Linear Collider TPC R & D

Ron Settles
for the LC TPC @ DESY PRC group
(among others)

LC TPC Groups

Aachen
Berkeley
Carleton/Montreal/Victoria
DESY/Hamburg
Karlsruhe
Cracow
MIT
MPI-Munich
NIKHEF
Novosibirsk
Orsay/Saclay
Rostock
St. Petersburg

PRC R&D-XX/XX
3 May 2003

Development of a TPC for the Future Linear Collider

Proposal PRC R&D-01/03 to the DESY Project Review Committee
Draft of Status Report 7 May 2003

The LC TPC group

Aachen, LBNL, Carleton/Montreal/Victoria, DESY/Hamburg, Karlsruhe, Kraków, MIT, MPI-Munich, NIKHEF, Novosibirsk, Orsay/Saclay, Rostock, St.Petersburg

Abstract

A Time Projection Chamber is foreseen as central tracker for a detector at the linear collider TESLA, and is being studied also for the other options of linear e^+e^- colliders. The LC TPC has to face significantly more complicated event topologies and higher backgrounds than at previous e^+e^- machines: this puts stringent requirements on the overall system design. In the present document the design issues and R&D plans are presented for developing such a high-performance TPC. An overview of the ongoing R&D by the collaborating groups is given, including a listing of related work outside this collaboration.

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E. Rulikowska
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-DAPNIA-CEA, Saclay France-

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-Petersburg Nuclear Physics Institute, St. Petersburg Russia-

[1]Supported by the Bundesministerium für Bildung and Forschung, Germany.
[2]The members from DESY, Hamburg University and NIKHEF would like to acknowledge the support of

ORY
CADE OF TRACKING STUDIES

: **First discussions on detectors in**
nisch-Partenkirschen (LC92). Silicon?

-1997: TESLA Conceptual Design
rt. Large wire TPC, 0.7Mchan.
: TESLA Technical Design Report.
pattern (GEM, Micromegas) as a
ine, 1.5Mchan.
01: Kick-off of detector R&Ds
001: DESY PRC for the TPC
udes north-American teams)

03: interim report

DRAFT – Recommendations of the 52nd
Meeting of the PRC
DESY 25-26th October 2001

PRC R&D-01/03: LC TPC R&D

The PRC **recommends** the **approva**
the proposed R&D programme. It
encourages the collaboration to perfo
high magnetic fields tests of the differ
end-plate geometries (GEM,
MICROMEGAS and standard wire
chambers) and to use the performanc
the ALEPH TPC as bench mark for a
TESLA detector. It asks for a status re
in one year.

Goal

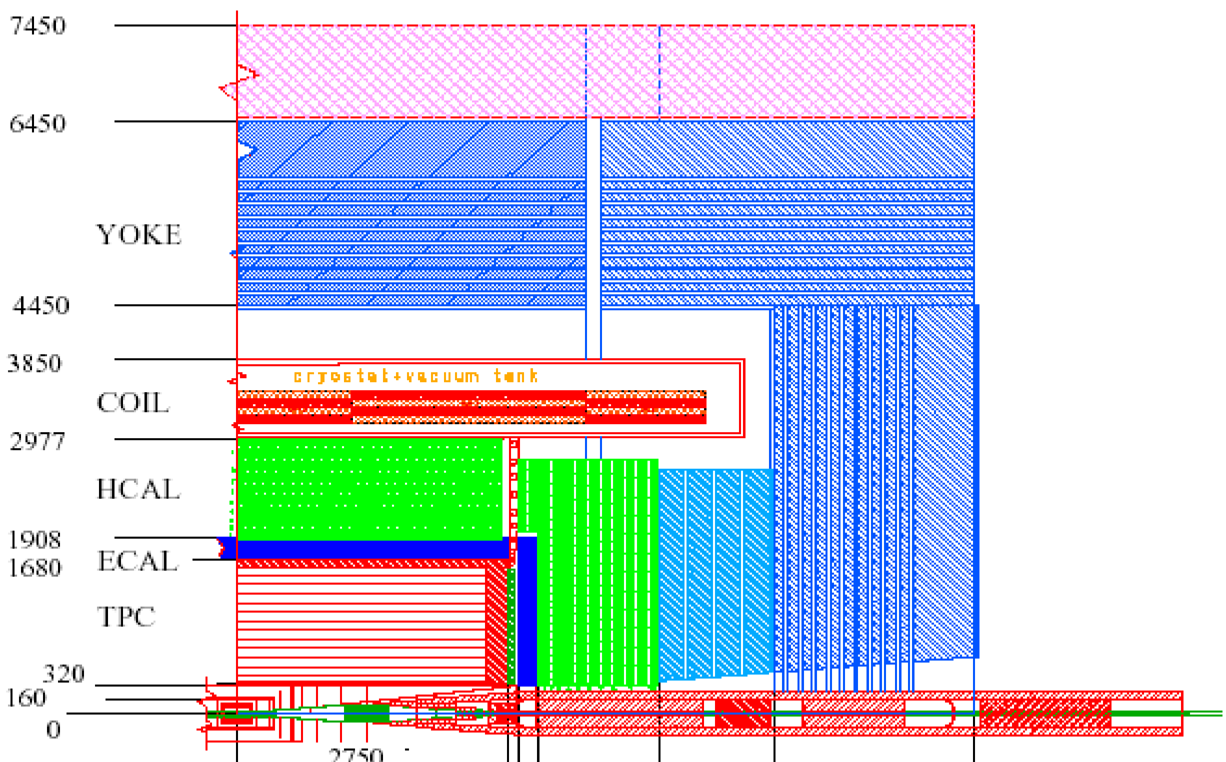
To design and build an ultra-high performance

Time Projection Chamber

…as central tracker for the LC detector
…where excellent vertex, momentum and jet energy precision are wanted…

- Track momentum $\delta(1/p_t) \sim 5 \cdot 10^5$ GeV/c^{-1}
- Energy flow $\delta E/E \sim 0.35/\sqrt{E}$

Energy flow
- granularity
- hermeticity
- min. material inside calos
- calos inside 4 T coil



The basic idea…

- Cost-effective way of instrumenting a large volume
- With continuous tracking and a minimum of material
- Want the largest possible granularity
  -- i.e. ~ $2 \cdot 10^9$ voxels
  -- the best possible s_{point} resolution
  -- the best possible 2-track resolution

Motivation

- large volume $\sim$ 40 m^3 $\rightarrow$ cost-effective way to instrument large volume
- continuous tracking $\sim$ 200 $\sigma_{point} \sim 100\mu m/\text{track} \rightarrow$ 99% tracking efficiency in high backgrounds
- mininimize material for $\sim 10^3 \gamma/\text{BX} \sim$ 3% (15%) X_0 barrel (endcaps) for energy flow
- timing precision $\sim$ 1–2 ns for BX i.d.
- more than happy with a large B field (drift || $\vec{B}$)
- good V^0 detection for energy flow
- good dE/dx ($\sigma \sim 5\%$) for particle I.D.
- 'gate' to eliminate ion feedback from gas-amplification region
- easy to maintain
- caveat: drift time integrates over 150 BX
  - therefore maximize granularity: $\sim\ 2 \cdot 10^6$ readout pads, 1000 time buckets
  - however, diffusion limit of single electron e.g. $\phi \sim$ 1.5mm for P10 gas in 4T field $\Rightarrow 8 \cdot 10^6$

Why…

- High granularity to ensure robust operation in presence of large backgrounds
- Continuous tracking to ensure good momentum-measuring precision and >98% pattern-recognition eff. in jets

TPC R&D Issues (1)

- backgrounds
  - simulations (TDR Table 7.1.6) imply $\sim 0.3\%$ occupancy,
  - but be ready for surprizes, e.g. $20 \times$ more, at Tesla start-up
- gas amplification
  - MPGD (micropattern gas detectors) GEM or Micromegas promise better granularity than wires
    * detect drifting electrons directly
    * no prf (pad response function) of wire-to-pad induced signal (but small one for charge spreading)
    * no $\vec{E} \times \vec{B}$ wire effect
  - are they robust? $\Rightarrow$ our R&D programme
  - wire chamber backup
- gas, fieldcage
  - Ar + which quencher?
    * CH_4 sensitive to neutron background
    * CO_2 slow, very high voltage FC needed
    * CF_4 fast but aggressive
  - influences operation and field-cage design

TPC R&D Issues (2)

- electronics
  - $r\phi$:
    - $\sim 2 \cdot 10^6$ pads $\approx 15\times$ Star
    - massive integration wanted with less material
  - z: faster sampling
    - > 20 MHz (Star type)
- pad structure
  - "pads partout"
  - however, if arriving e^- cloud hits only one pad (short drift dist. for MPGD), resolution degraded:
  - how to "spread the charge"?ideas...
    - chevron pads?
    - conductive glass?
    - resistive coating?
    - capacitive coupling?
    - diffusion?
    - ...?

TPC R&D Issues (3)

- gating, distortions
  - minimize the $\oplus$-ion feedback from amplification region
  - study gating plane to eliminate $\oplus$-ion feedback
  - devise techniques to keep systematics $< 10\mu m$ ($3\times$ smaller than lep)
- mechanics
  - goal:
    * $3\%X_0$ in r, $15\%X_0$ in z
    * non-trivial (start now)
  - roll back TPC to work on inner detectors
  - $\rightarrow$ fieldcages, endcaps ...
- cooling
  - for large number of channels non-trivial
  - TESLA operation allows to ramp off between trains
  - $\Rightarrow\sim$ kW per side

Plans(1) G=GEM, M=Micromegas, 3=Gem, Micromegas or Wires

Topic	Aachen	Berkeley	DESY/Ham	Karlsruhe	Krakow	MIT	MPI-Munich	NIKHEF	Novosibirsk	Orsay/Saclay	Carlet./Mont	Rostock
MPGD development	G			G					G	M		
MPGD operation	G	3	G	G					G	M	3	
MPGD signal pickup	G	3	G							M	3	
Si readout								3				
MPGD ageing				G		G				M		
MPGD tower			G							M		
MPGD ion feedback	G		G	G					G	M	3	
MPGD B-field behaviour			G	G						M		
MPGD 2-track resolution			G							M		
Gas studies					3	3	3			3		
Gas system					3							
Electronics		3					3			3		3
Endplate Design		3	G				3					
Cooling		3					3					
Mechanics			G				3					
Fieldcage Design			3				3					
Calibration												
- MPGD Simulation	G									M	3	
- Pad simulation			3							3	3	
- Alignment			3				3	3		3		
- Laser		3					3					
Software			3							3		

Plans(2)

- Priorities
  - compile information/knowhow on MPGDs
  - begin electronics/mechanics/fieldcage studies
- Timescale
  - make decisions based on R&D toward realistic MPGD o
    wire prototype within 1.5 years
  - design/build this prototype following year, then start seriou
    testing

General Happenings…

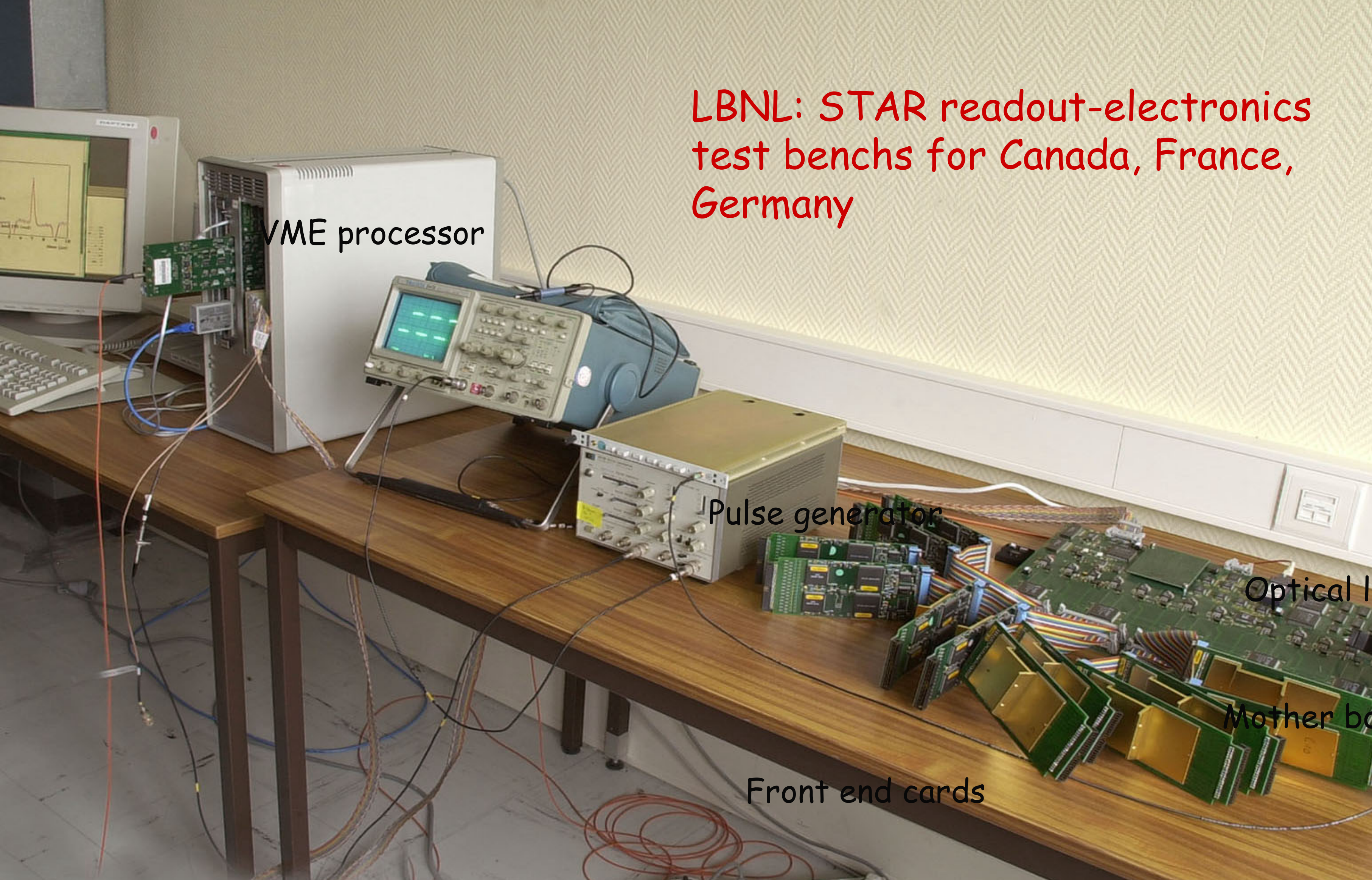
- Steering committee—1 representative + alternate per country:

Alexei Buzulutskov
Madhu Dixit, Dean Karlen
Mike Ronan, Ulrich Becker
Paul Colas. Vincent Lepeltier
Elzbetha Rulikowska
Joachim Mnich, Stefan Roth
Jan Timmermans
RS

- Video, VRVS and/or phone TPC R&D meetings about every 6-8 weeks
- Task-sharing among groups, e.g.

