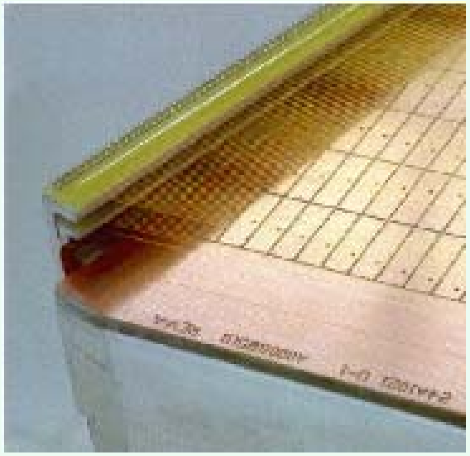
LCTPC: GEM Readout Results and TPC Software

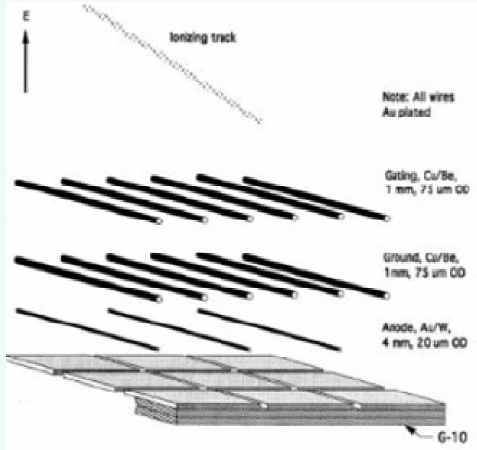
Daniel Peterson, Cornell University [1]

Outline:

[1] supported by the US National Science Foundation

GEM introduction

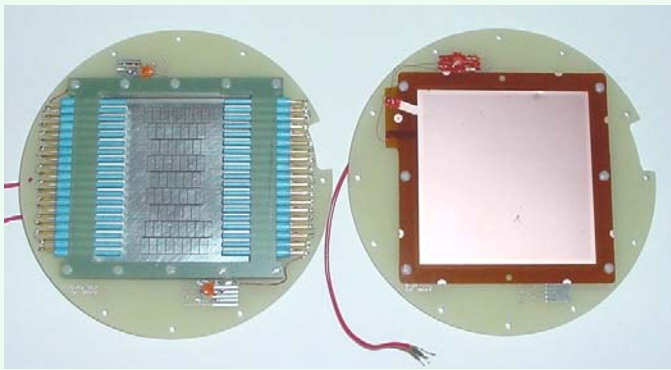


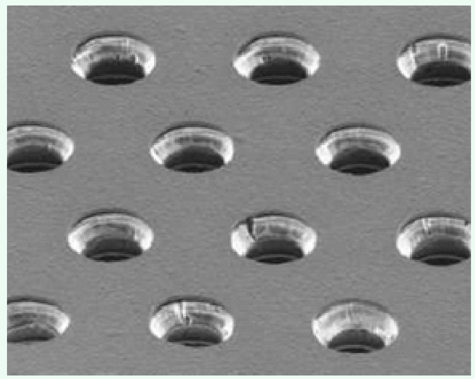


Wires used in existing TPCs

- STAR
- Alice

Signal is too wide



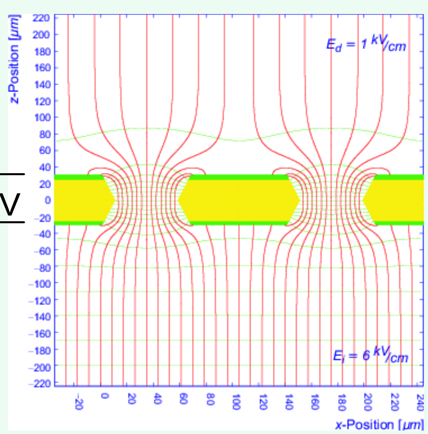


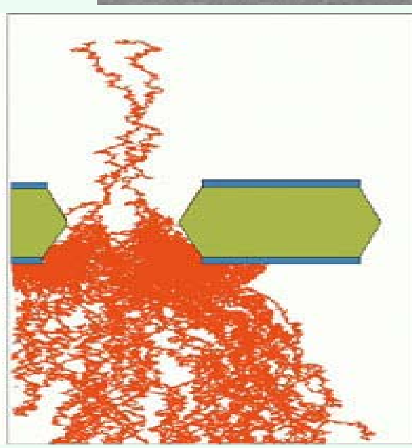
Alternative gas amplification

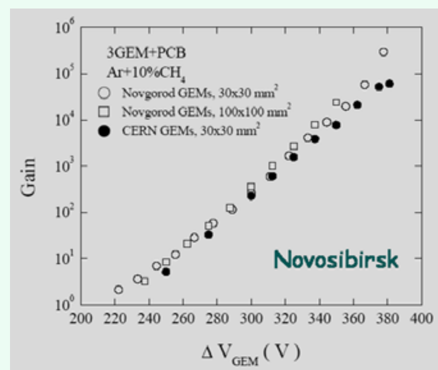
- GEM
- (Micromegas in next talk)

50 μm copper clad foil
70 μm holes
140 μm hole pitch
up to 80 kV/cm in hole

300-400V





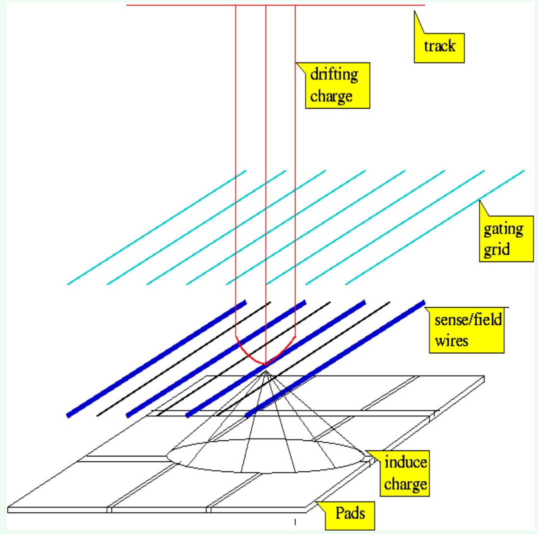


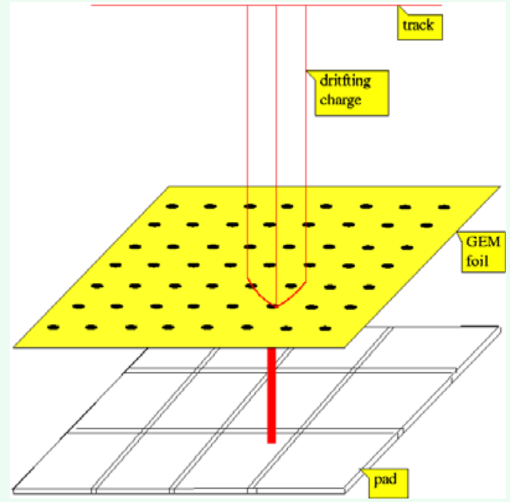
gain ~ 100
at 400V

Signal size

Wires: wide inductive signal

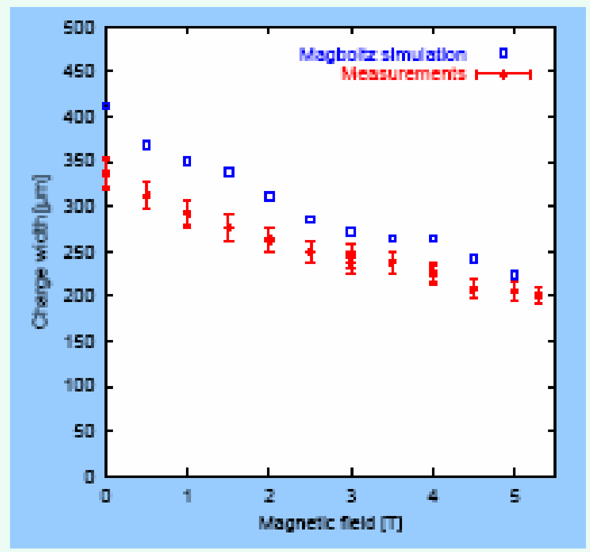
GEM: narrow transfer signal





Measured signal width:
- 3-GEM
- strip anodes
- B= up to 5 Tesla

~ 250 μm at B=4 Tesla



A. Vogel, Aachen, Durham 2004

Signal size, and other requirements for a TPC

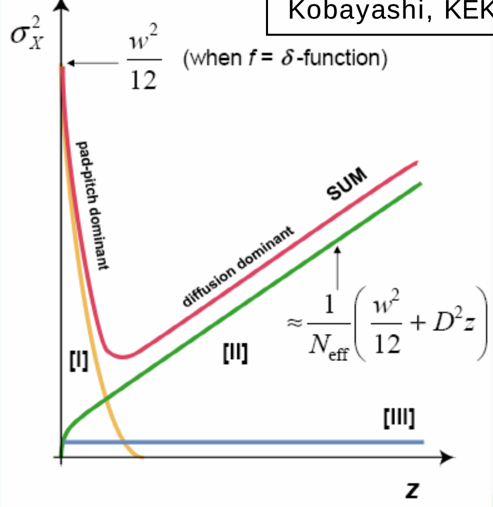
Signal is very narrow

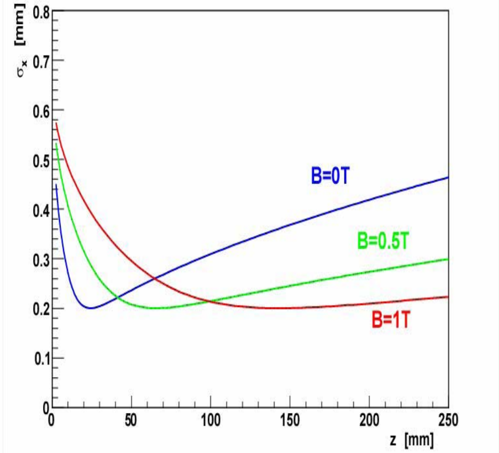
results in deteriorated resolution at small drift

due to insufficient charge sharing (hodoscope effect)

hodoscope effect decays faster with increased diffusion.

