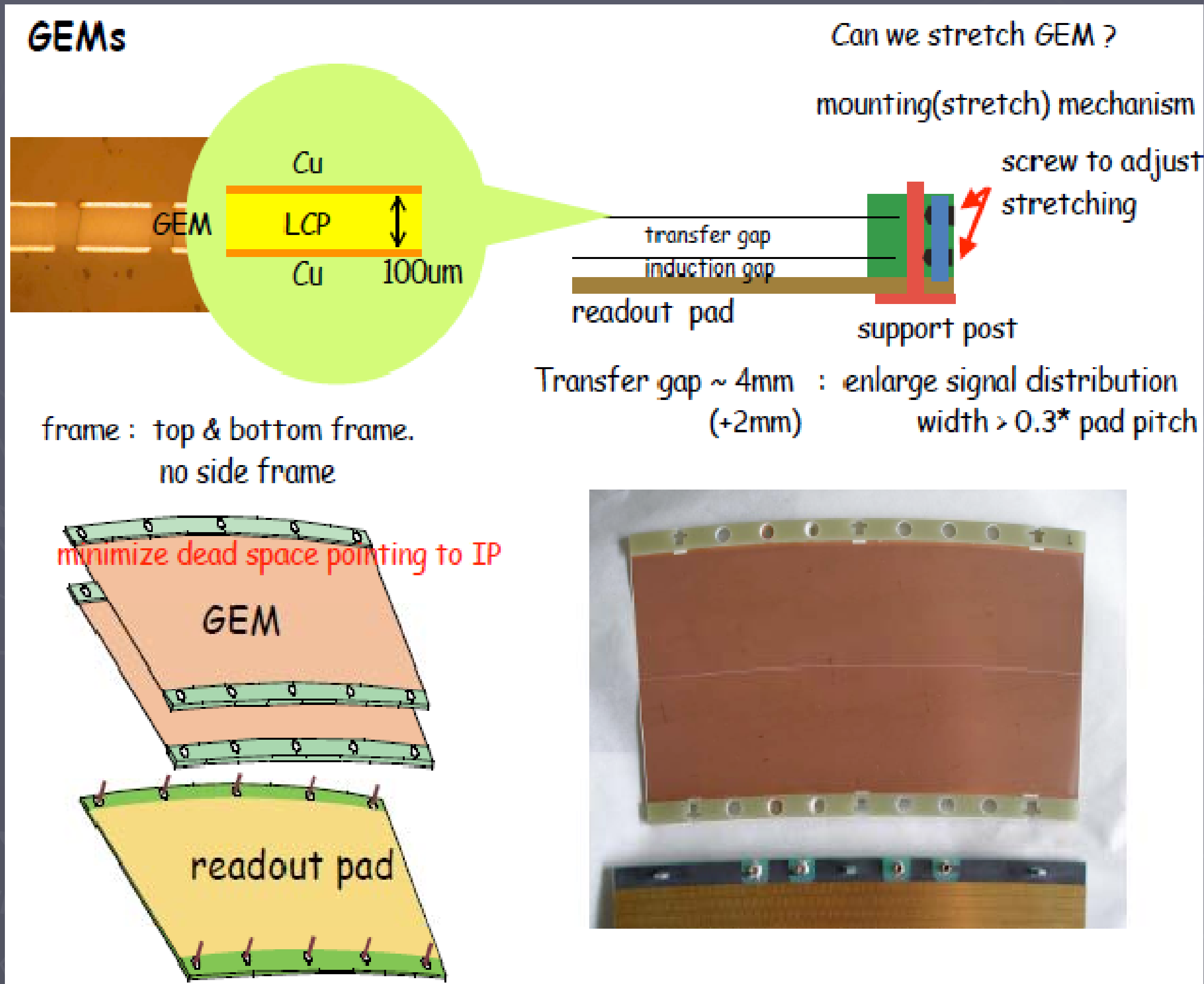
CDC group, Tsinghua

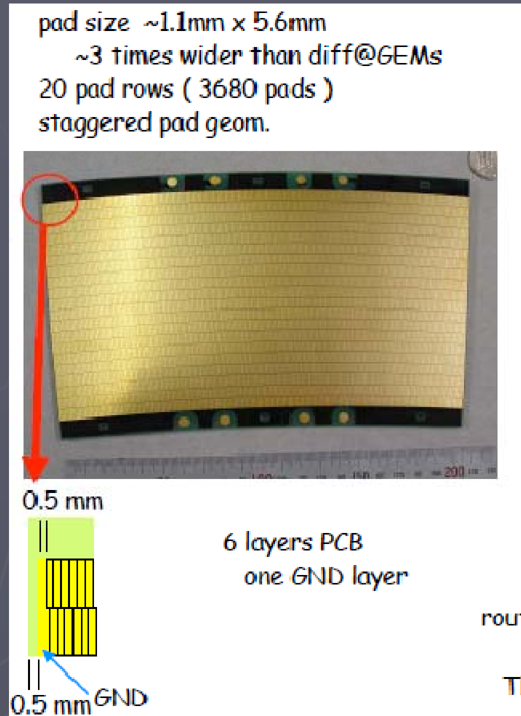
Double GEM with a Gating GEM

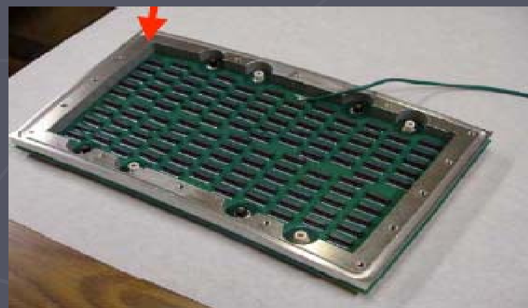
(4 Modules Expected at the Beginning of Year at DESY)

Double thick (100μm) GEM with a (thin 25μm) gating GEM:

(Gating GEM is not drawn)