--LBNL providing Star electronics for Canadian, French, German labs
--MPI providing Aleph electronics
--Desy 5T magnet to be used by ~5 Canadian and German groups
--Saclay 2T magnet to be used by North American and French groups
--MicroMEGAS work by Canadian, French and US groups
--GEM progects by Canadian, German, Russian and US groups
--Fieldcage studies started in Russia and Germany
--Electronics work in Canada, Germany, Holland

LBNL: STAR readout-electronics test benchs for Canada, France, Germany



A few more examples of activities

First, without B-field

Then, with B-field

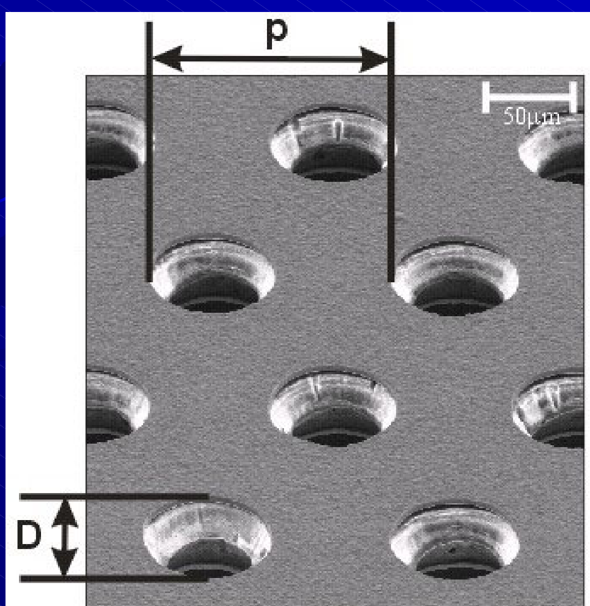
(more complete list in our upcoming LC Note)

GEM and Micromegas

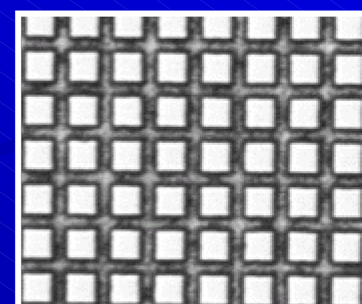
GEM: Two copper perforated
oils separated by an insulator

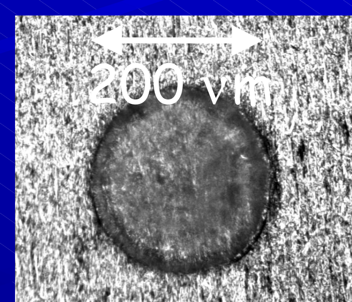
The multiplication takes place
n the holes.

Usually used in 2 or 3 stages



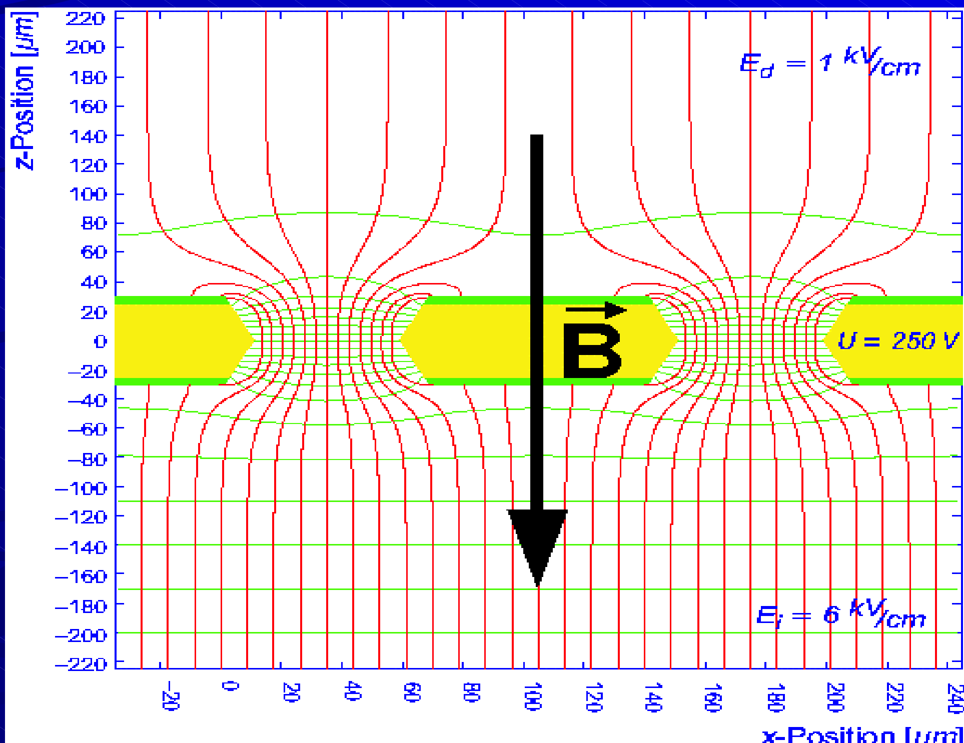
Micromegas : a micromesh sustained by 50-100 νm - high insulating pillars.
The multiplication takes place between the anode and the mesh
One stage

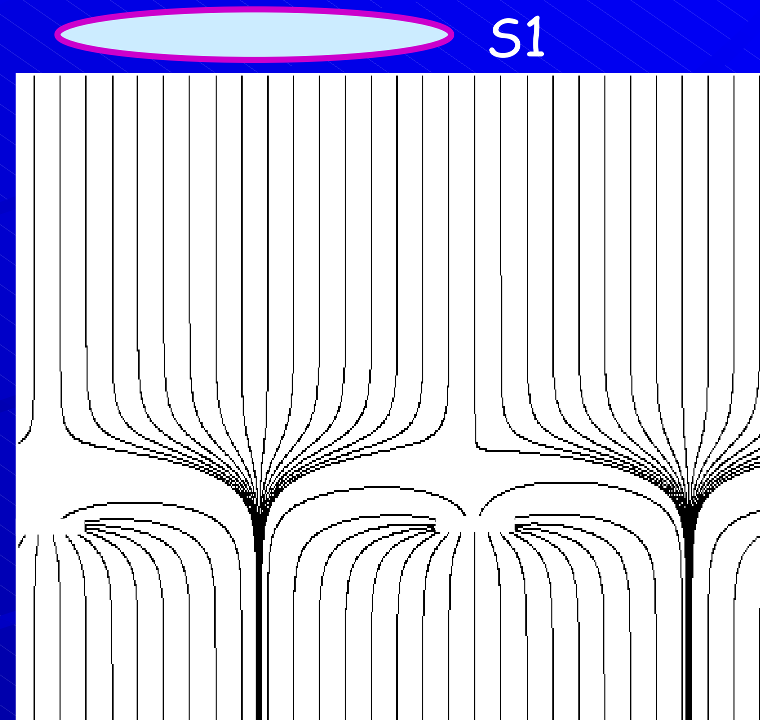




GEM and Micromegas

$S1/S2 \sim E_{amplif} / E_{drift}$





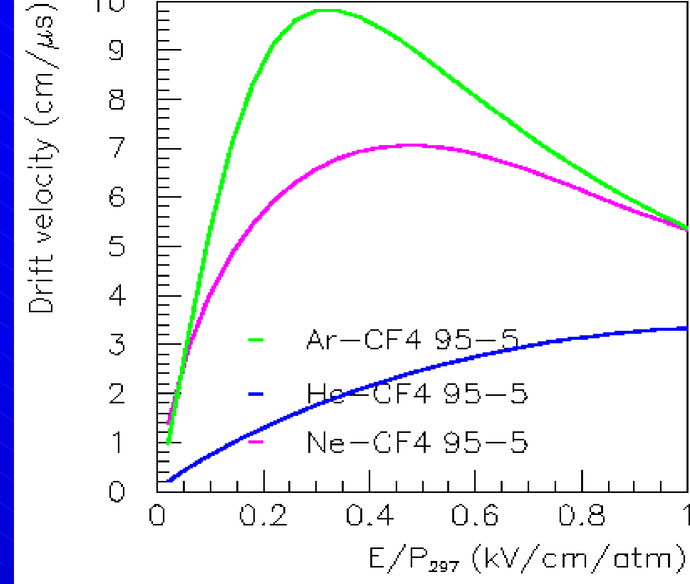
ME GOALS OF THE STUDY

ess the new technologies

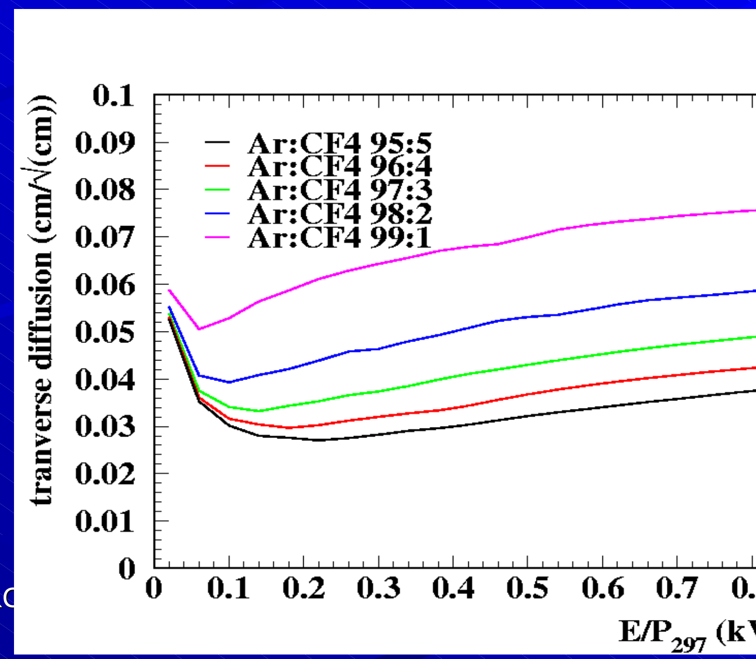
- Choose a gas
- Understand the electron transparency, extraction efficiency, ion feedback
- Check that micropattern detectors keep their good properties in a magnetic field
- Study dE/dx resolution
- Obtain optimal position resolution
- Get in touch with industry for detector manufacturing (thinner frames, grids)

mprove the wire chamber technology

- Orsay: Small-gap, Asymmetric wire chamber
- Munich: wire/Gem/Micromegas chamber for measurements in 5T Desy magnet



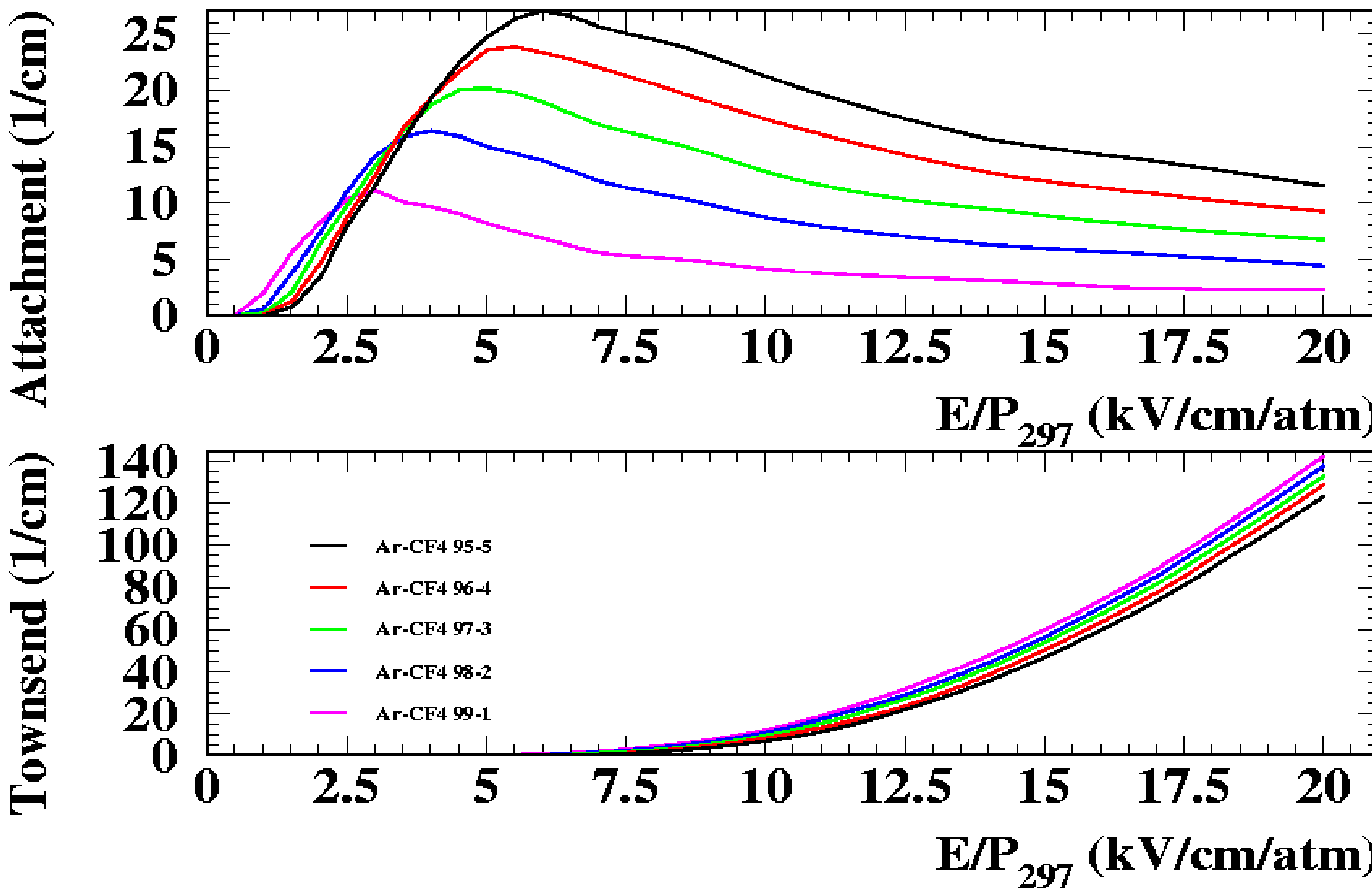
ξυ >20 -> potential transverse diffusion
less than 200 νm at 1m