Kobayashi, KEK, Bangalore 2006





Particular case:

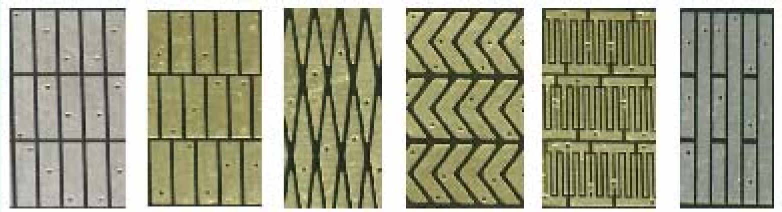
Pad width = 2.3mm

Pad Distribution Function=δ

D=469, 285, 193 μm/(cm)$^{1/2}$

improved resolution at all drift requires
- narrow pads, or
- diffusion within the gas amplification .

(creative pad shapes do not improve resolution)



158 119 130 220 260 174
Resolution (mm)

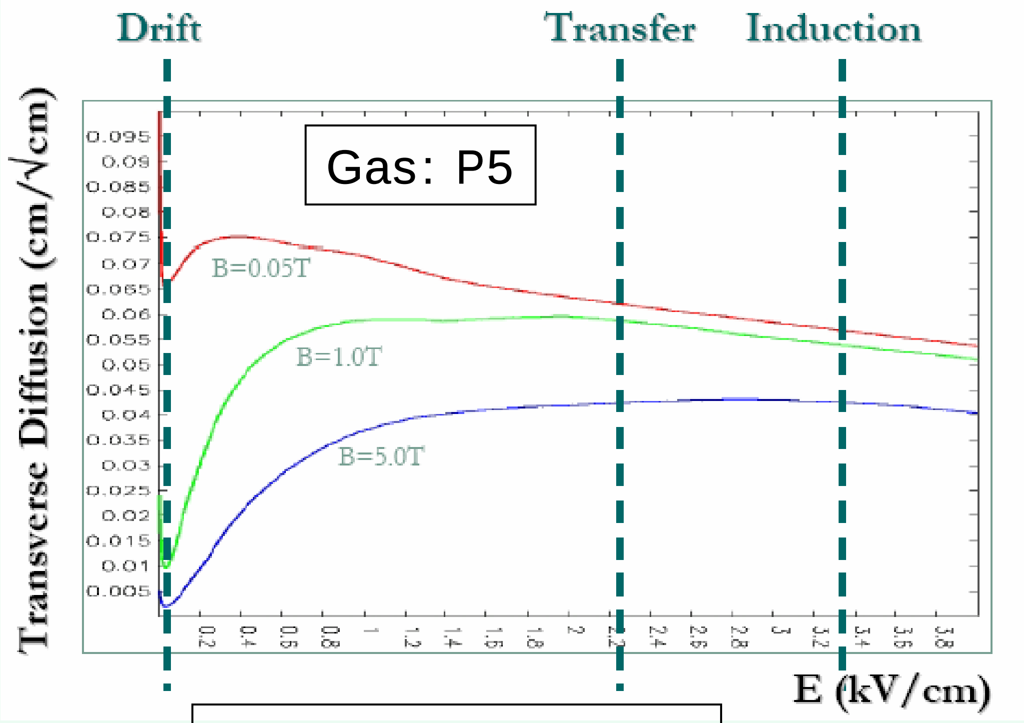
B. Ledermann, Karlsruhe, Vienna 2005

Use of diffusion in the transfer field

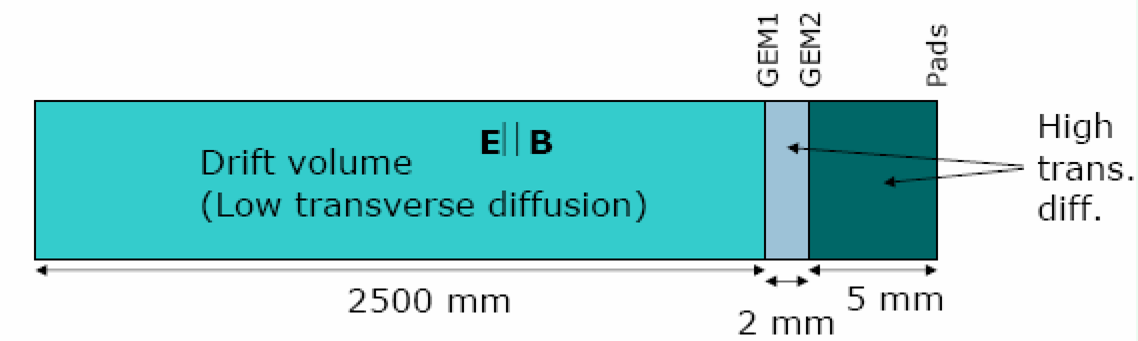
Diffusion properties of the gas can be used to defocus the GEM signal.

optimal resolution
Signal size (σ) ~ ¼ pad width
2mm pad width → 0.5mm signal

transfer and induction gaps can be increased to defocus the GEM signal

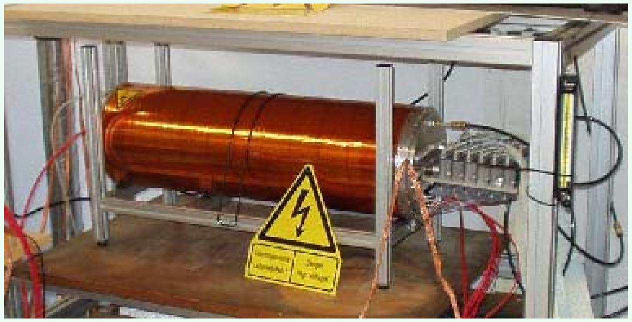


D. Karlen, Victoria, Paris 2004

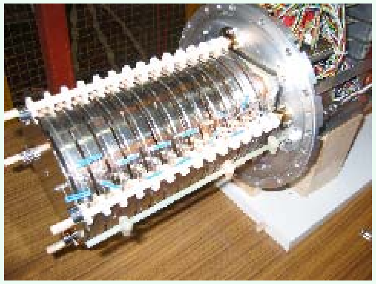


The small prototypes

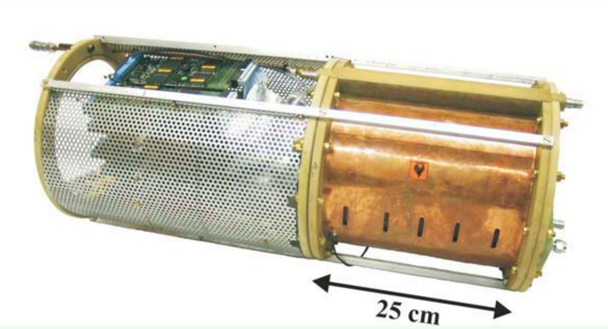
Chambers used to study GEMs



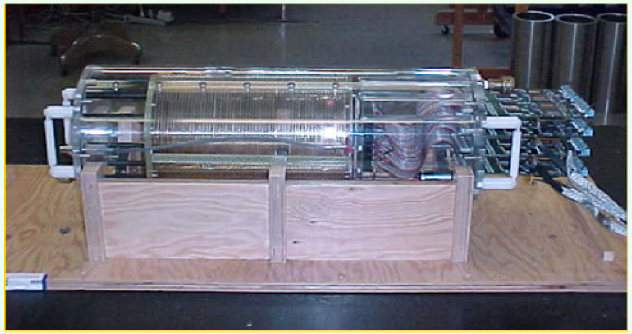
DESY



MPI/Japan



Karlsruhe



Victoria

Cornell

signal size, diffusion

gas characteristics
extracted from fit variance
on event-by-event basis

"TDR" Ar:CH_4:CO_2 93:5:2 230 V/cm
"P5" Ar:CH_4 95:5 90-160 V/cm

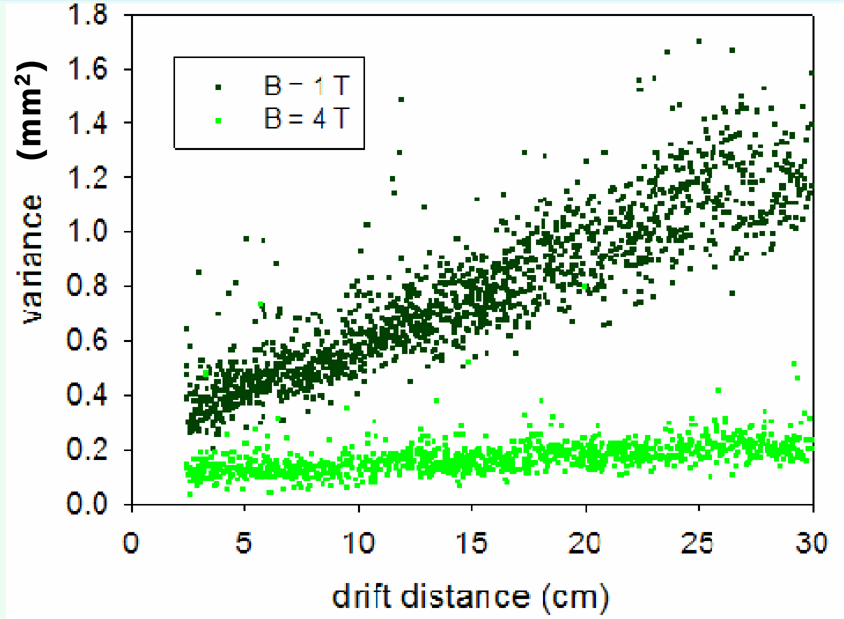
pad width: 2.0 mm , 1.2 mm

intercept → defocusing term
Slope → diffusion constant

TDR gas, signal width at zero drift
σ_0=.92 mm (0T)
.51 mm (1T)
.32 mm (4T)

diffusion constant
D=348 μm/cm$^{1/2}$ (0T)
205 μm/cm$^{1/2}$ (1T)
70 μm/cm$^{1/2}$ (4T)