Pre-prototype

Double GEM Module with a gating GEM

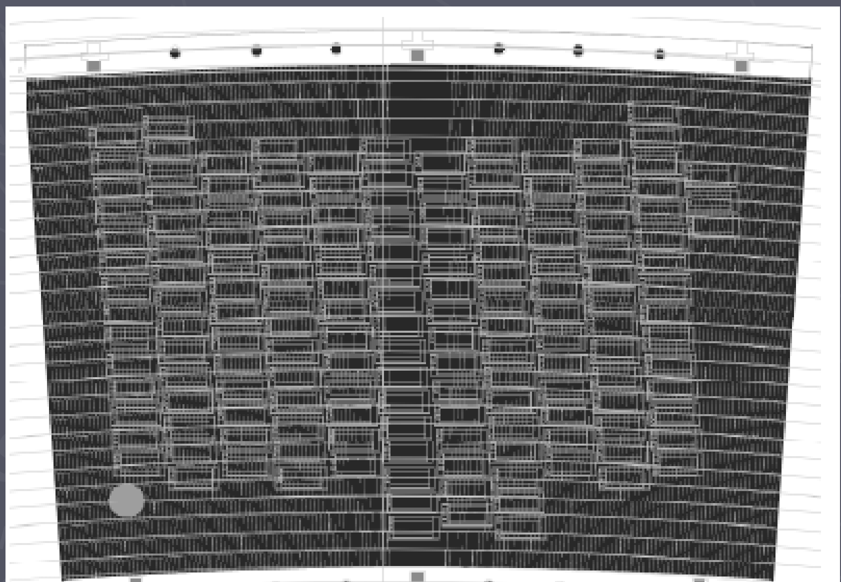
Pad PCB board: 8-9 layers

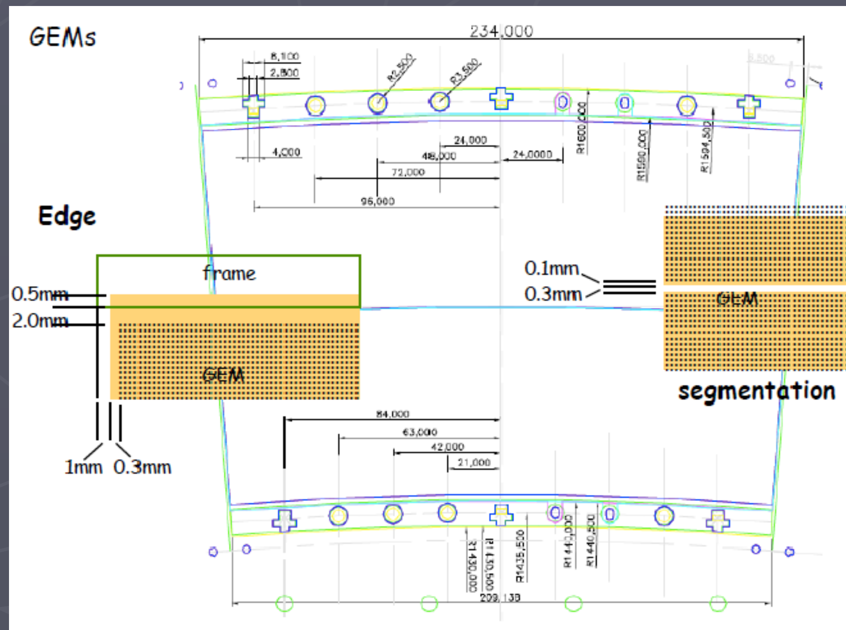
28 pad-rows x 176(192) pads for inner (outer) 14 rows
Pad size: ~1.2 x 5.4 mm^2 pads.

PCB layout is being modified at Tsinghua Univ. Smaller pad size and routing of GEM HV are issues.

GEMs:

Thick GEMs and thin gating GEMs have been fabricated by a company (SiEnergy).