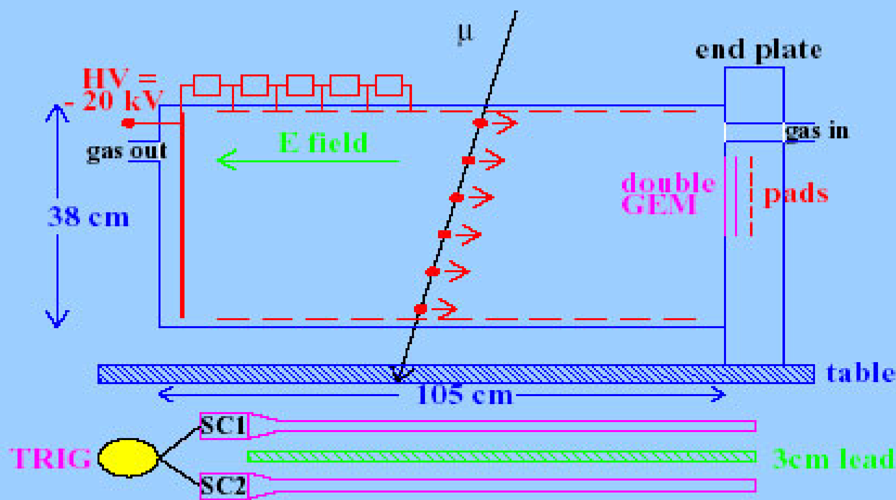
Ar CF_4

Drift properties: attachment is negligible below V/cm and above 15 kV/cm

(supported by Saclay/Orsay measurements)

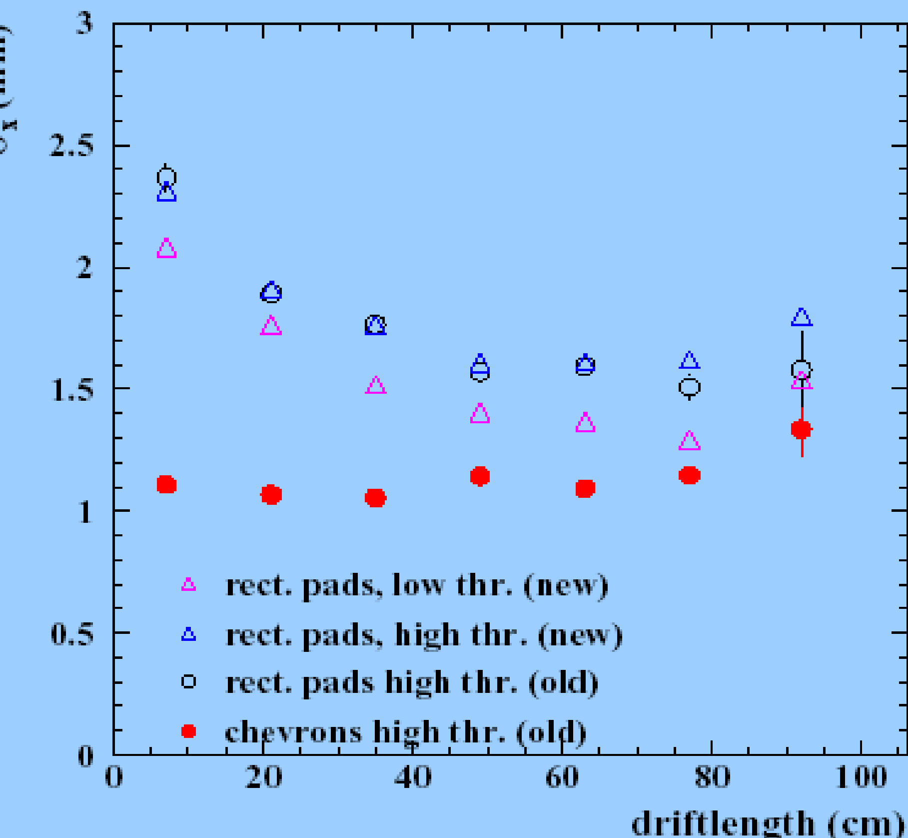


DESY/Hamburg large *Gem* prototype (B=0)



- gas: Ar-CH_4-CO_2 (93-5-2)
- cosmic muons
- double GEM structure
- trigger: 2 scintillators
- readout: ALEPH preamps + TPD + MAC II + Labview

DESY/Hamburg

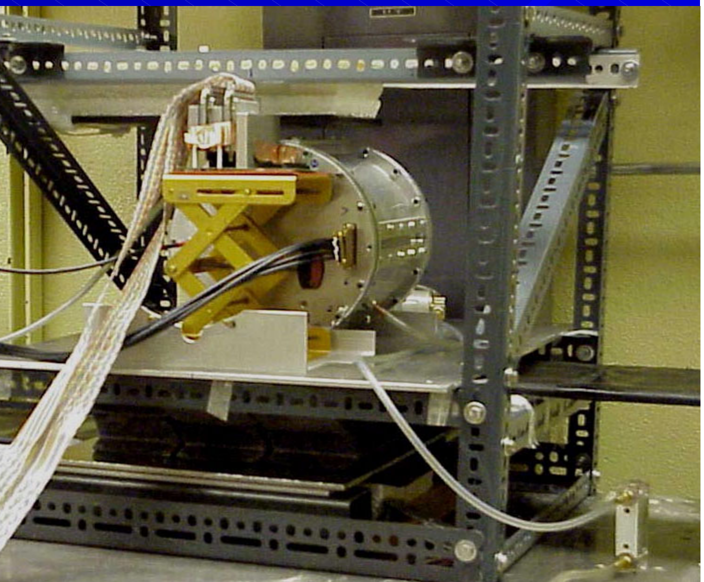


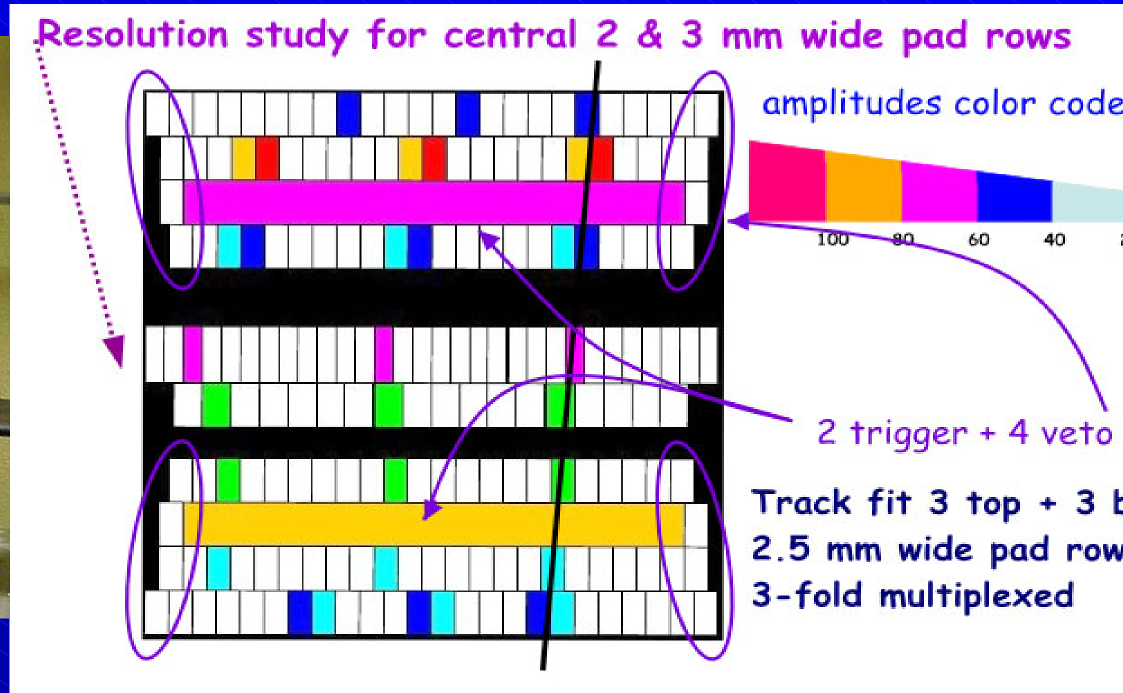
- Old data were taken … pads on HV, bad … nal/noise ratio
- New data were ta… with grounded p… good signal/noise rat…
  ⇒ Reduced thres… value possible
- New measurement … chevrons soon to co…

For the first time the diffusion limit is visible from the measurements (rise at long drift distances)

Double GEM TPC Cosmic Ray Tests

Carleton/Victoria/Montreal





cm drift (no **B** field)

ph TPC preamps + Montreal 200 MHz FADCs

ls can share track charge due to transverse diffusion

Ar CO_2(90:10), small $\tau_T \sim 200$ νm / · cm

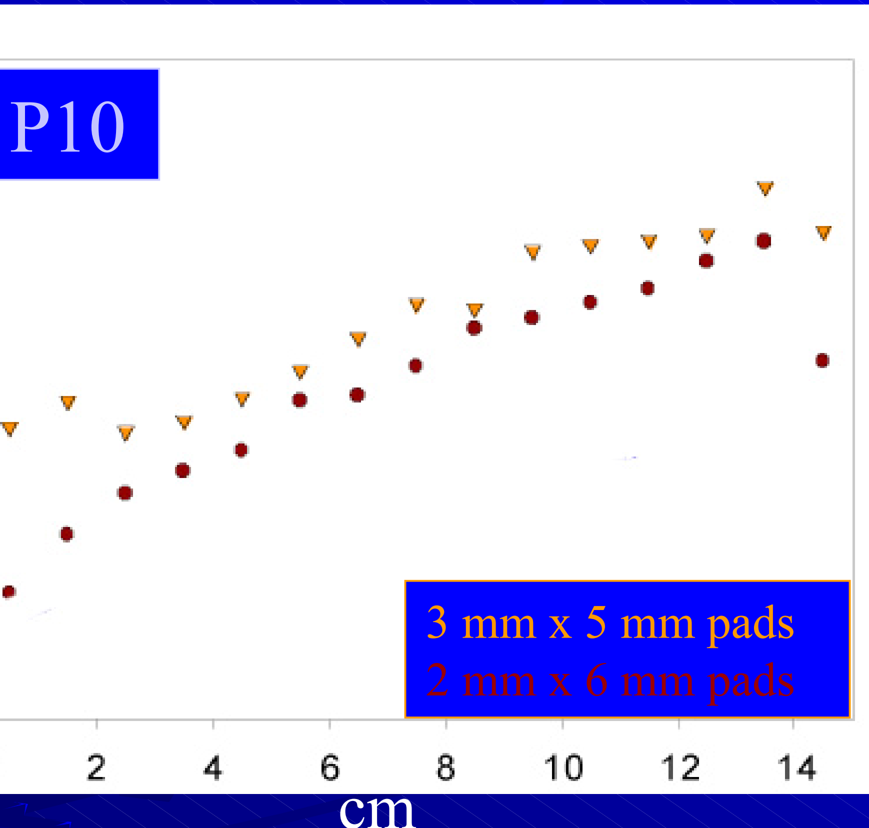
P10 Ar CH_4(90:10), large $\tau_T \sim 500$ νm / · cm

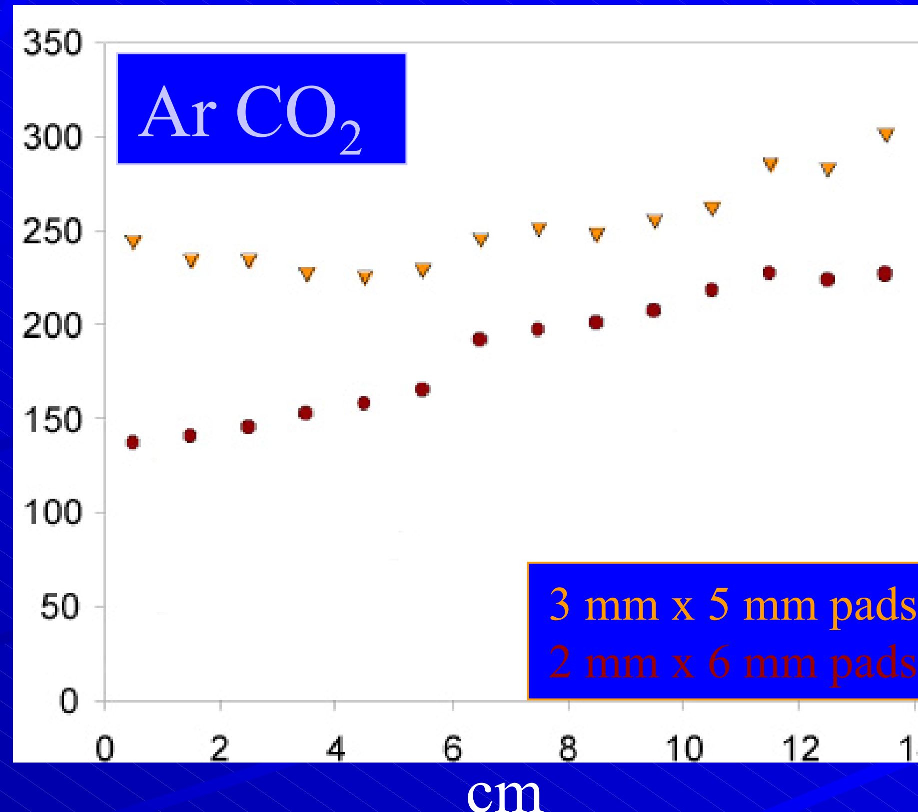
mpute pad centroids, measure resolution for different width pads