P5, σ_0 = .38 mm(4T)
D= 34 μm/cm$^{1/2}$ (4T) ref slide 5



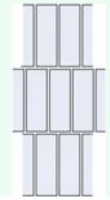
Data	v_d [cm/μs]	v_d sim [cm/μs]	D [μm/$\sqrt{\text{cm}}$]	D sim [μm/$\sqrt{\text{cm}}$]	σ_0 [μm]	σ_0 sim [μm]
p5B4w	3.84 ± 0.08	3.64	76 ± 5	67 ± 1	429 ± 2	350 ± 2
p5B4n	3.85 ± 0.04	4.14	34 ± 5	43 ± 1	382 ± 1	369 ± 1
tdrB4w	4.51 ± 0.05	4.52	71 ± 10	69 ± 1	367 ± 4	262 ± 1
tdrB4n	4.54 ± 0.06	4.52	70 ± 5	69 ± 1	319 ± 3	255 ± 1
tdrB1n	4.66 ± 0.06	4.52	205 ± 10	206 ± 2	509 ± 2	289 ± 2
tdrB0n	4.68 ± 0.06	4.52	348 ± 20	468 ± 10	918 ± 15	580 ± 1

D. Karlen, Victoria, Snowmass 2005

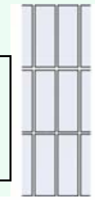
Transverse resolution, signal size

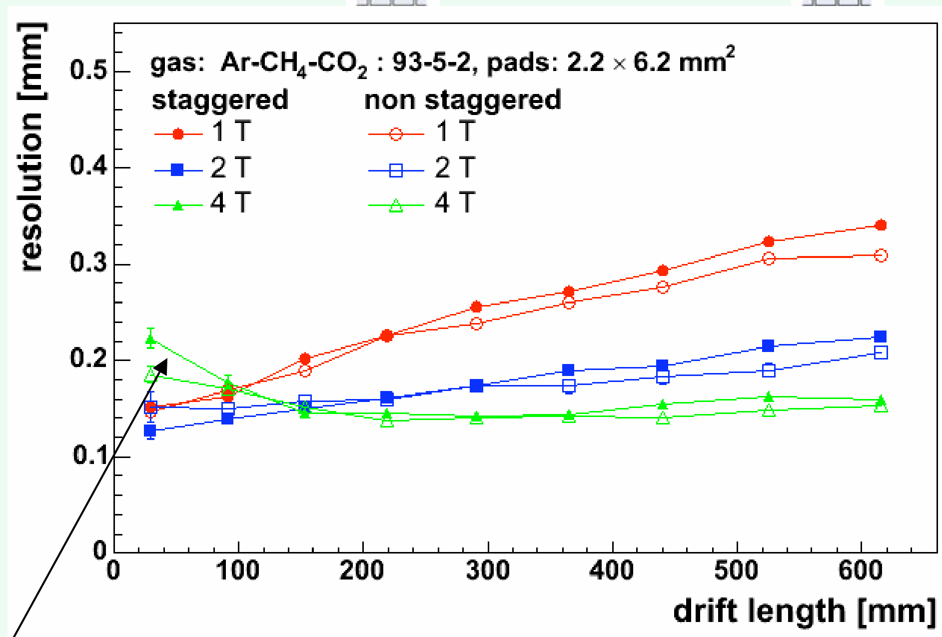
DESY measurements
3-GEM, each 325V
Transfer gaps: 2mm, 2mm, 3mm
$Ar:CH_4:CO_2$ 93:5:2
pad width: 2.2 mm
B = 1, 2, 4 Tesla
cosmics

staggered

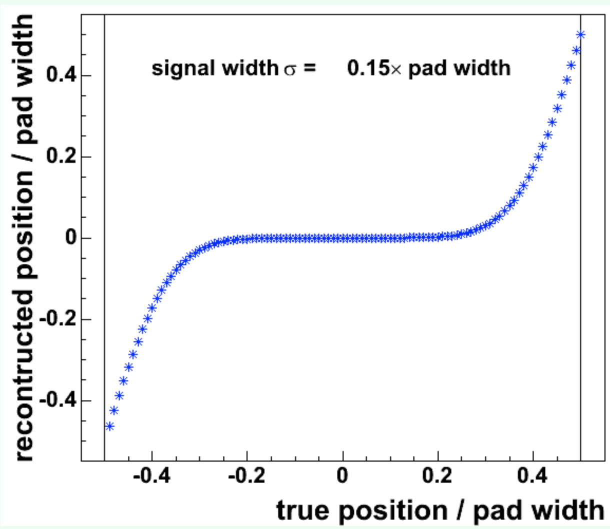


non-staggered





width derived from fraction of 1-pad hits



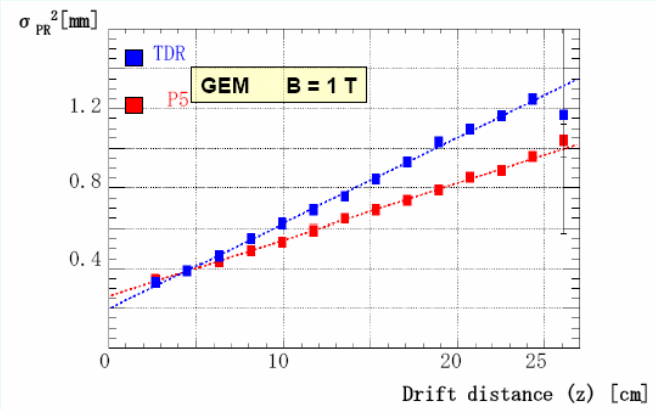
σ= 0.15 x 2.2mm
= 0.33mm (2 Tesla)

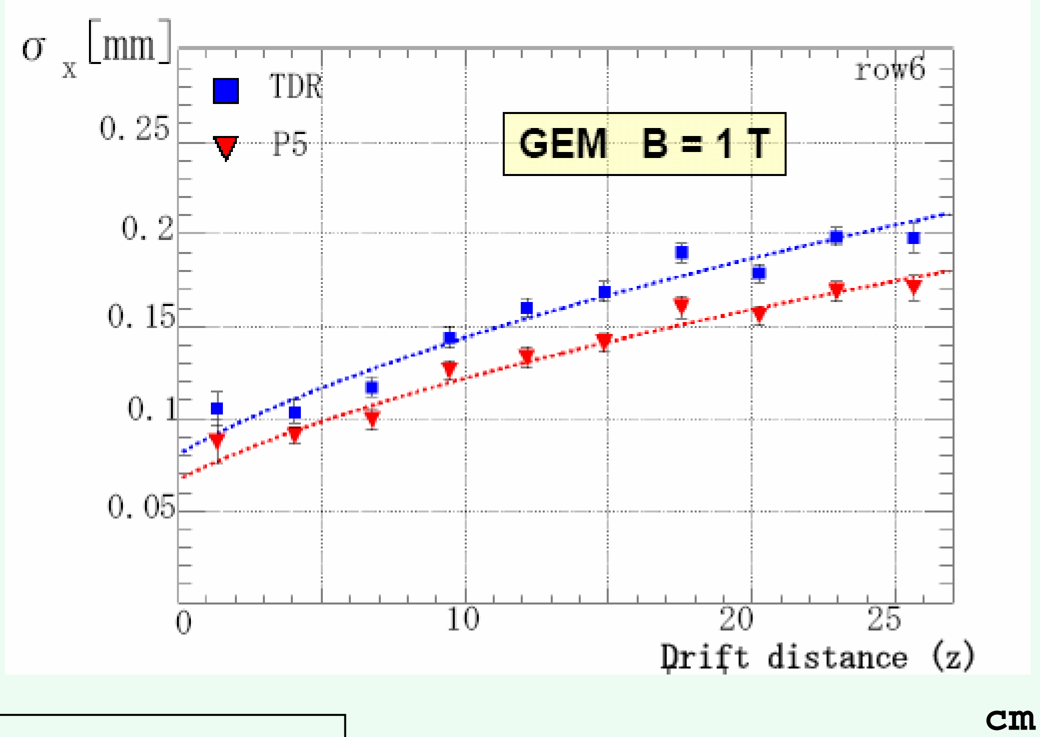
Rise indicates pad size is too large for signal width at 4 Tesla

K. Ikematsu, DESY, Bangalore 2006

Transverse resolution, signal size

MPTPC (build at MPI) measurements
3-GEM, each 330V
Transfer gaps: 1.5, 1.5, 1.0 mm
Ar:CH_4:CO_2 93:5:2 220V/cm
Ar:CH4 95:5 100V/cm
pad width: 1.27 mm staggered
B =1 Tesla
4 GeV/c pion beam





with σ_0^2 = 0.2mm^2, σ_0= 0.45mm
4σ_0 (90% containment) = 1.8mm

TDR gas, 1T, D=207 μm/cm$^{1/2}$
(ref 205 from Victoria measurement)