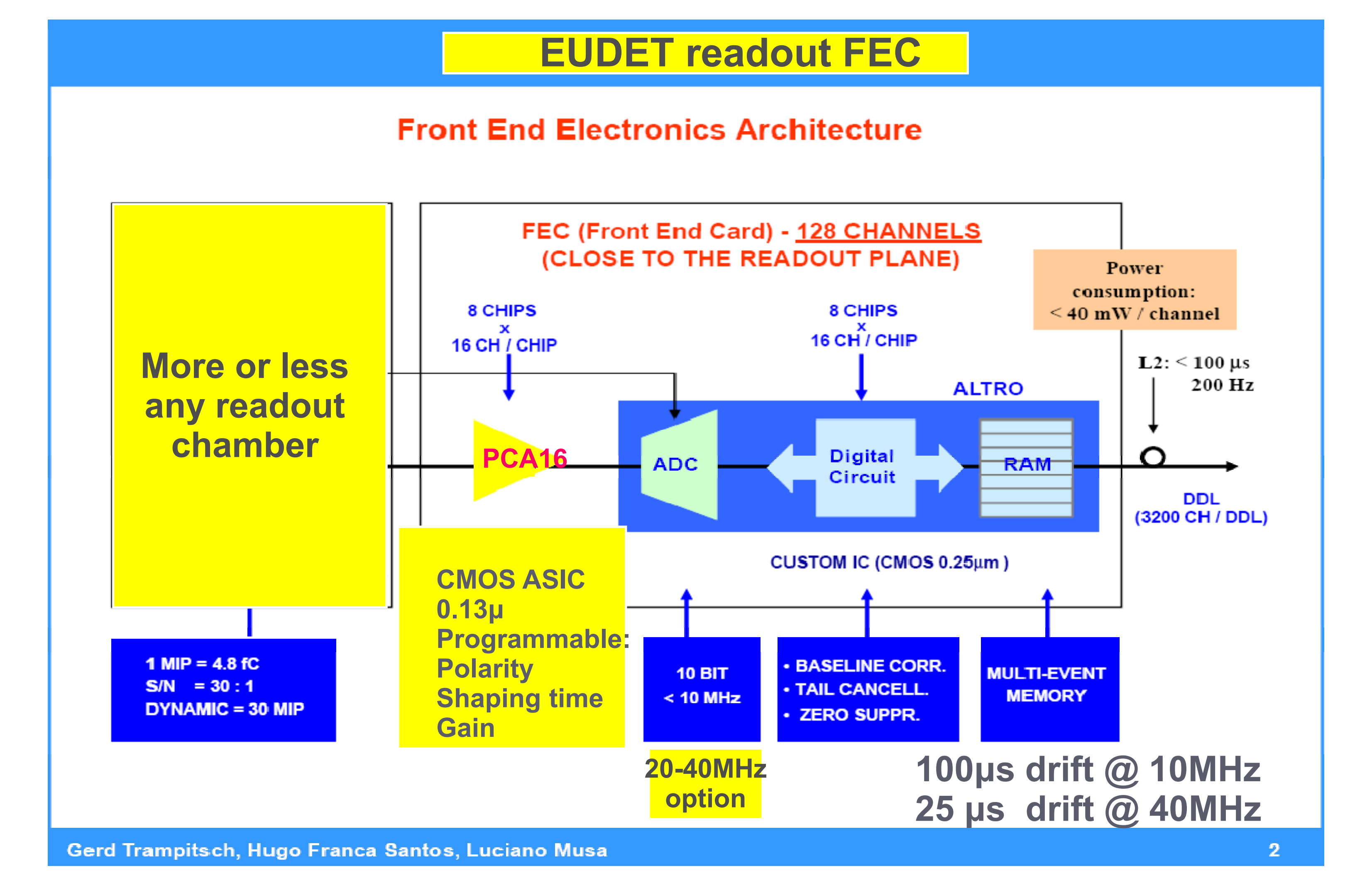




ALTRO GEM Electronics: S-ALTRO

CERN/Lund

Based on the existing PASA + ALTRO electronics designed for the Alice TPC
PASA is replaced by PCA16 for MPGD readout.