Resolution vs Drift Distance for Different Pad Widths

$|\varphi| < 0.1$

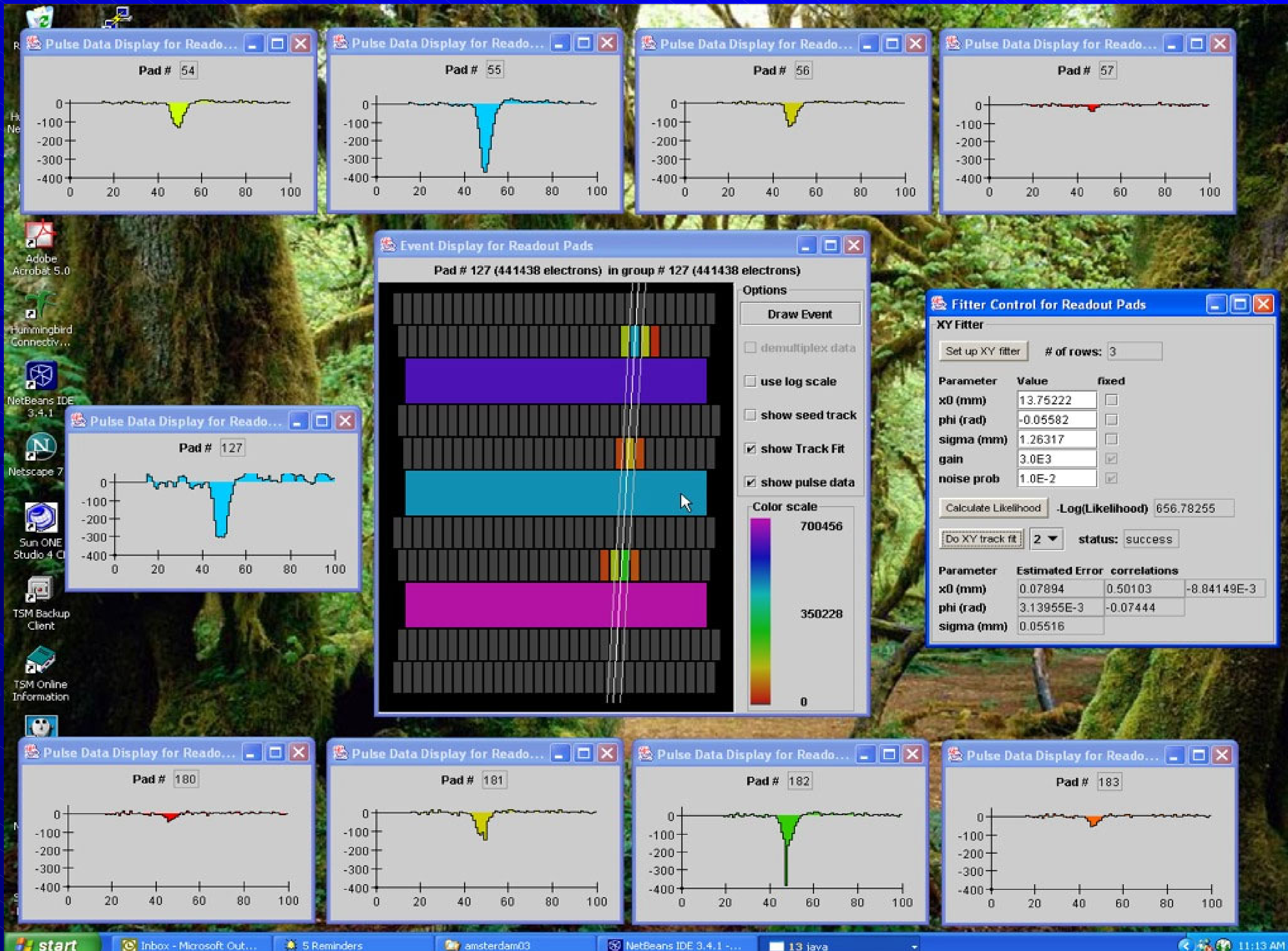
Carleton/Victoria/Montreal





First Cosmic Signals observed with STAR electronic

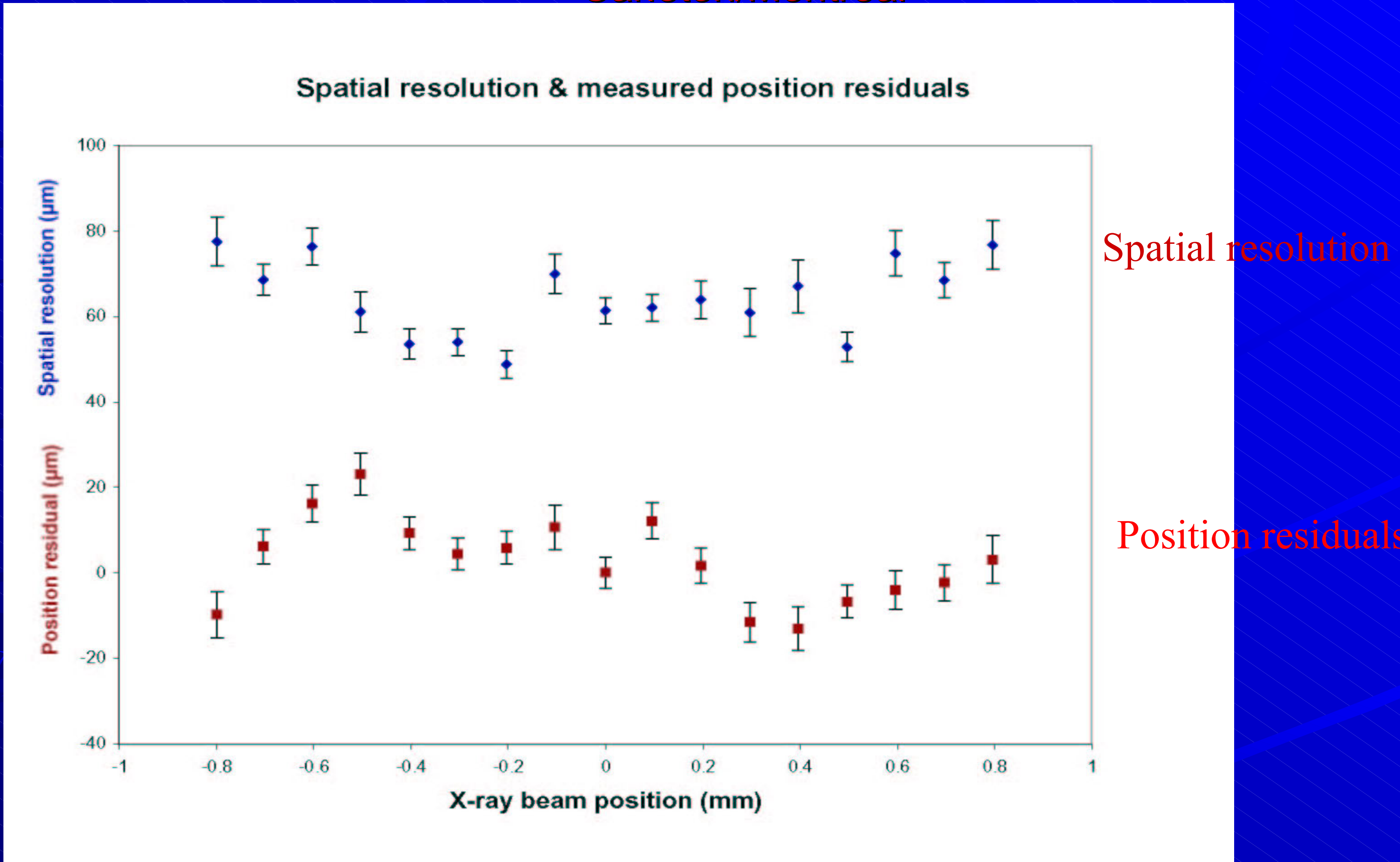
Victoria



Spatial Resolution in a GEM with Resistive Anodes

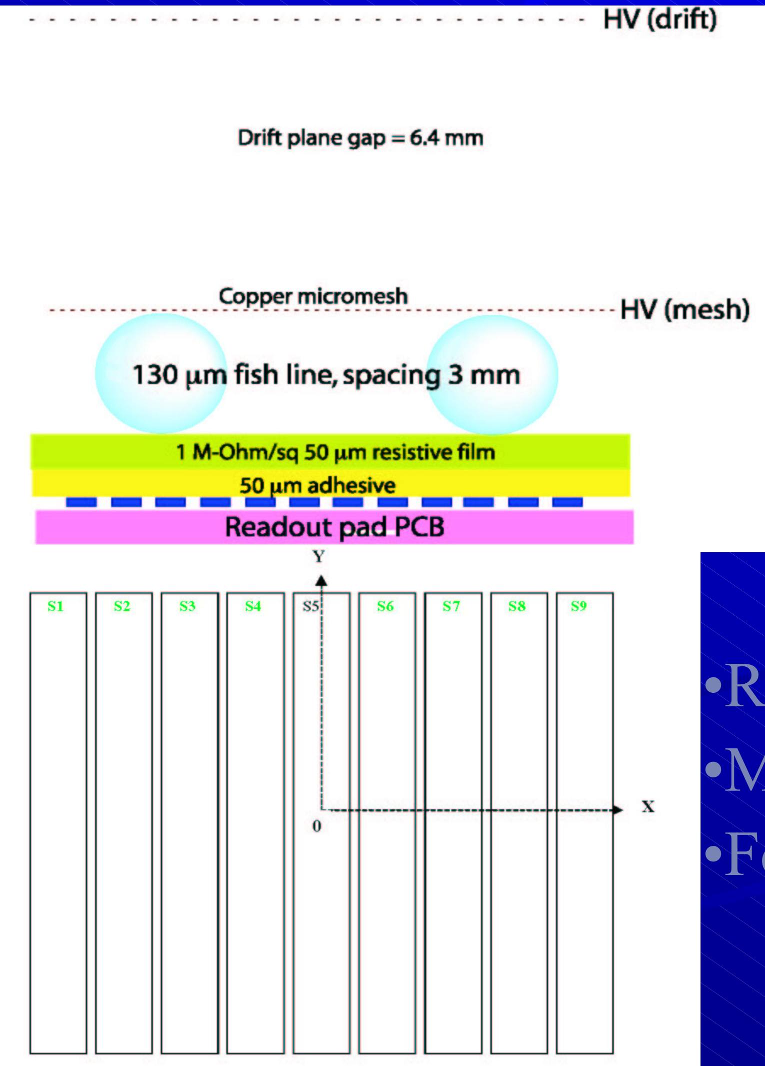
(1.5 mm x 7 cm readout strips, 50 μm collimated 4.5 keV x rays)

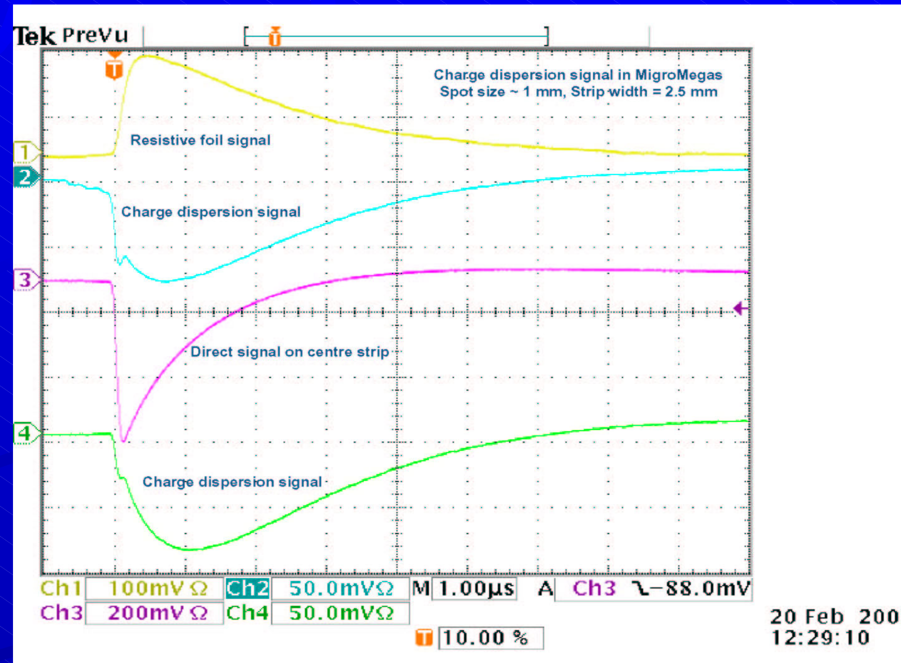
Carleton/Montreal



serve Charge Dispersion Pulses in a Resistive Anode μMegas Carleton/Orsay/Sac

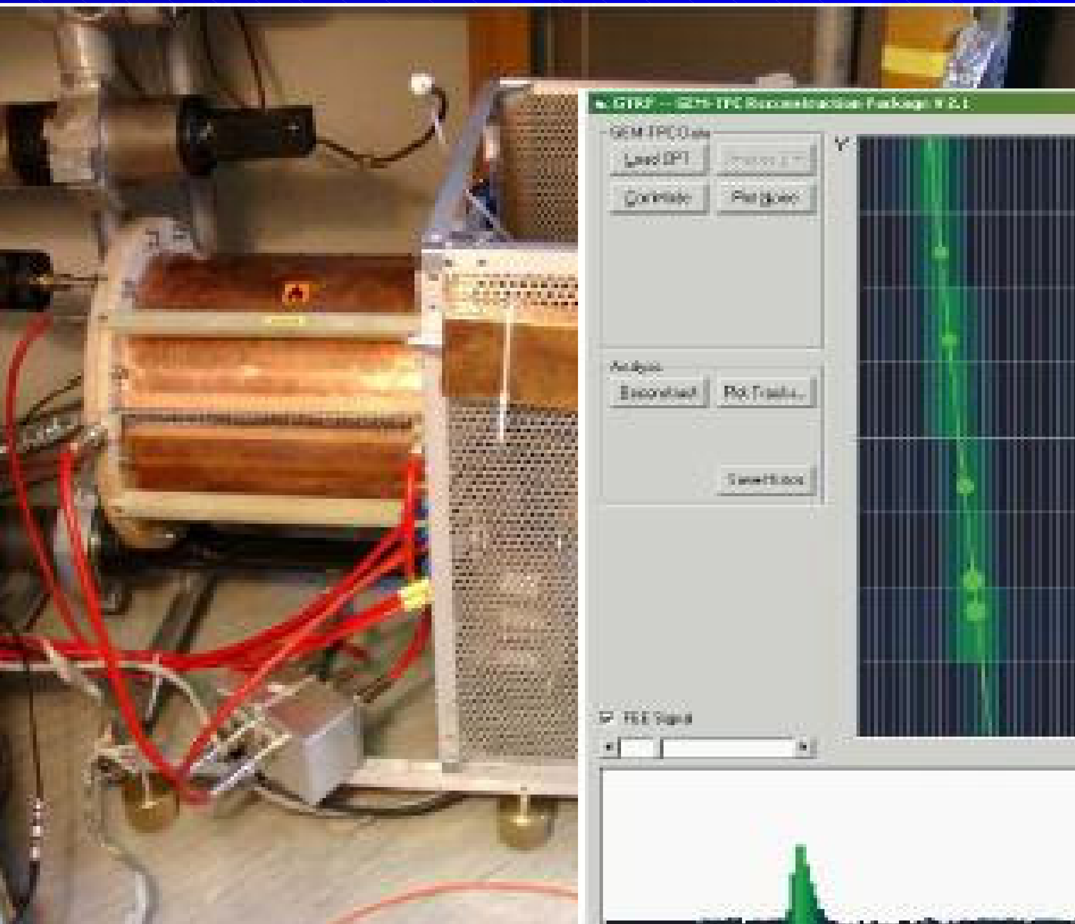
Signals on 2.5x70 mm^2 readout strips (^{55}Fe Ionization spot ~ 700 μm centred on strip 3