M. Kobayashi, KEK, Bangalore 2006

Transverse resolution, signal size

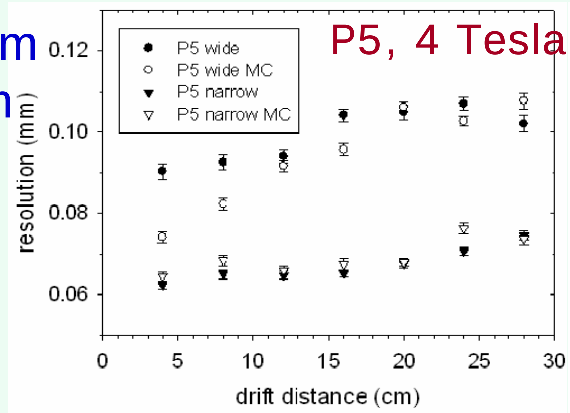
Victoria measurements
2-GEM, 372V, 380V

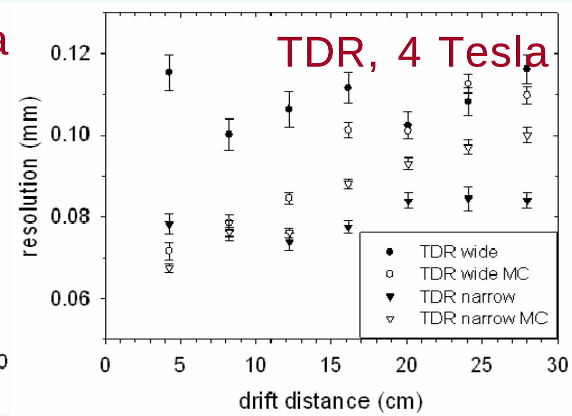
Transfer gaps: 2mm, 5mm

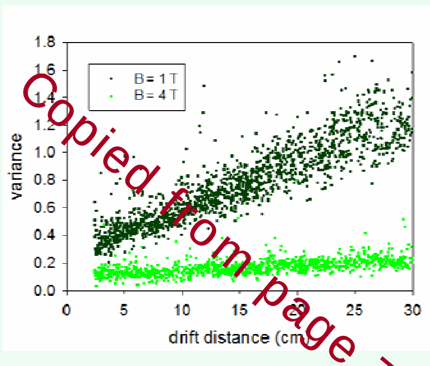
Ar:CH4:CO2 93:5:2 230 V/cm
Ar:CH4 95:5 90-160 V/cm

pad width: 2.0 mm , 1.2 mm

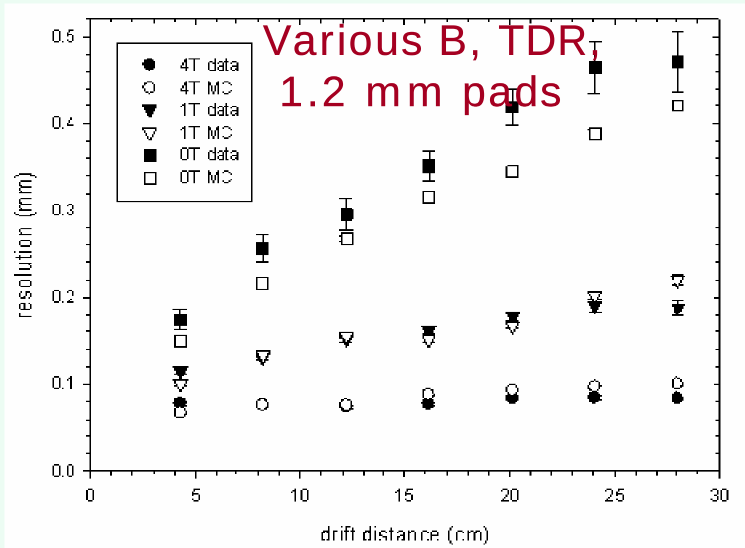
B = 0, 1, 4 Tesla
cosmics







Width measurements
TDR gas, σ_0=.92 mm (0T)
.51 mm (1T)
.32 mm (4T)

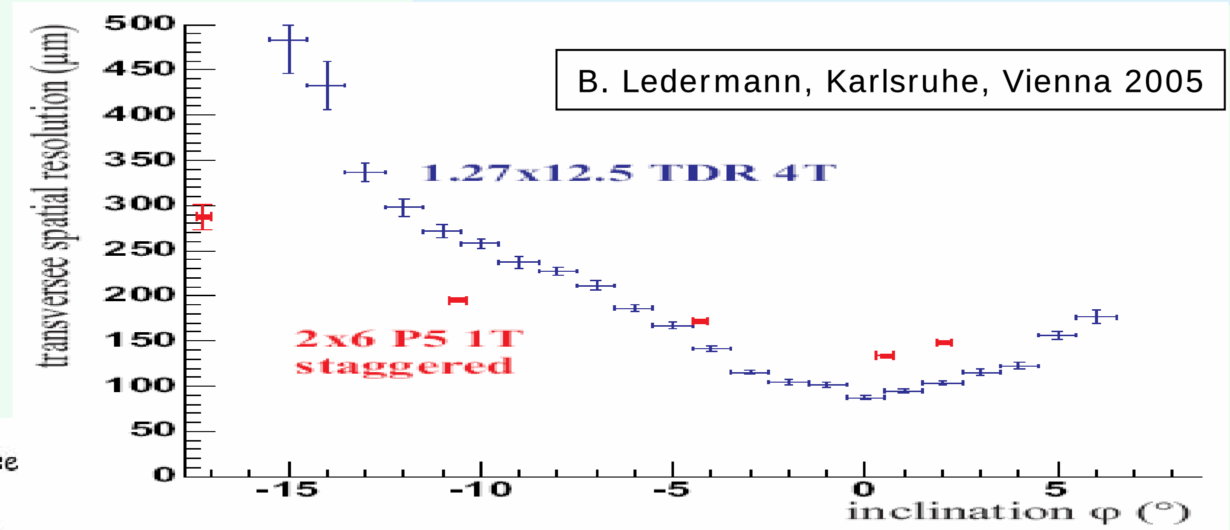


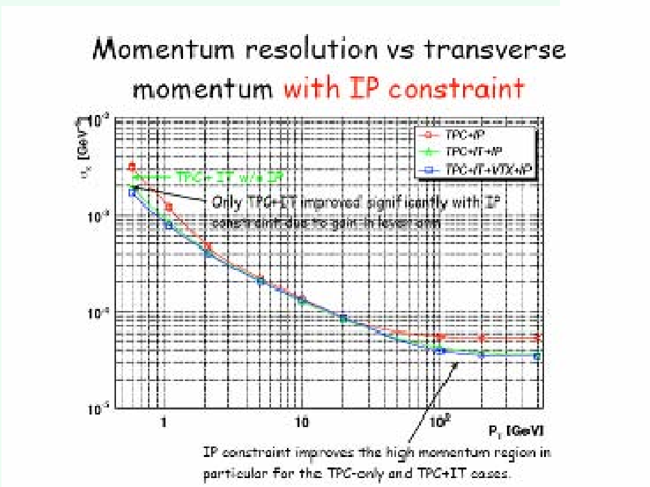
dataset	Resolution [μm] (data)	Resolution [μm] (sim.)
p5B4w	108 ± 1	92 ± 1
p5B4n	68 ± 1	68 ± 1
tdrB4w	117 ± 2	100 ± 1
tdrB4n	83 ± 1	87 ± 1

D. Karlen, Victoria, Snowmass 2005

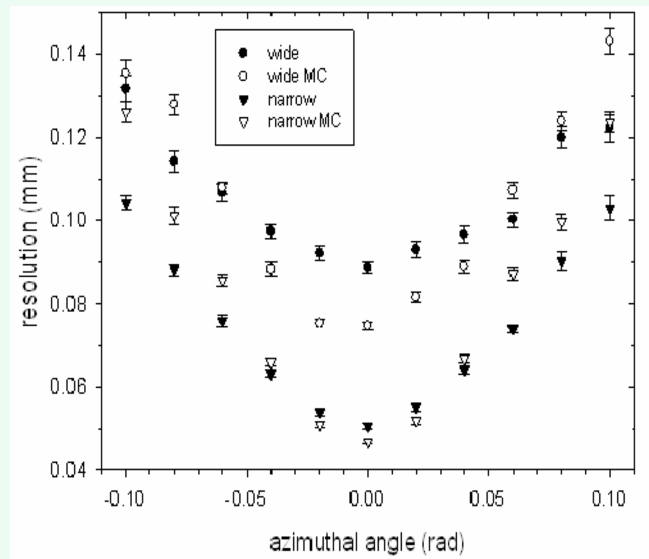
Track angle effects

Karlsruhe





Victoria



D. Karlen, Victoria, Snowmass 2005

But, momentum resolution dominated by scattering for P > 50 GeV/c; entrance angle, α > .04 radian