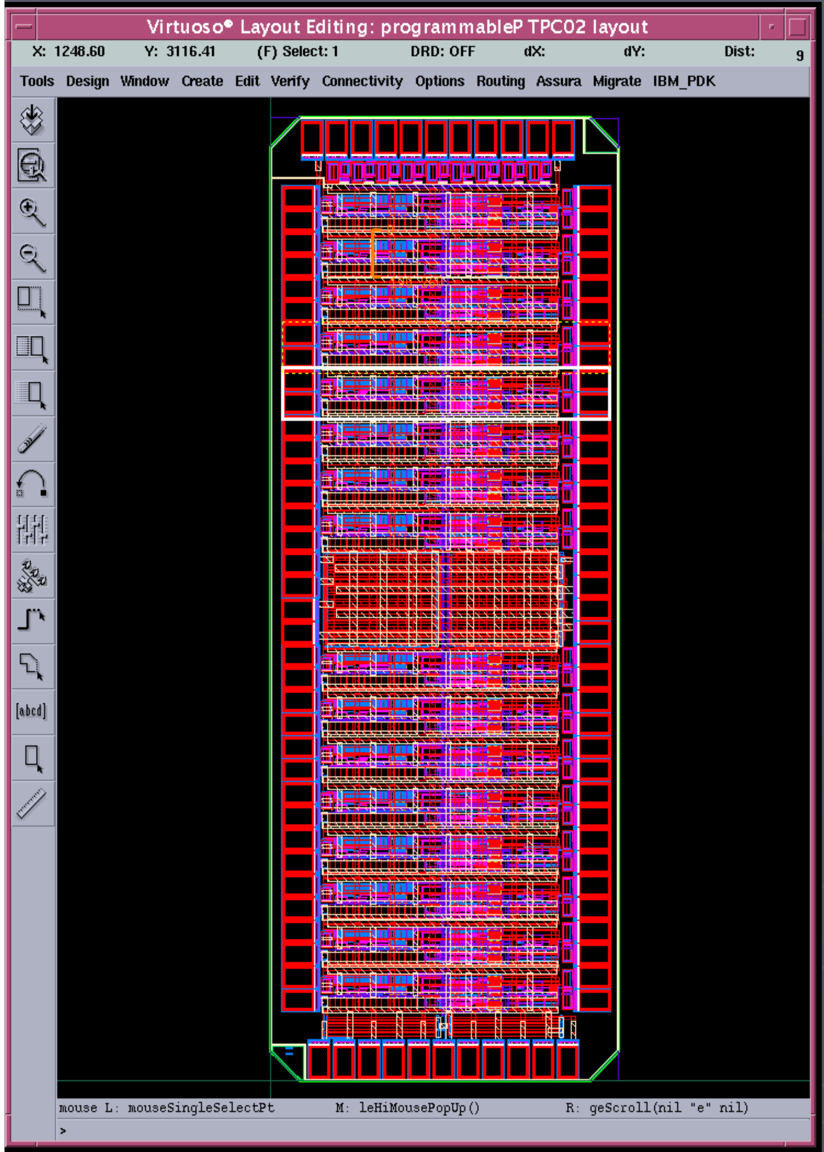
ALTRO GEM Electronics

ALTRO Digitizer + Drift storage

- Differential input from PCA 16
- 16 channels per chip
- 10 bit resolution, 1mV per ADC channel
- 1k samples per event

- 10MHz sampling in ALICE : 100microsecs drift
- 20MHz : 50microsecs drift
- Ca 125 chips with enhanced sampling freq. 40MHz
- Pedestal subtraction, common to all samples
- Advanced zero suppression - good data is sequence (selectable) of non-zero samples.
- Pulse data + pre and postsamples
- 4 event buffering. (multievent buffering not used here)
- several other ALICE features for MWPC pulses are disabled

ALTRO GEM Electronics
New Programmable Charge Amplifier (PCA 16)