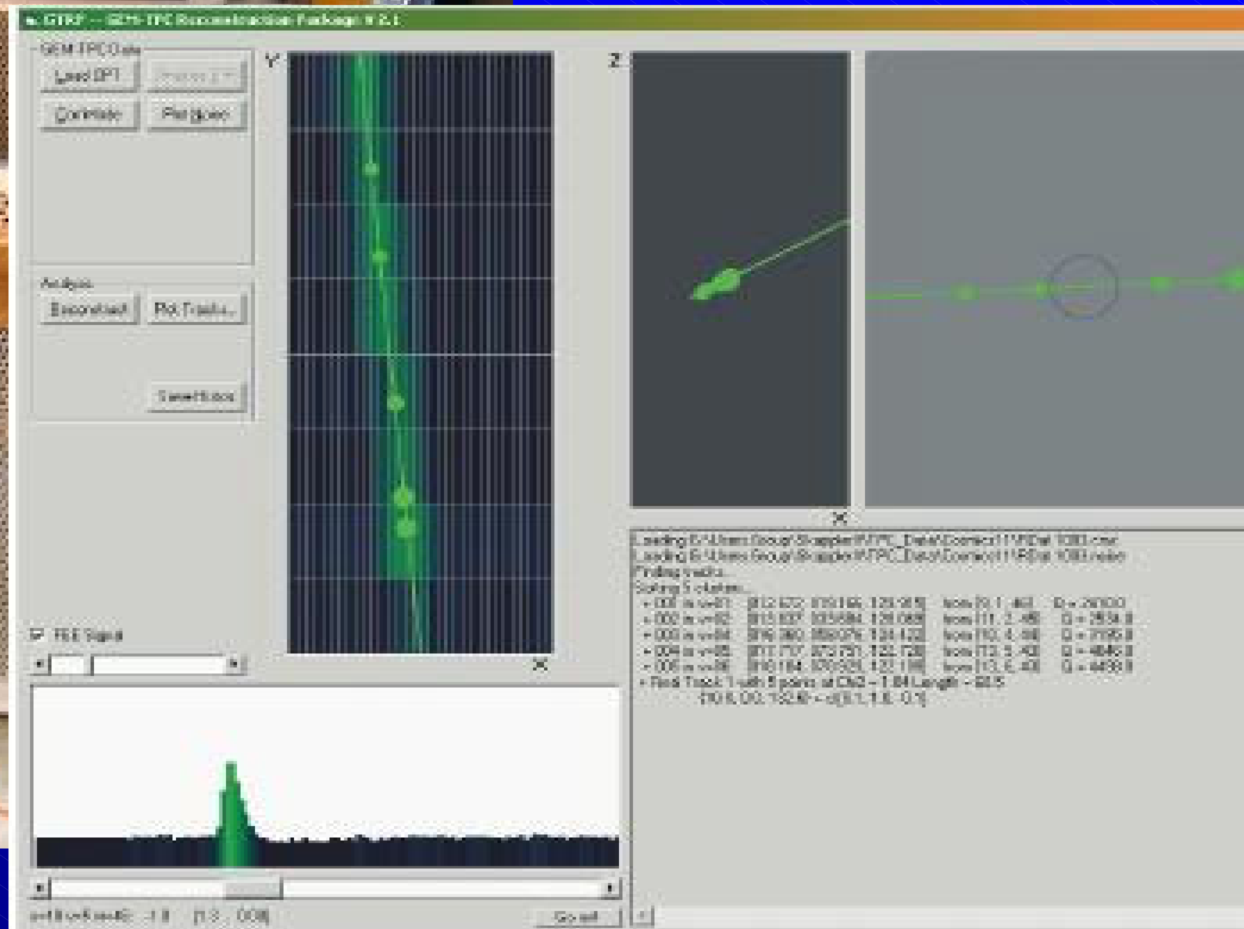




- Resistive anode/readout same as GEM
- Micromesh on frame made by CERN
- For P10 (argon), optimum gap ~ 30 μm

PC cosmic tests at Karlsruhe





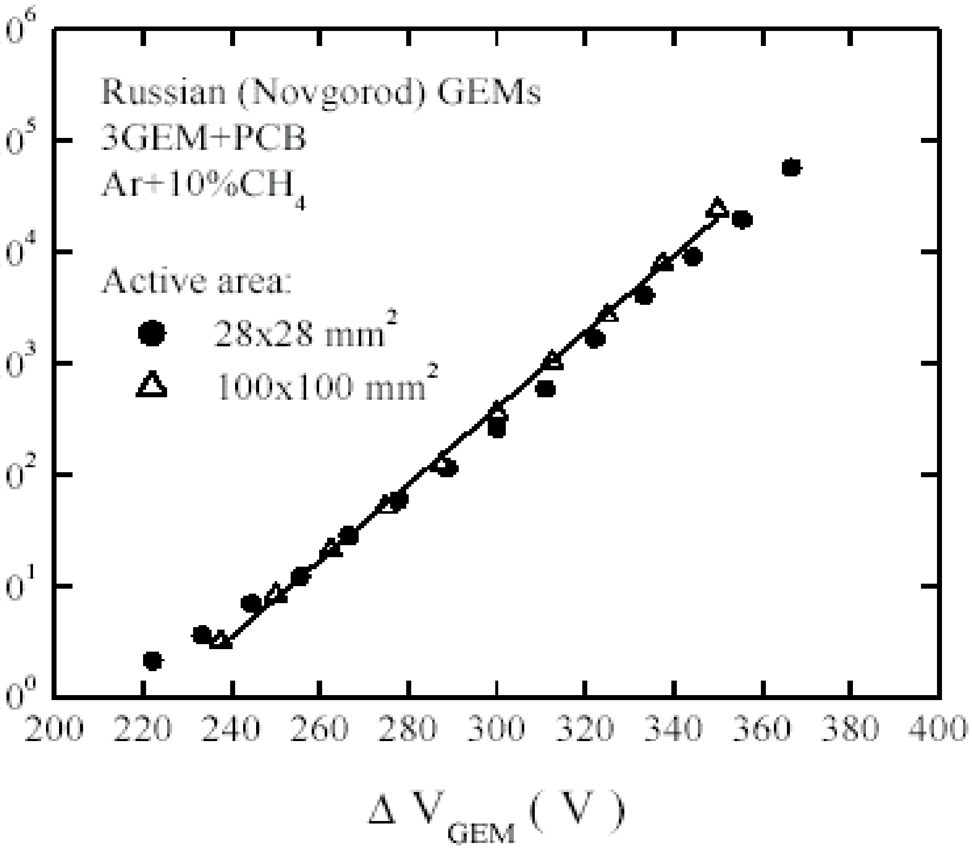
- osmic ray setup using STAR electronics
- Measured resolution 124 νm, S/N = 18:1

J. Kaminski

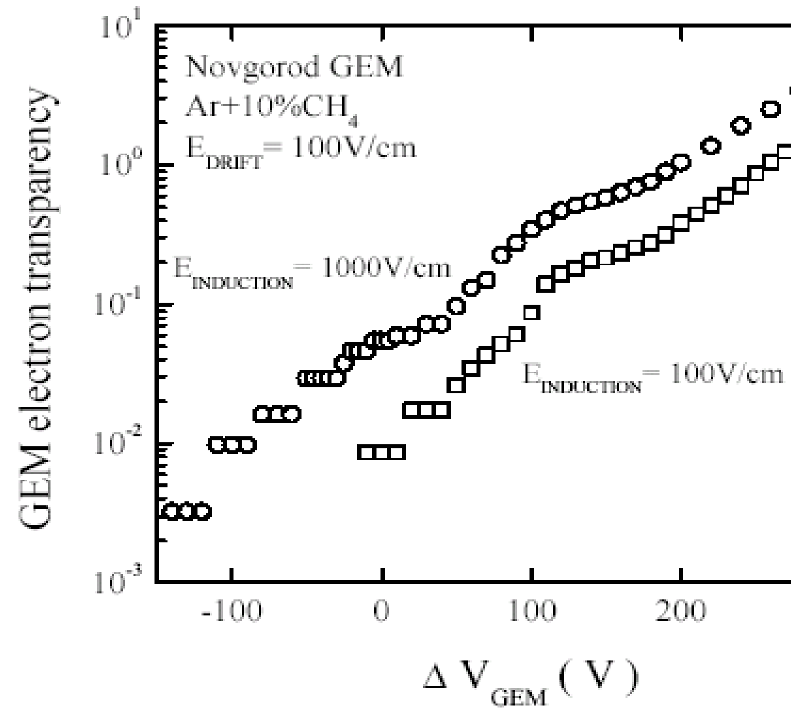
Novosibirsk:

Russian GEM manufacturing company in Nijni Novgorod

(80 vm holes at a 140 vm pitch)



GEM electron transparency vs GI



Possibility of gating the 1st G by pulsing the HV on it.

Aachen-DESY-Hamburg-Rostock

- Diffusion limit of resolution seen
- Resolution measurements for chevrons and long term stability measurements will be done
- Build a small TDC based readout
- Measurements in magnetic field will continue in July after HERA shutdown
- By then, the new TPC prototype is expected to be operational as well

Orsay-Saclay

- Tests have been performed in a magnetic field
- Cosmic setup under construction with Berkeley
- Collaboration began with Canada for resolution improvement studies

Nikhef

Silicon pixels for a dig readout. See individua electrons to reconstru cluster by cluster.

First need a GEM or a Micromegas to multipl electron by 10^4

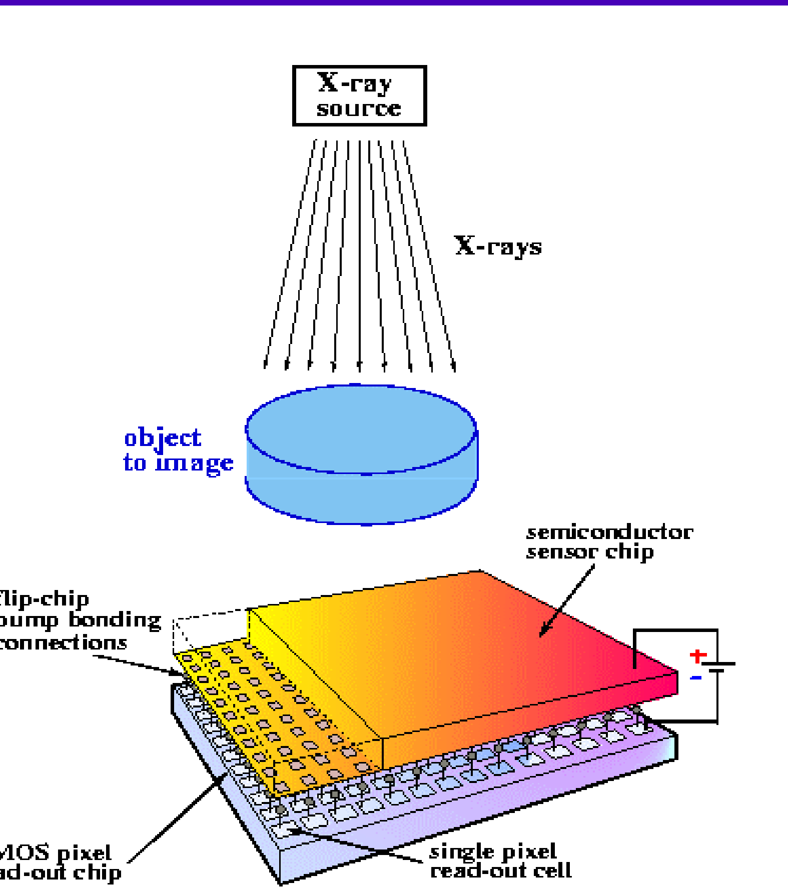
Medipix chip under stu Nikhef (Harry Van der Jan Timmermans)