Longitudinal resolution

Longitudinal resolution

B field as shown

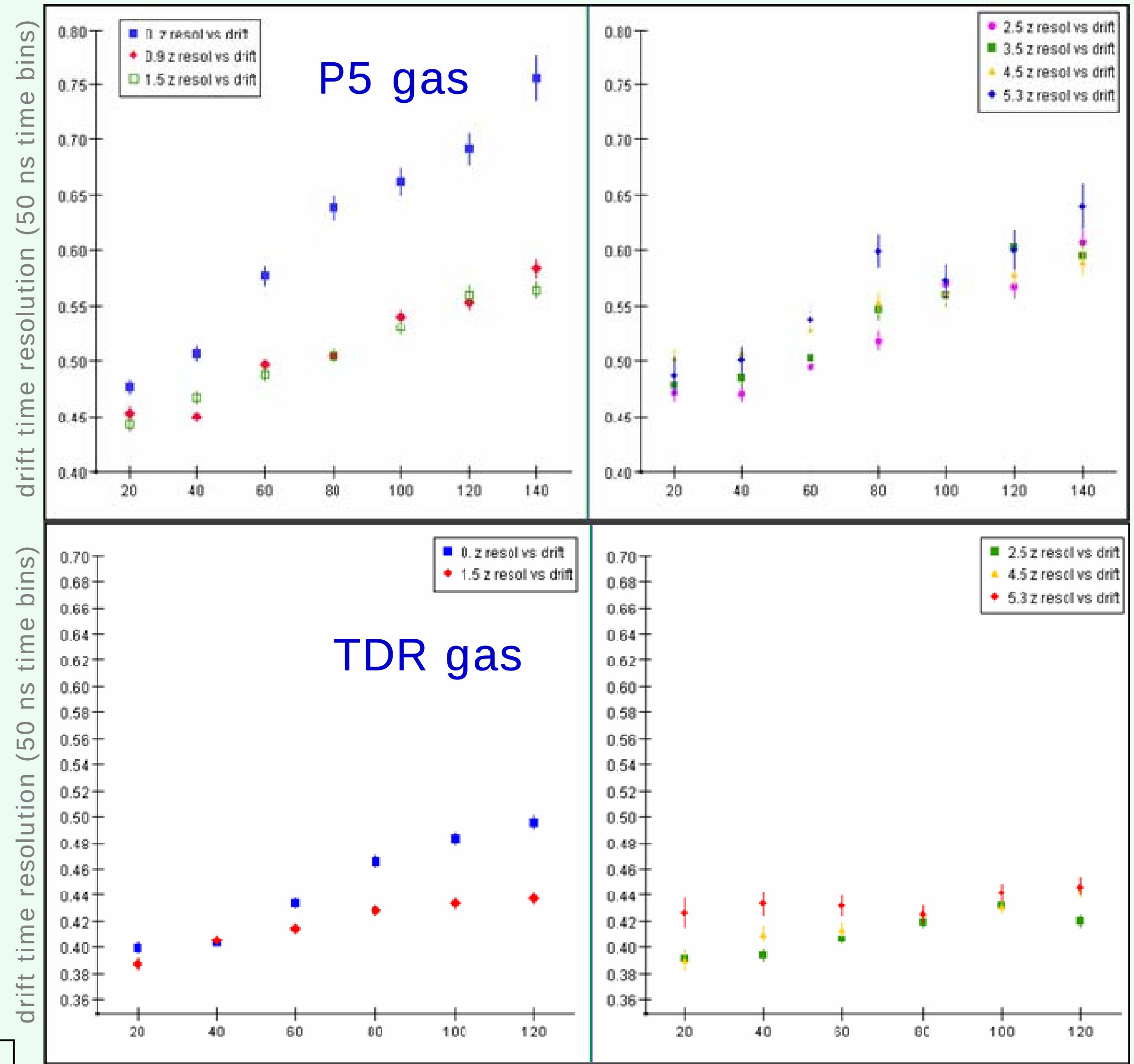
(Not a property of the GEM)

1.6 mm

0.8 mm

1.6 mm

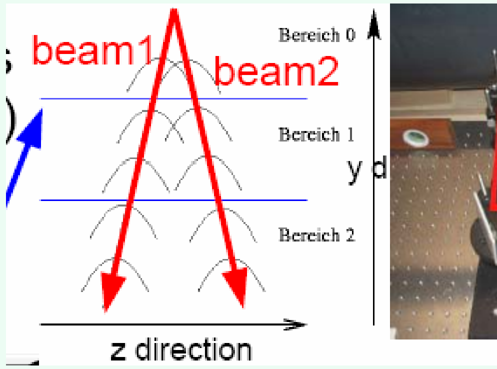
0.8 mm

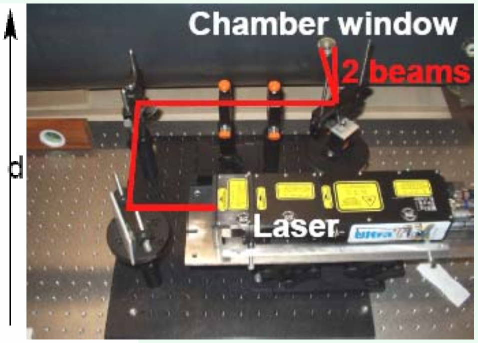


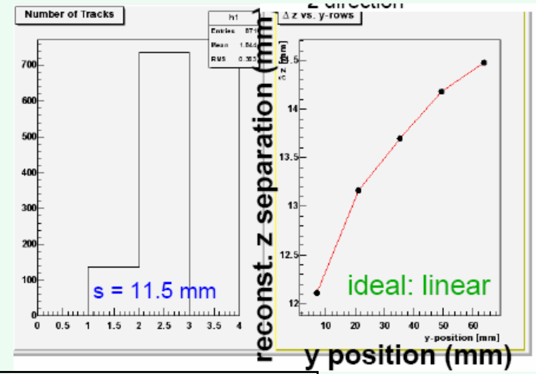
G. Rosenbaum, Victoria, Victoria 2004

2-track resolution

Z separation:
10 mm



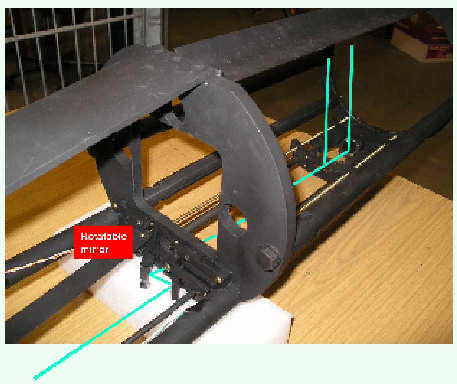


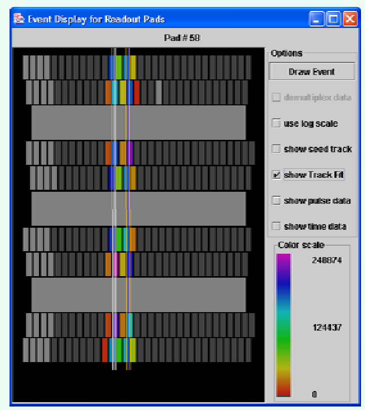


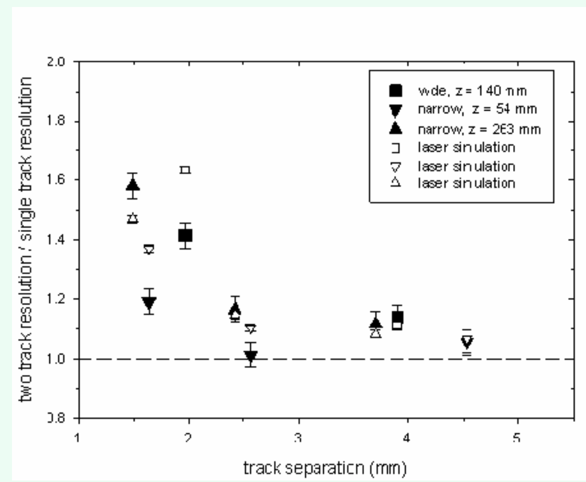
P. Wienemann, DESY, Stanford 2005

Transverse
separation:

1.5 pad width
σ_0 = .32 mm (4T)



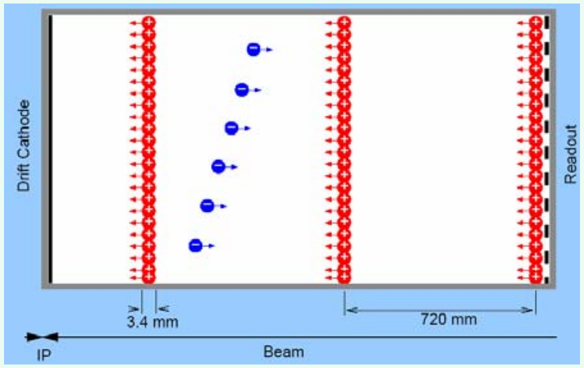




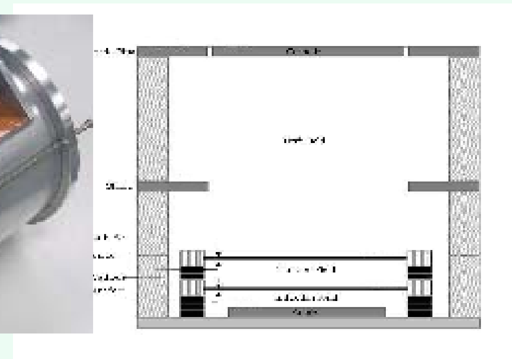
Δx=3.8 cm, Δz=0

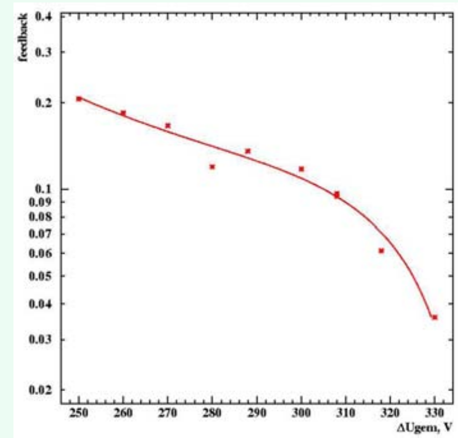
D. Karlen, Victoria, Snowmass 2005

Ion feedback (back drift)