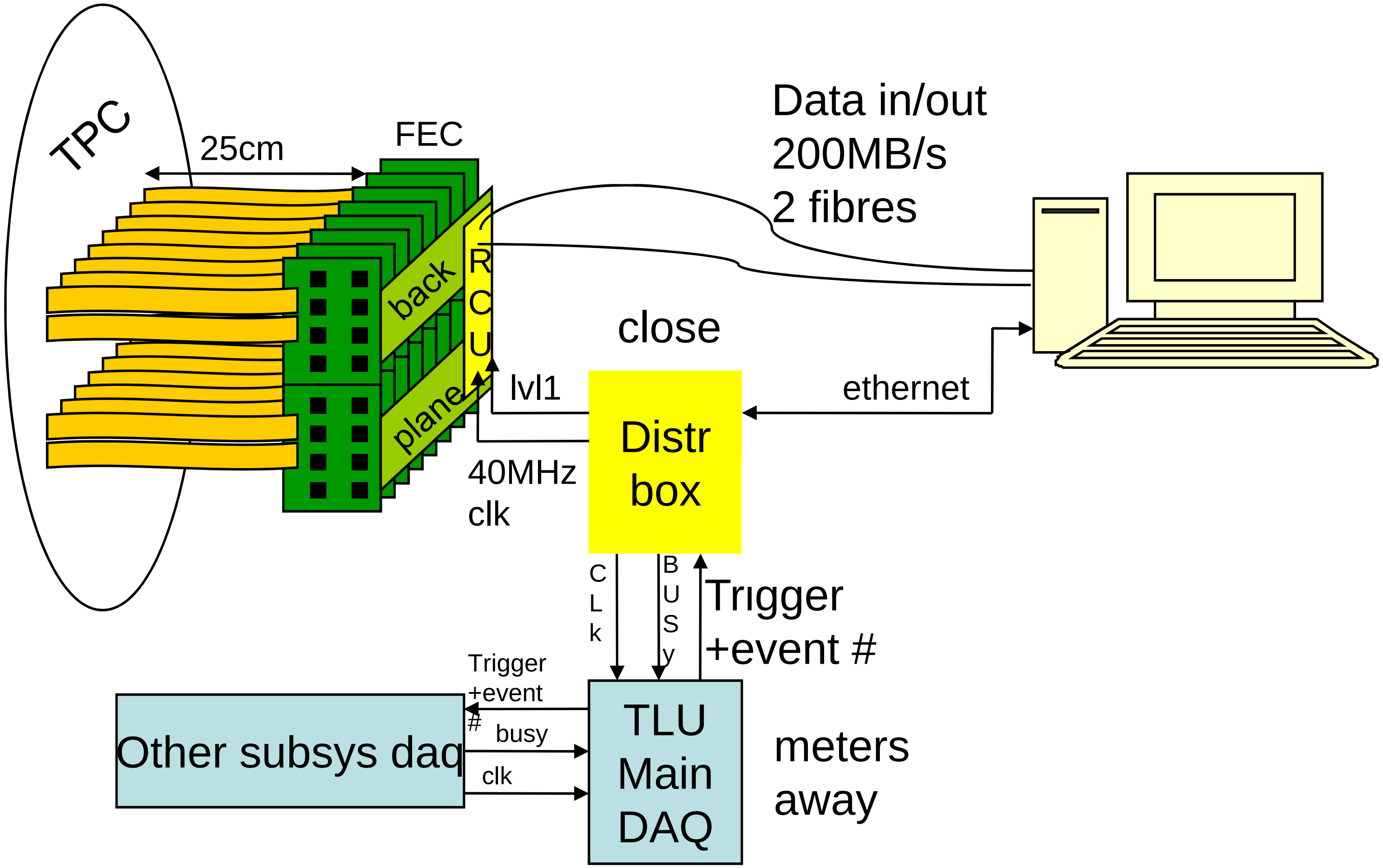


Both for MPGD & MWPC

- 1.5 V Supply, power consumption
- < 8 mW/channel
- 16 channel charge amplifier + anti-aliasing filter
- Single ended preamplifier
- Fully differential output amplifier
- Both signal polarities
- Power down mode (wake-up time = 1 ms)
- Programmable peaking time
- (30 ns – 120 ns) – 3rd order semi Gaussian pulse shape
- Programmable gain in 4 steps (12 – 27 mV/fC)
- Pre-amp-out mode (by pass shaper)
- Tunable time constant of the preamplifier
- Pitch 190.26um, Channel length 1026um,
- Chip dimensions = 1.5mm x 4mm