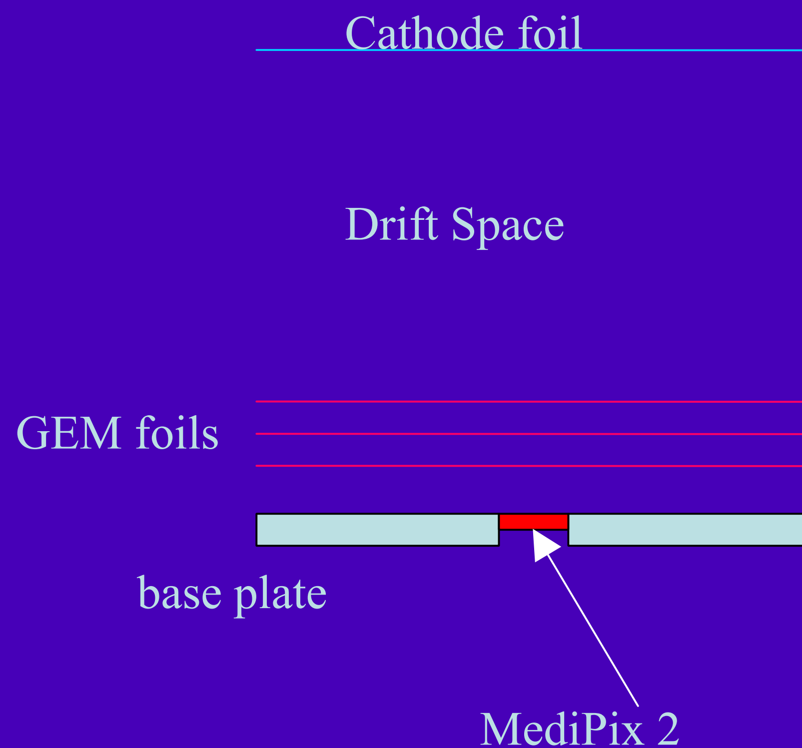
First results very soon

MAY BE THE FUTUR

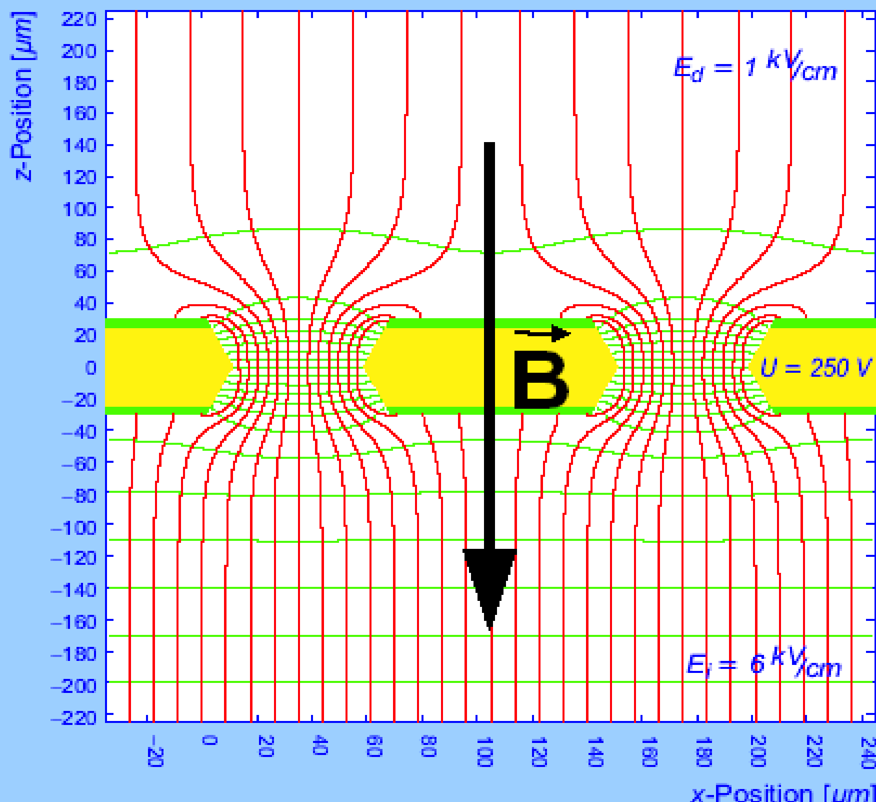
NIKHEF

MediPix 2 pixel (Jan Visschers et al)





$$\vec{v}_{\text{drift}} \propto \hat{\vec{E}} + \omega\tau(\hat{\vec{E}} \times \hat{\vec{B}}) + \omega^2\tau^2(\hat{\vec{E}} \cdot \hat{\vec{B}})\hat{\vec{B}} \quad \text{with} \quad \omega = \frac{e}{m}B$$



ALEPH: $B = 1.5$ T

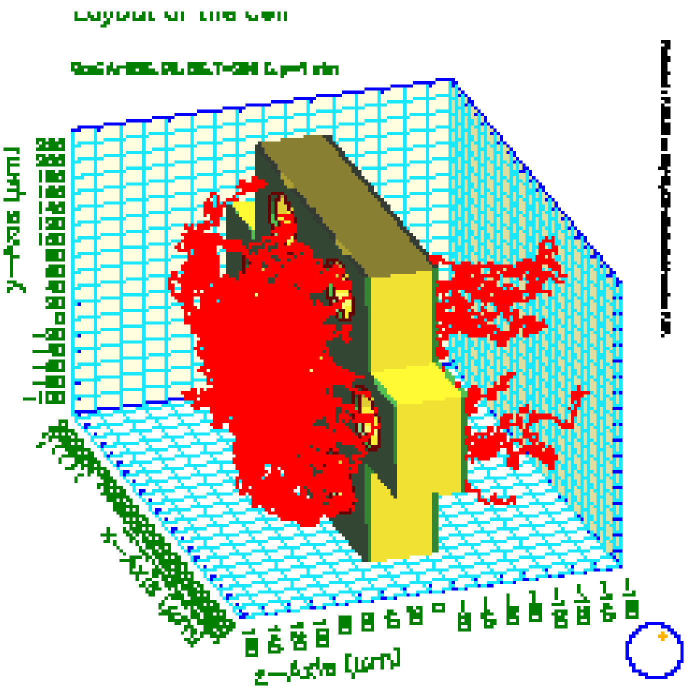
$(\omega\tau)_{e^-} = 8.9$

TESLA: $B = 4$ T

$(\omega\tau)_{e^-} \approx 24$

Due to the high value of wt and the low grid transparency, does it work in a magnetic field? -> Simulations in Aachen (next slide)

Simulations (Aachen)...



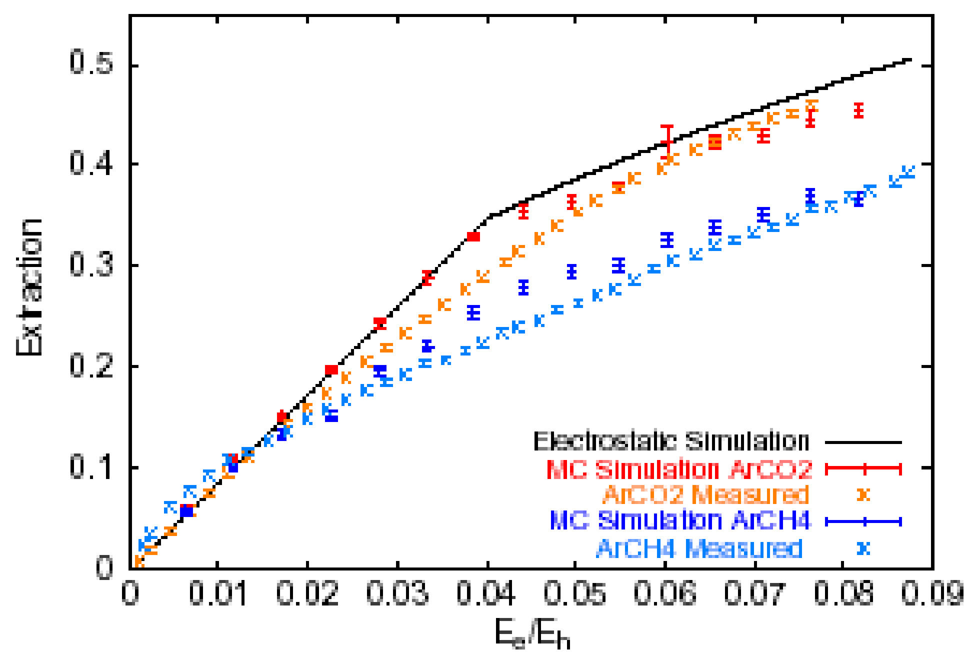
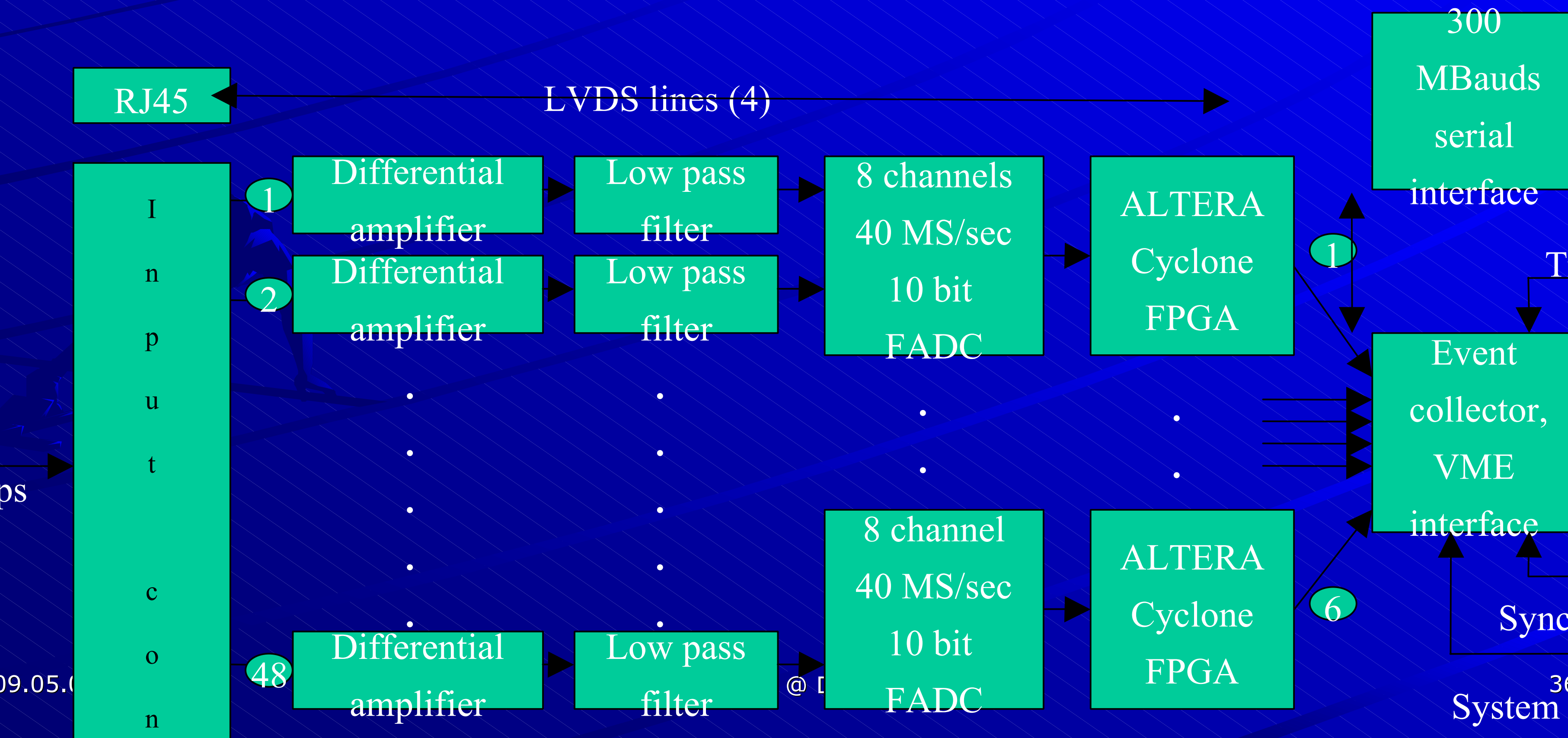


Figure 2: Numerical simulation of GEM structures. Shown are simulated drift lines and the calculted extraction efficiency compared to the measured one.

Readout Electronics :

A low cost DAQ card for detector R&D applications is developed at Université de Montréal for the KOPIO collaboration:

- Prototype version has VME interface
- 48 channels per card
- Based on 40 MS/sec 10 bit ADC
- Estimated fabrication cost for the VME prototypes is about 55 Euros/channel.