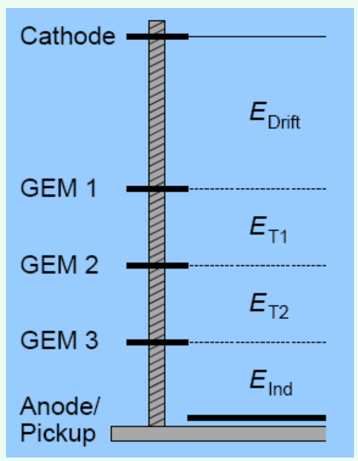
DESY
3-GEM
Novorod GEM
TDR Gas





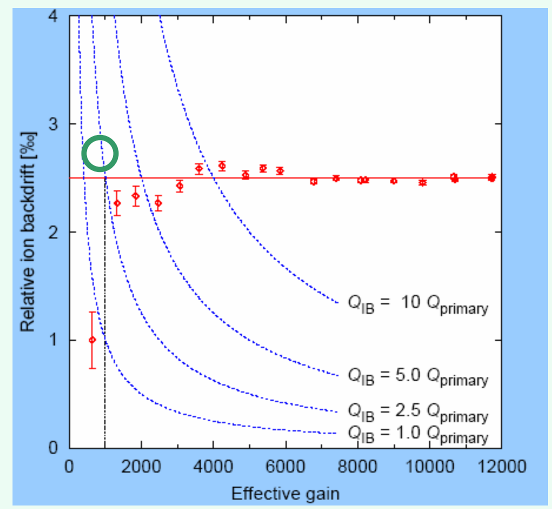
P. Weinemann, DESY, Berkeley 2003

Aachen
3-GEM
B=4 Tesla
for G_{eff}=1000,
Q_{IB}~2.5 $Q_{primary}$



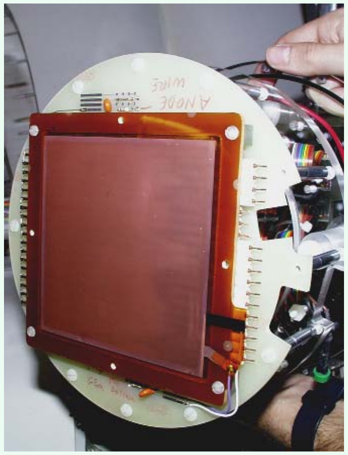
Optimization

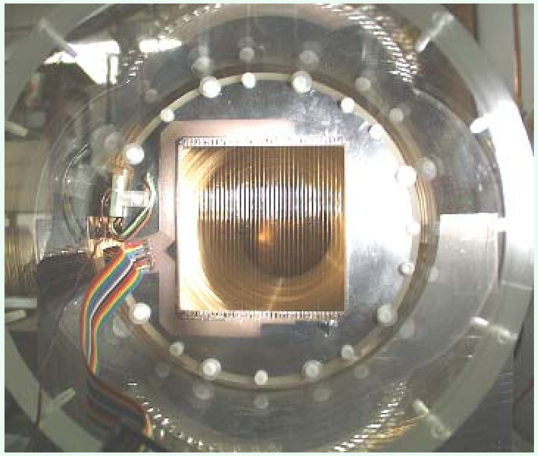
E_{drift}	240V
U_{GEM1}	small influence
E_{T1}	MAXIMUM
U_{GEM2}	small influence
E_{T2}	minimum
U_{GEM3}	MAXIMUM
E_{ind}	MAXIMUM

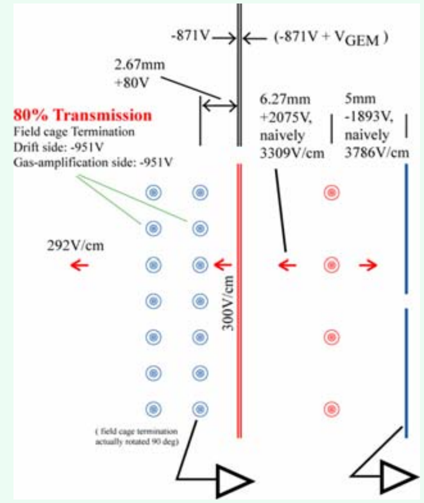


A. Vogel, Aachen, Durham 2004

Possibility of using a GEM ion gate



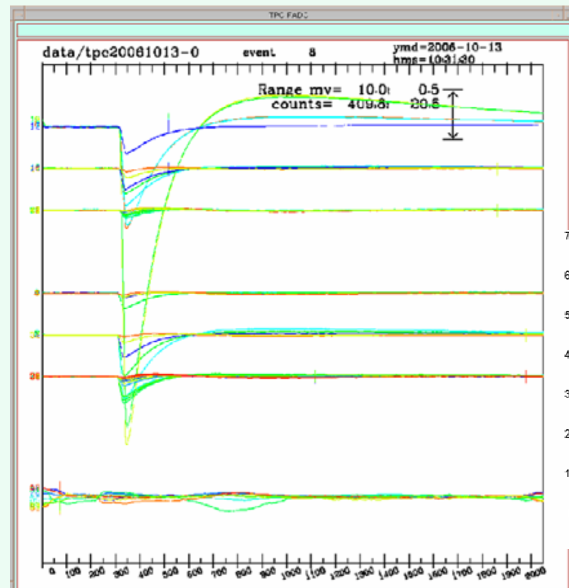


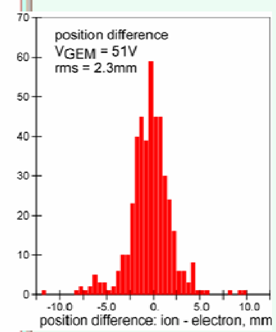


suppressed ion feedback in GEMs
may not be as low as 1/gain

must consider implementing a gate
wire gates are complex
investigate use of a GEM gate

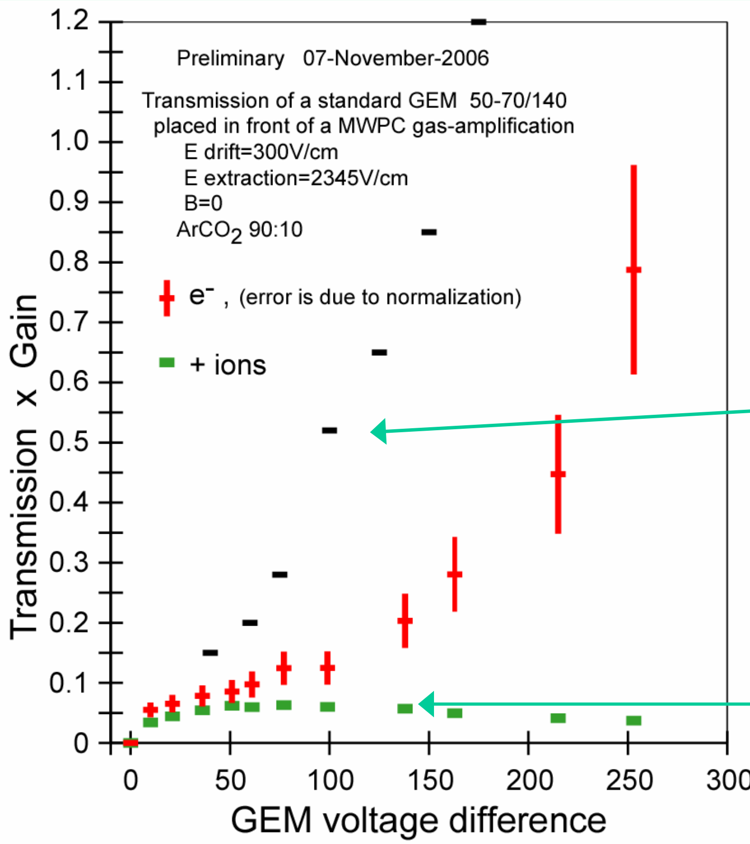
Measure GEM transparency e^- and +ions
GEM mounted on MWPC
MWPC: electron measurement, ion source
field gage termination, ion measurement
anode traces 82 μs full scale, ion 656 μs



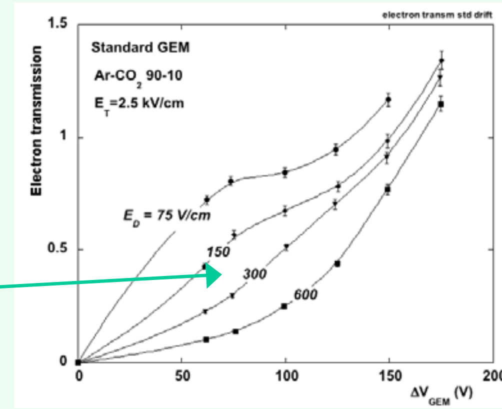


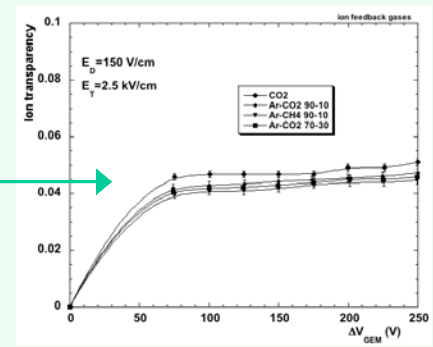
D. Peterson, Cornell, Valencia 2006

GEM transmission



D. Peterson, Cornell, Valencia 2006





F. Sauli et al, IEEE Nucl. Sci Symp NS-50 2003 803

should be careful designing a gate

Measurements will be repeated in a magnetic field.

Expand to measure ion feedback from various gas amplification.