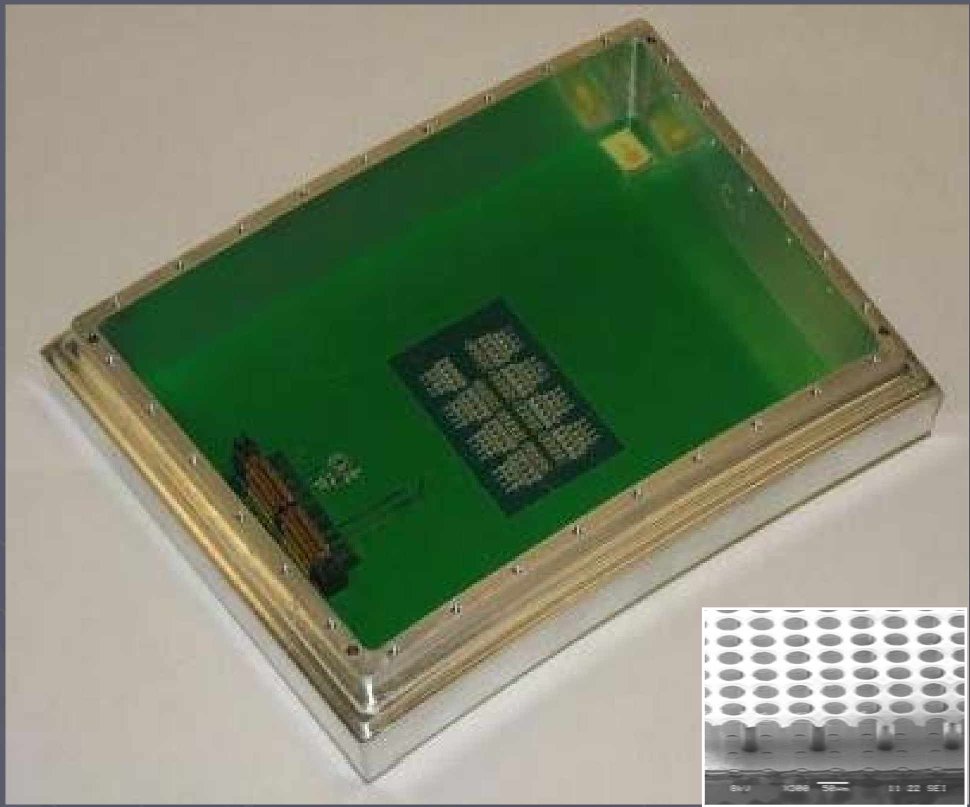
ALTRO GEM Electronics

2048ch (16 FEC) (EUDET) → 10,000ch (LC TPC LP test)

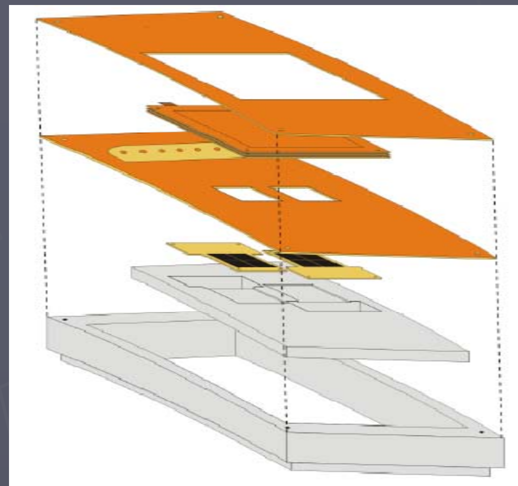


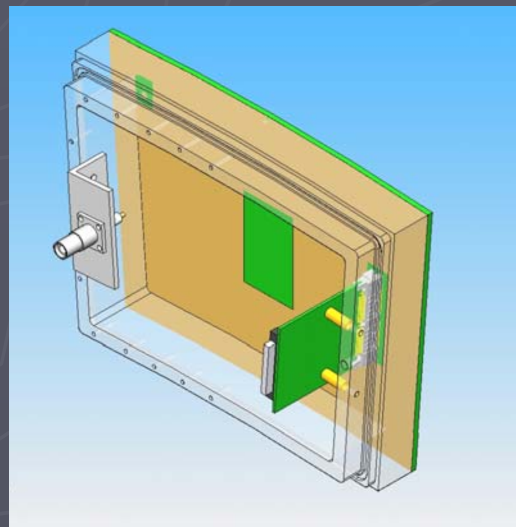
Detector Module of Digital TPC
MicroMEGAS/GEM + Up to 8 TimePix

Saclay/NIKHEF



Ingrid MicroMEGAS TimePix: 8 chips





Conclusions

MPGD provides a new TPC with large number of space points and the excellent point resolution of 50 – 100 microns; **A truly-visual 3D tracker works in high magnetic filed**.

There are **three options of MPGD TPC for ILC**: (a) Digital TPC with Ingrid TimePix, (b) Bulk MicroMEGAS and resistive anode readout and (c) GEM + narrow pad readout.

Digital TPC with Ingrid TimePix can be the ultimate TPC with really diffusion-limited resolution. We need, however, carry out necessary R&D and prove that it is.

LC TPC collaboration performs the **TPC Large Prototype test at DESY** from this fall using the EUDET facility.