- Max. magnetic field > 5 T
- Diameter of opening 28 cm
- Total length 187 cm

t TPC studies in the magnet on December 18, 2002

Aachen : small GEM de
for current measurem

2T magnet in Julich

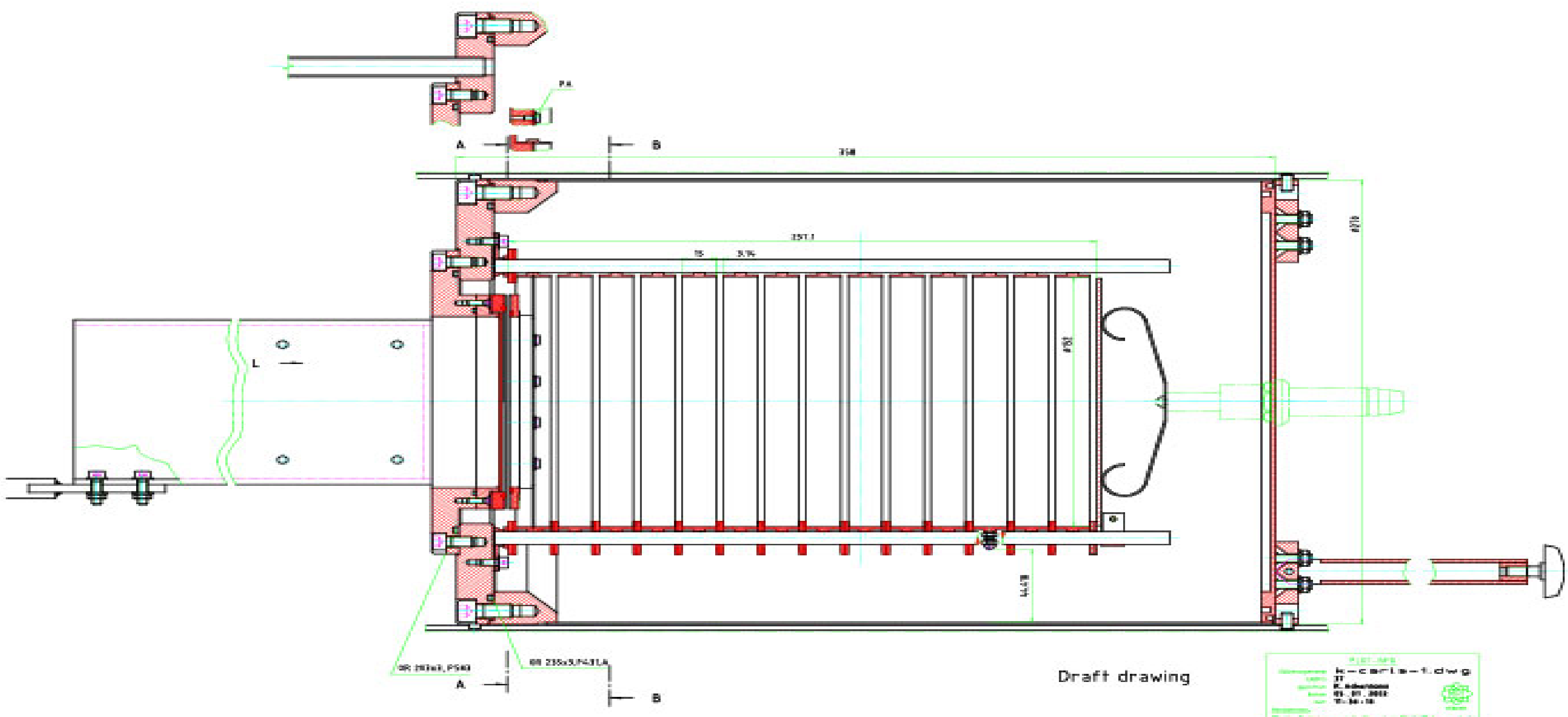
5T magnet in DESY

(Orsay-Saclay : 1cm ar
15cm micromegas TPCs
current measurements

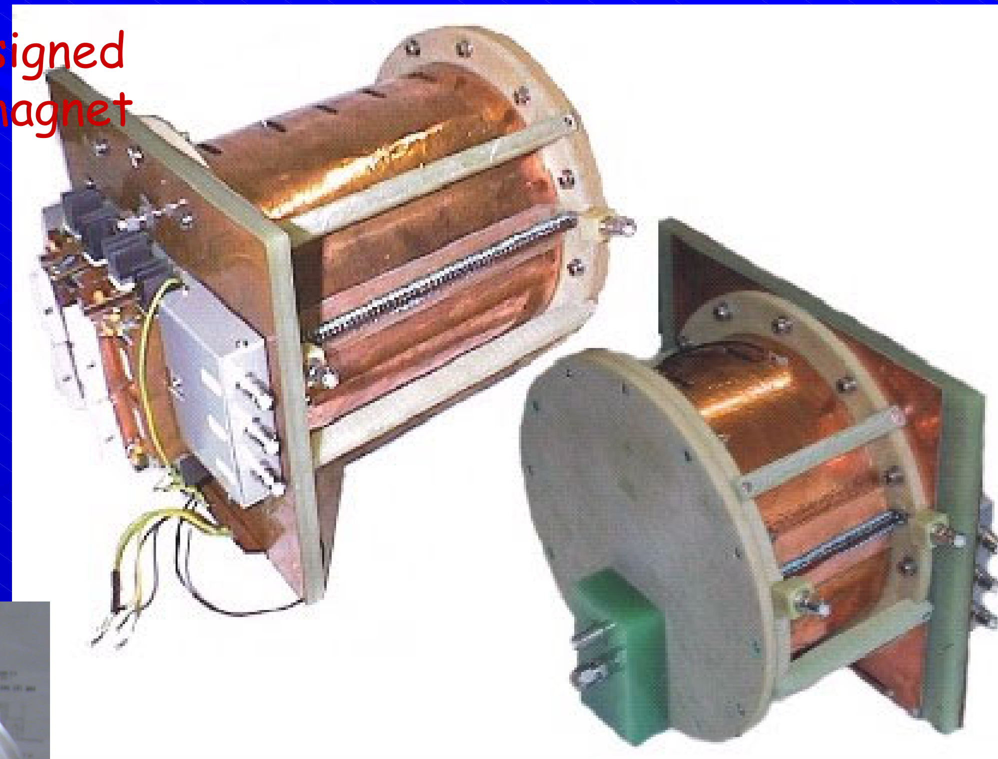
2T magnet in Saclay

TPC studies in the Saclay magnet
(June 2002, Feb 2003)
2Tesla, 53cm bore diameter

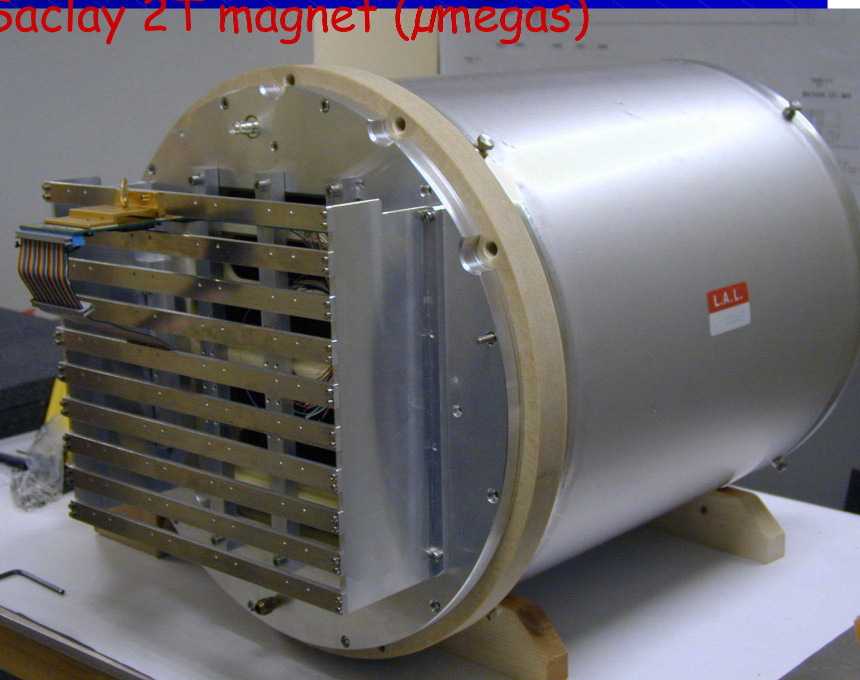
MPI-Munich prototype for Wires, Gem or Micromegas test in 5T magnet (wire version -> almost ready…)



Karlsruhe/CERN --> designed to fit in the DESY 5T magnet (Gem)

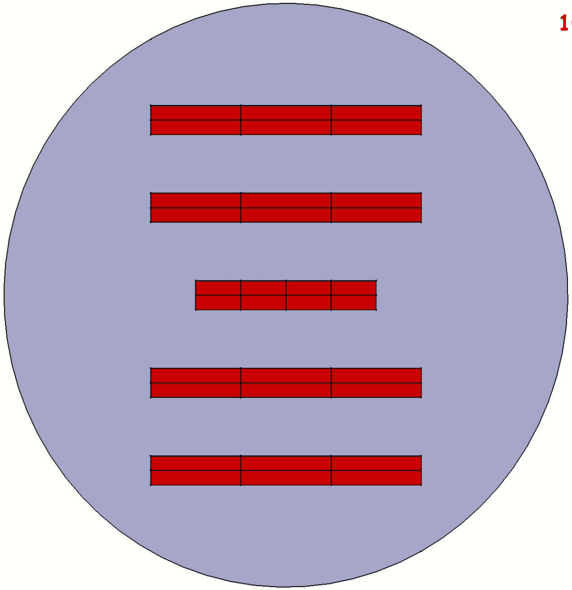


rkeley/Orsay/Saclay to fit Saclay 2T magnet (μmegas)

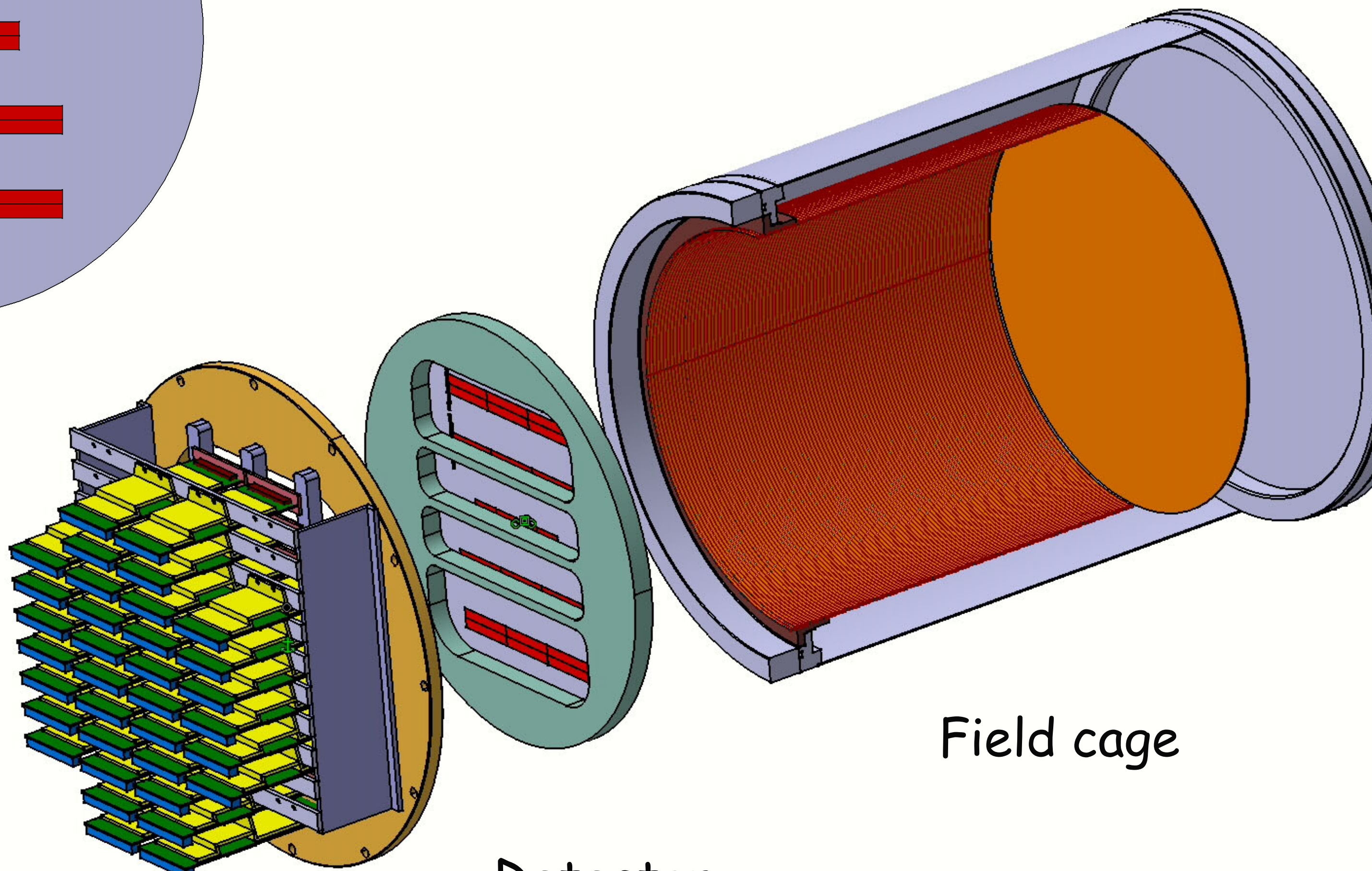


Both will make use of the STAR electronics

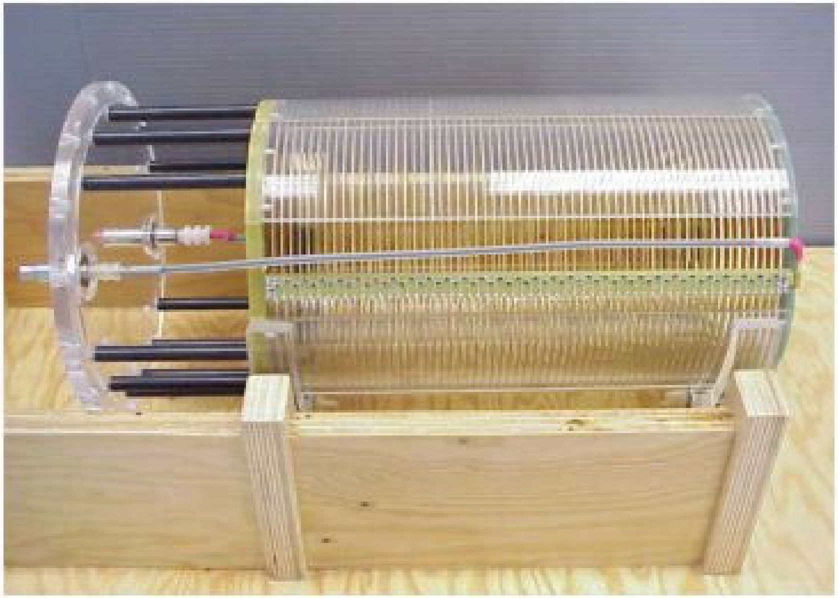
Berkeley-Orsay-Saclay TPC under construction