Electron measurement does not agree with source/current measurements.

Ion measurement does agree, not sensitive to mixture.

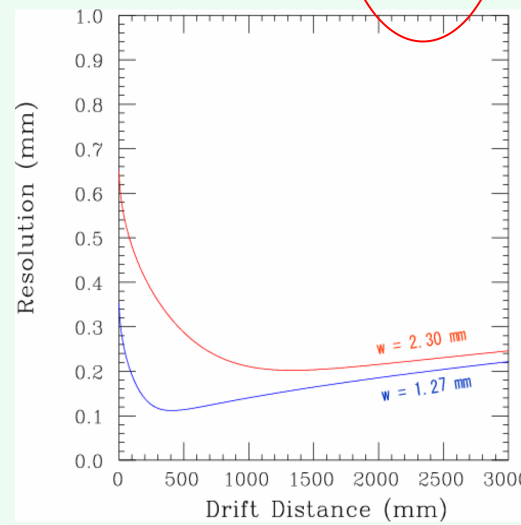
Summary

"TDR Gas" Ar:CH4:CO2 93:5:2				B=1 Tesla			B=4 tesla		
Data set	GEMs	transfer gap total (mm)	pad width (mm)	signal s drift=0 (mm)	diffusion constant $\mu m/cm^{1/2}$	transverse resolution (10cm drift) (μm)	signal s drift=0 (mm)	diffusion constant $\mu m/cm^{1/2}$	transverse resolution (10cm drift) (μm)
DESY	3	7	2.2			160	0.33 (2T)		165
Victoria	2	7	2.0	0.51			0.32	70	105
MPI/CDC	3	4	1.27	0.45	207	140			
Victoria	2	7	1.2	0.51	205	120	.032	70	75

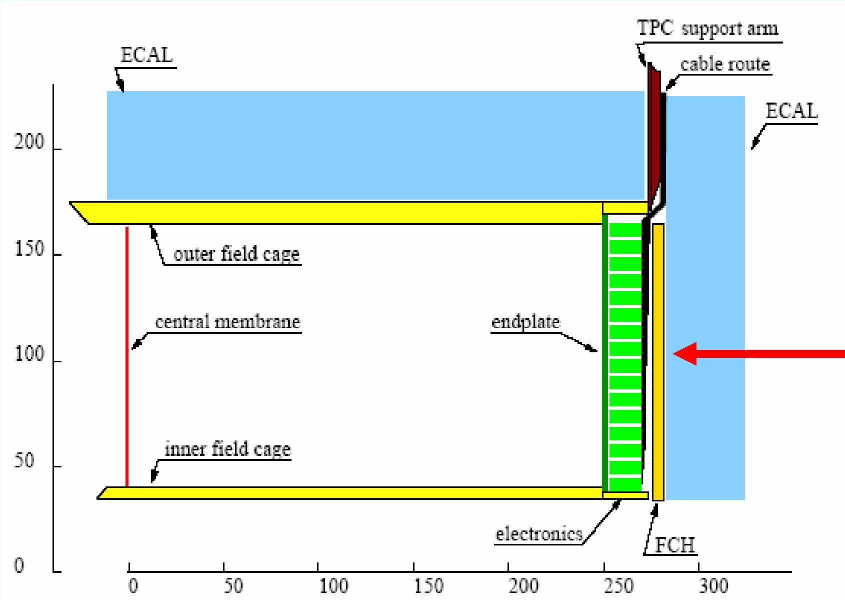
with drift distance: 250 cm
and diffusion constant 70 $\mu m/cm^{1/2}$ (TDR gas),
and 27 primary ions
contribution to resolution, from diffusion…

213 μm, will be dominant contribution

with P5, improved transverse resolution
degraded longitudinal resolution



M. Kobayashi, KEK, Bangalore 2006



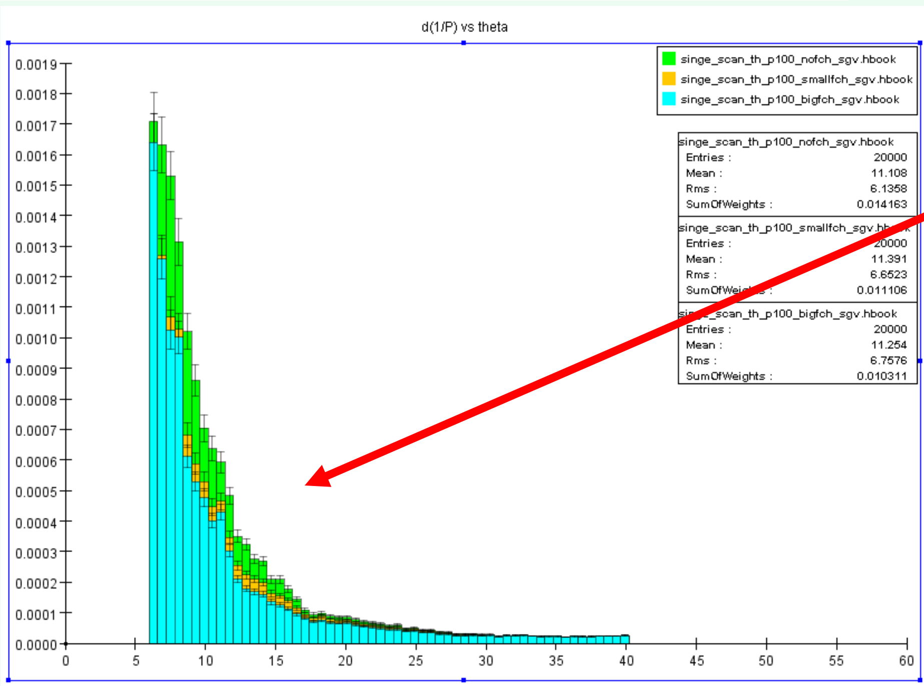
GEM end cap tracker

An end cap tracker is an integral part of the TPC implementation

matching point at entry to Ecal

pattern recognition in TPC

improved d(1/p) for ~7^o < θ < ~16^o

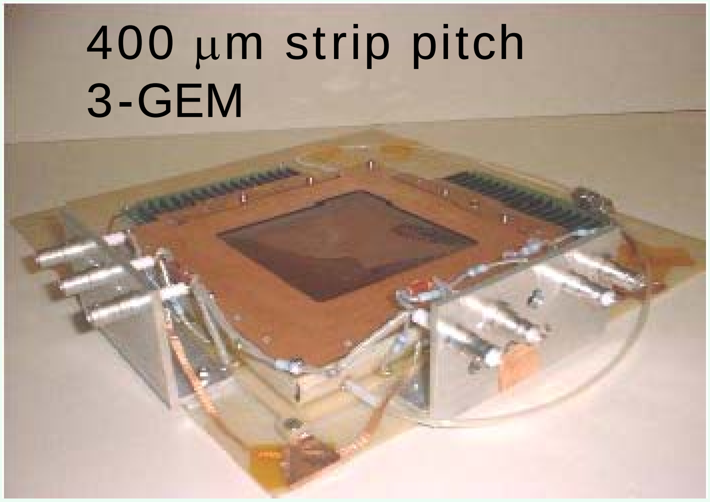


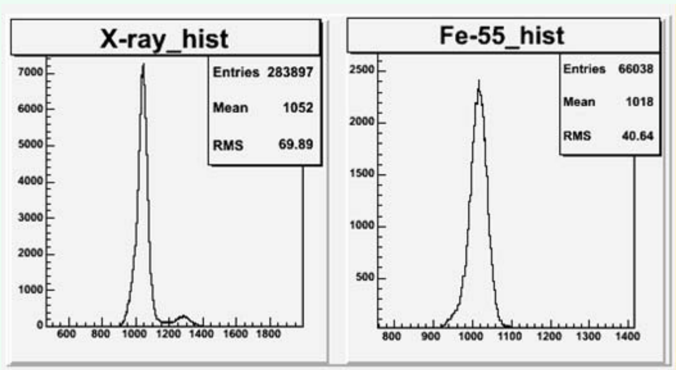
Silicon detectors is one option.

Louisiana Tech is investigating a GEM device.