Extra slides

MP TPC Prototype with Cosmic Rays

TPC: MP-TPC

MPGD:

- 3 layers of CERN GEM
- 10cm x 10cm
- 1.17 x 6 mm pads
- 7 pad-rows readout
- Inter-GEM and GEM-pad gap: 1mm (so far)
- $V_{gap} = V_{GEM}$ (so far)

Electronics: ALEPH

Gas: Ar-CF4(3%)-Isobutene

Magnet: Max. 1T

KEK Cryogenic Center

Gas Gain Fluctuation

Coordinate = Gain-Weighted Mean

PDF for Gain-Weighted Mean of N electrons

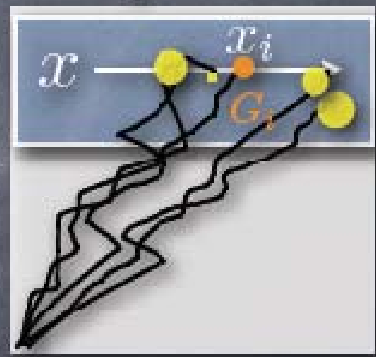
$$P(\bar{x}) = \sum_{N=1}^{\infty} P_I(N;\bar{N}) \prod_{i=1}^{N} \left(\int dx_i P_D(x_i;\sigma_d) \int d(G_i/\bar{G})\, P_G(G_i/\bar{G};\theta) \right) \delta\left(\bar{x} - \frac{\sum_{i=1}^{N} G_i x_i}{\sum_{i=1}^{N} G_i} \right)$$

Gaussian diffusion as before

Gain-weighted mean

Gas gain fluctuation (Polya)

$$\theta = \begin{cases} 0 & : \ \text{exp.} \\ \infty & : \ \delta\text{-fun} \end{cases}$$



$$P_G(G/\bar{G};\theta) = \frac{(\theta+1)^{\theta+1}}{\Gamma(\theta+1)} \left(\frac{G}{\bar{G}}\right)^{\theta} \exp\left(-(\theta+1)\left(\frac{G}{\bar{G}}\right)\right)$$

$$\sigma_{\bar{x}}^2 \equiv \int d\bar{x}\, P(\bar{x})\, \bar{x}^2 = \sigma_d^2 \left\langle \frac{1}{N} \right\rangle \left\langle \left(\frac{G}{\bar{G}}\right)^2 \right\rangle \equiv \sigma_d^2 \frac{1}{N_{eff}}$$

$$N_{eff} = \left[\left\langle \frac{1}{N} \right\rangle \left\langle \left(\frac{G}{\bar{G}}\right)^2 \right\rangle \right]^{-1} = \frac{1}{\left\langle \frac{1}{N} \right\rangle} \left(\frac{1+\theta}{2+\theta} \right) < \langle N \rangle$$

Spatial Resolution of MPGD TPC
A Full Analytic Formula: Three terms

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/

$$\sigma_{\tilde{x}}^2 \equiv \int_{-1/2}^{+1/2} d\left(\frac{\tilde{x}}{w}\right) \int d\bar{x}\, P(\bar{x};\tilde{x})\,(\bar{x}-\tilde{x})^2 = \int_{-1/2}^{+1/2} d\left(\frac{\tilde{x}}{w}\right) \left[[A] + \frac{1}{N_{eff}}[B]\right] + [C]$$

- Purely geometric term

$$[A] = \left(\sum_j (jw)\ \langle f_j(\tilde{x}+\Delta x)\rangle - \tilde{x}\right)^2$$

- Diffusion, gas gain fluctuation & finite pad pitch term

$$[B] = \sum_{j,k} jkw^2\ \langle f_j(\tilde{x}+\Delta x)\, f_k(\tilde{x}+\Delta x)\rangle - \left(\sum_j jw\, \langle f_j(\tilde{x}+\Delta x)\rangle\right)^2$$

$$\langle f_j(\tilde{x}+\Delta x) f_k(\tilde{x}+\Delta x)\rangle = \int d\Delta x P_D(\Delta x;\sigma_d)\, f_j(\tilde{x}+\Delta x)\, f_k(\tilde{x}+\Delta x)$$

$$\langle f_j(\tilde{x}+\Delta x)\rangle \equiv \int d\Delta x P_D(\Delta x;\sigma_d)\, f_j(\tilde{x}+\Delta x)$$

- Electronic noise term

$$[C] = \left(\frac{\sigma_E}{\bar{G}}\right)^2 \left\langle \frac{1}{N^2} \right\rangle \sum_j (jw)^2$$