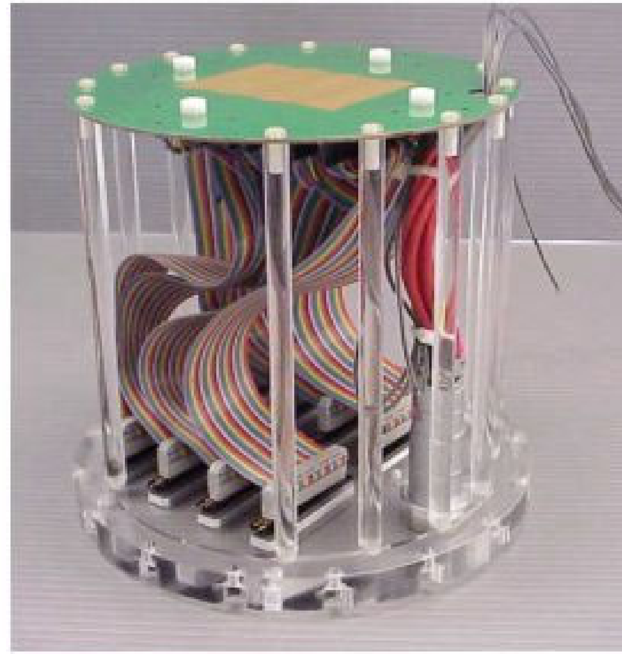


Pad layout



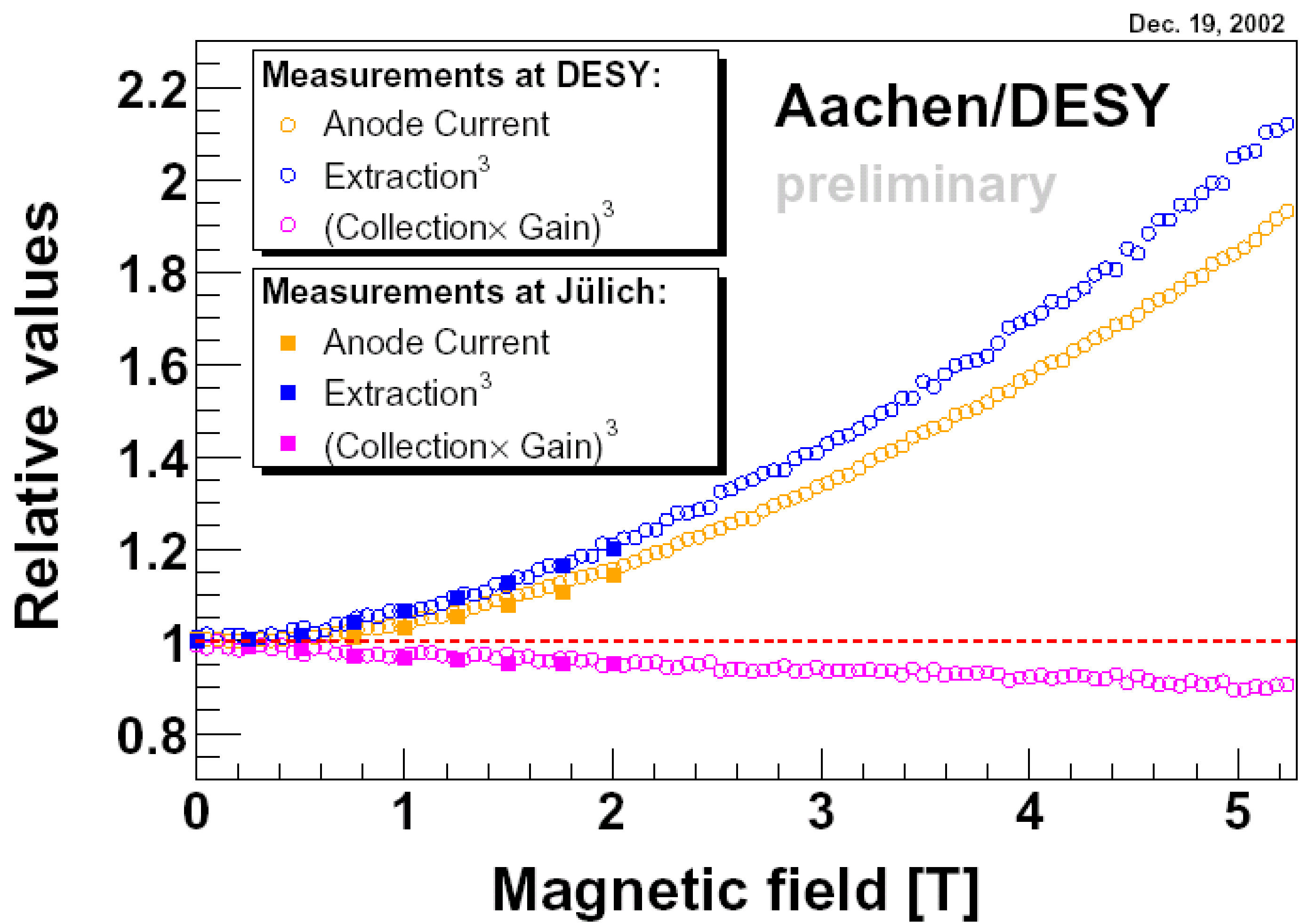
ewly Operational GEM TPC Designed for B Field Tests -- Victoria



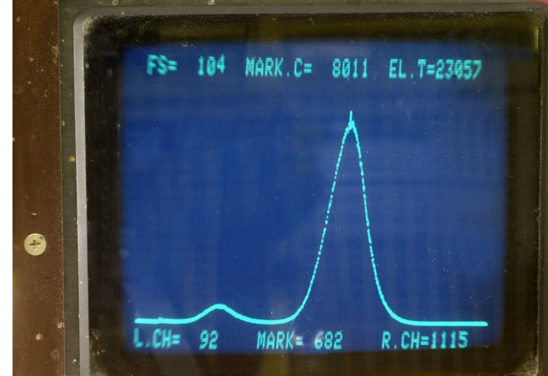


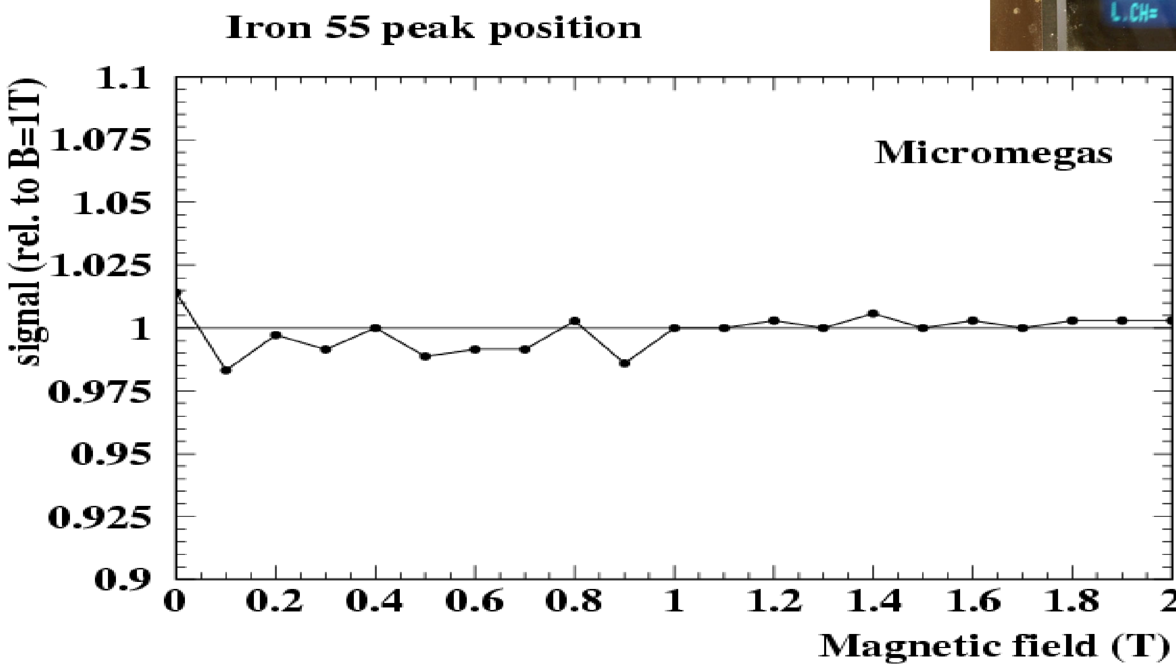
- 30 cm drift, 22 cm O.D. , 256 readout pads (60 mm ∝ 10 mm)
- Signals read out with STAR electronics
- Plans for magnetic field tests 1 T at TRIUMF & 5T at DESY
- Also lots of simulation-work on measuring prec. w/ MPGDs

Electron transfer in magnetic fields

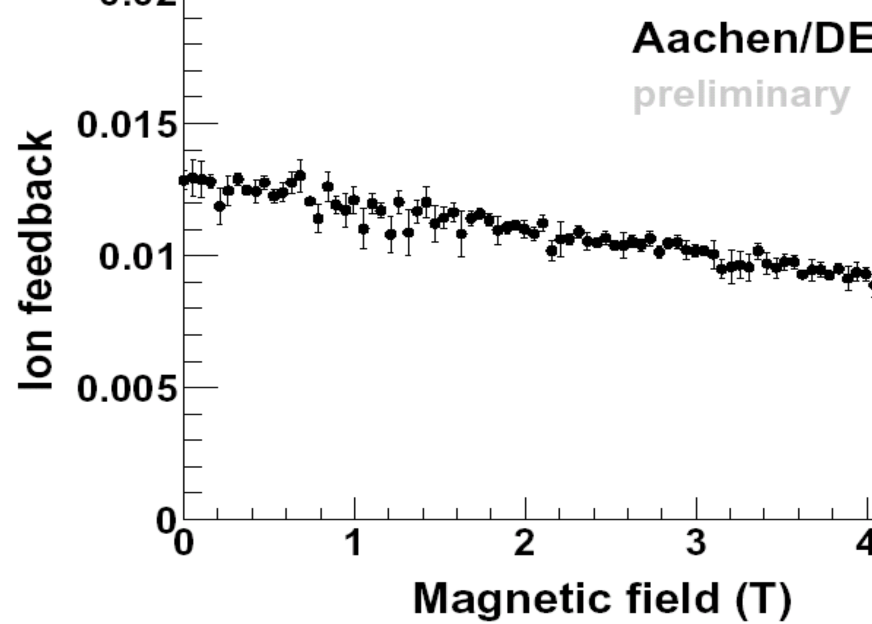


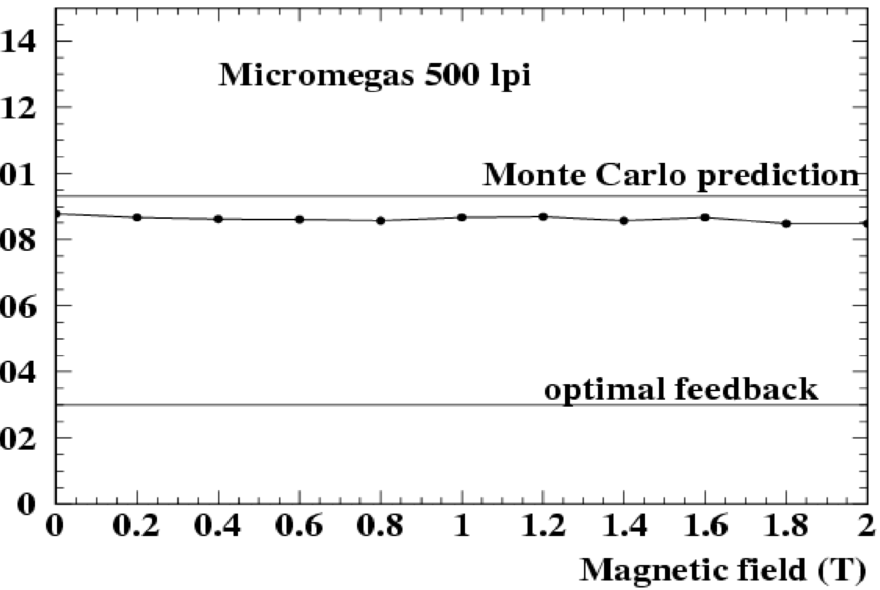
Orsay-Saclay: no change observed
n the iron 55 peak position beween 0 and 2T

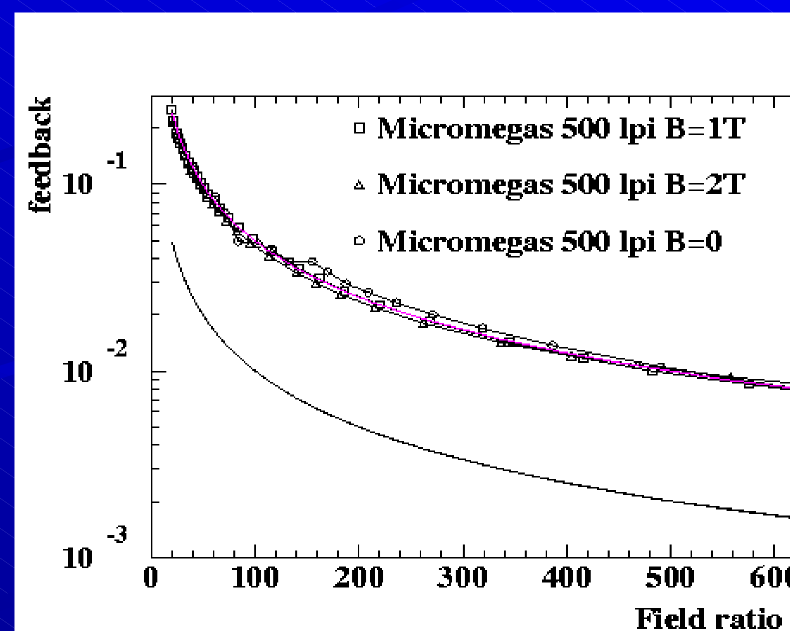




No deterioration of the ion feedback (rather a small improvement) for Gems -->







The ion feedback is well understood for micromegas

Other activities:

Lorentz-angle meas., Gas studies,
Gem resolution/manufacturing at

MIT

Gas studies at

Cracow

Work on TPC field cage starting at

Desy (prototyping)

St. Petersburg (field simulations)

TPC-related work outside our collaboration…

-- BNL

-- Chicago/Perdue/3M

-- Chicago/Perdue

-- Cornell (UCLC)

-- MIT (LCRD)

-- Temple/Wayne State (UCLC)

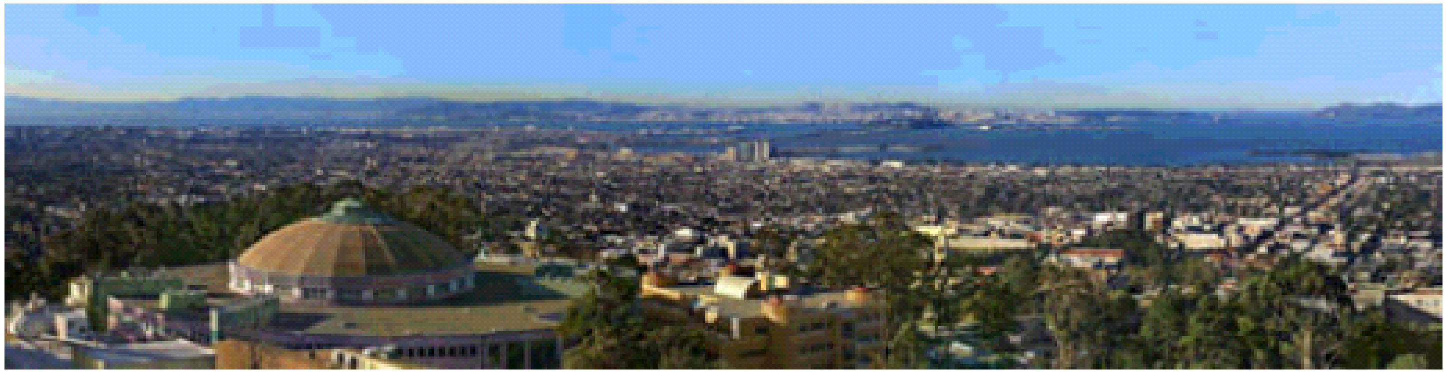
-- Yale

? see Madhu Dixit's NA Gaseous-Tracking talk at our world LC tracking meeting at the Amsterdam Ecfa/Desy workshop:
http://alephwww.mppmu.mpg.de/~settles/tracking/amsterdamtracking/talkswelcome.html

-- Asia

? see Norair Khlatyan's Asian Gaseous-Tracking talk at same meeting

Time Projection Chamber Symposiu



Date: Friday, 17 October 2003

Location: Lawrence Berkeley National Laboratory (LBNL)

Hosts: LBNL Physics and Nuclear Science Divisions, and the U.S. Department of Energy (DOE)

Mike Ronan

Milestone exercise

Prove MPGD perf. in B-field	2004
Iterate design electronics, fieldcage, mechanics	2004-2006
"Large" MPGD TPC prototype design	2005
Large prototype testing	2005-2006
Final design all components	2007
4 years for construction	2011
Commission TPC alone	2012
Install in LC detector	2013
Commission detector	2014

The bottom line 07.05.03

- A good start, lots of action, but

  ...need more experience under our belts

  to be able to choose the technology,

  gas, etc
- Work on fieldcage, electronics, mechanics in its infancy
- We can make good use of the extra time for state-of-the-art improvements
- Testbeams will be needed in ~ 1 year