L. Sawyer, Louisiana Tech, 2007

GEM end cap tracker





Small chamber comparison of
Fe-55 source and pulsed x-ray
gas: Ar:CO_2 70:30

L. Sawyer, Louisiana Tech, 2007

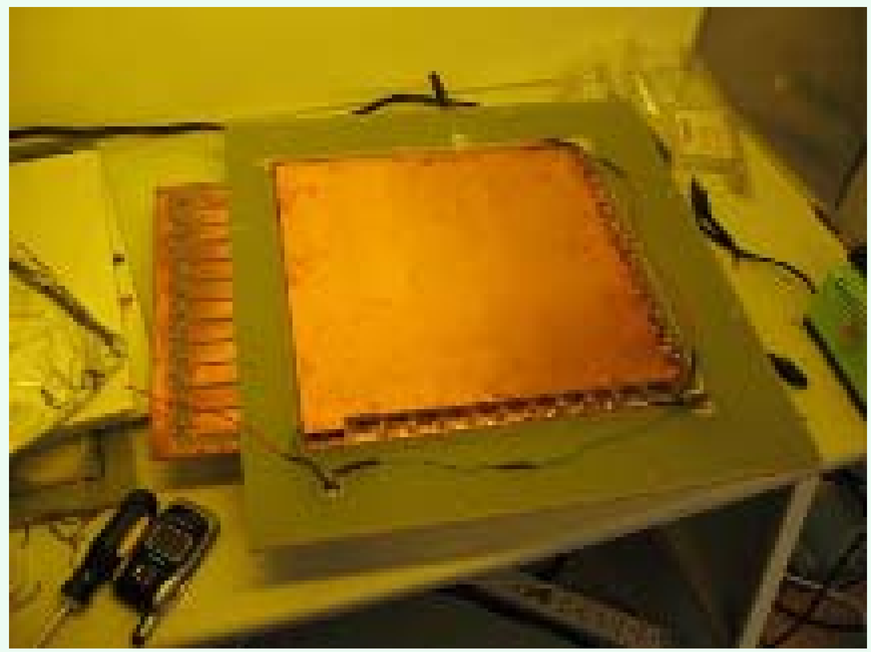
10cm x 10cm built and tested

30cm x 30cm built Fall 2006

foils are 3M, in cooperation with
Arlington digital-Hcal

Beam tests at Fermilab in Spring 2007

Developing curved GEM foils
for endcap geometry



SOFTWARE

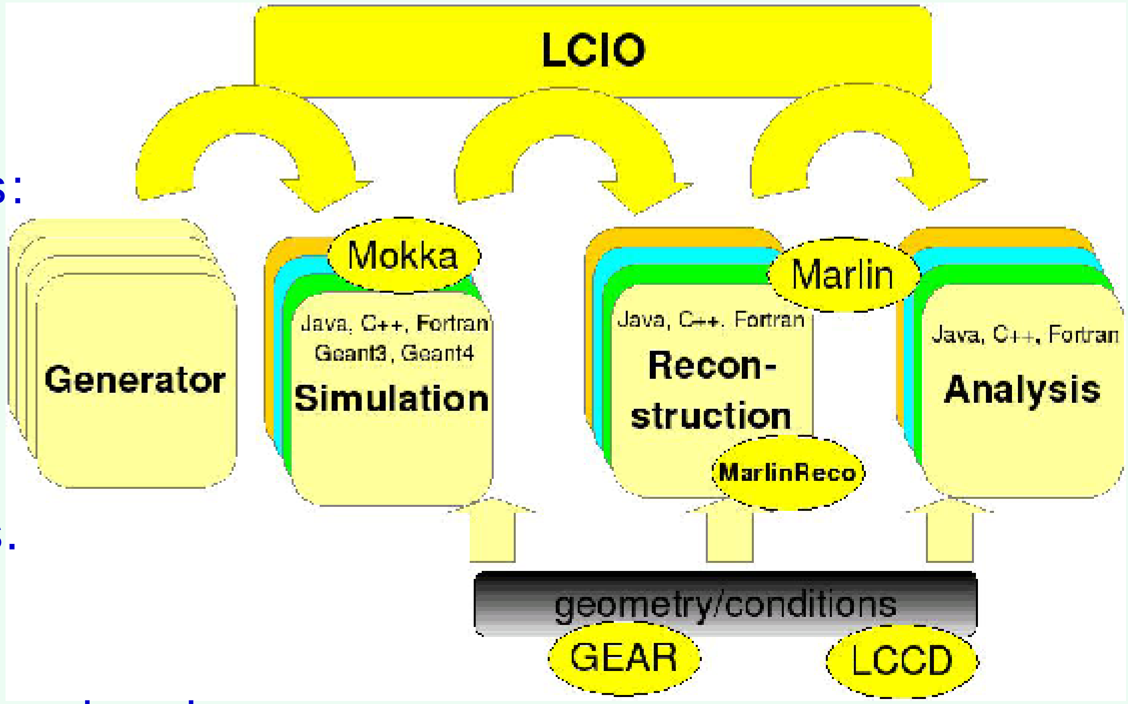
Software in Europe uses a framework as shown.

Based on Pythia, Mokka, Marlin, Geant4, LCIO, LCCD
(JSF software in Asia (Jupiter, Uranus) has similar functionality.)

Will walk-through a description of
using European framework

Will describe
ongoing development of tools:
specific design questions

effects of
hit overlap,
noise simulation
magnetic field distortions.



Will mention the efforts to organize the
reconstruction for prototypes, especially the large prototype.

Physics event generation: Phythia

```
File Edit Options Buffers Tools Fortran Help

      IMPLICIT DOUBLE PRECISION(A-H, O-Z)
      COMMON/PYDATR/MRPY(6),RRPY(100)
      ECM=500D0
      NEV=25

      MRPY(1) = 535244
      CALL PYGIVE('MSEL=6')
      CALL PYGIVE('MDME(190,1)=1')
      CALL PYGIVE('MDME(191,1)=1')
      CALL PYGIVE('MDME(192,1)=1')
      CALL PYGIVE('MDME(194,1)=1')
      CALL PYGIVE('MDME(195,1)=1')
      CALL PYGIVE('MDME(196,1)=1')
      CALL PYGIVE('MDME(198,1)=1')
      CALL PYGIVE('MDME(199,1)=1')
      CALL PYGIVE('MDME(200,1)=1')
      CALL PYGIVE('MDME(206,1)=0')
      CALL PYGIVE('MDME(207,1)=0')
      CALL PYGIVE('MDME(208,1)=0')
      CALL PYGIVE('CKIN(1)=170D0')

C...Initialize.
      CALL PYINIT('CMS','e-','e+',ECM)

C...Begin event loop.
      DO IEV=1,NEV
         CALL PYEVNT
         CALL PYHEPC(1)
         CALL PYEDIT(3)

C         call pylist(1)
C         call pylist(5)
*
       CALL HEP2G4
*
      ENDDO
************************************************************
      STOP
      END
************************************************************
      SUBROUTINE HEP2G4
*
* Output /HEPEVT/ event structure to G4HEPEvtInterface
*
* M.Asai (asai@kekvax.kek.jp)  --  24/09/96
*
************************************************************
      PARAMETER (NMXHEP=4000)
      COMMON/HEPEVT/NEVHEP,NHEP,ISTHEP(NMXHEP),IDHEP(NMXHEP),
     &JMOHEP(2,NMXHEP),JDAHEP(2,NMXHEP),PHEP(5,NMXHEP),VHEP(4,NMXHEP)
       DOUBLE PRECISION PHEP,VHEP
*
      WRITE(3,*) NHEP
      DO IHEP=1,NHEP
       WRITE(3,10)
     >  ISTHEP(IHEP),IDHEP(IHEP),JDAHEP(1,IHEP),JDAHEP(2,IHEP),
     >  PHEP(1,IHEP),PHEP(2,IHEP),PHEP(3,IHEP),PHEP(5,IHEP)
10    FORMAT(4I7,4(1X,e15.8))
      ENDDO
*
      RETURN
      END

----:---F1  ttbar.f         (Fortran)--L50--All-------------------
```

run Pythia

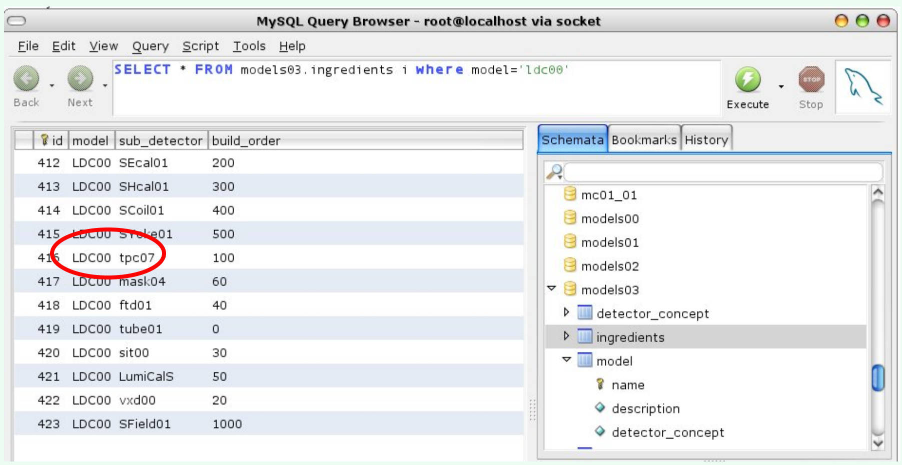
input
- beam parameters
- event type

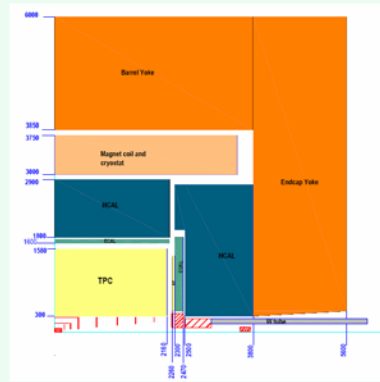
output
- track list
- (escaping interaction)

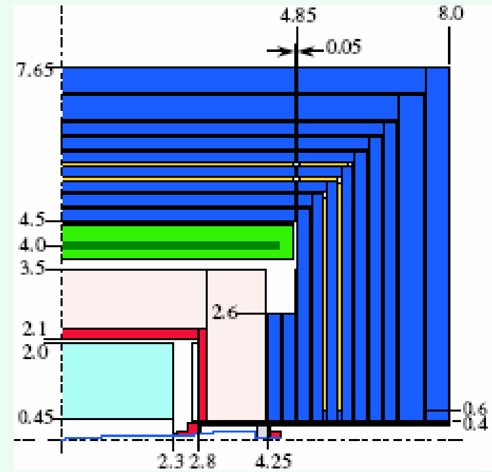
HEPEvt file

```
File Edit Options Buffers Tools Help
    241
      3     11      0      0  0.00000000E+00  0.00000000E+00  0.25000000E+03  0.51000000E-03
      3    -11      0      0  0.00000000E+00  0.00000000E+00 -0.25000000E+03  0.51000000E-03
      3     11      0      0  0.00000000E+00  0.00000000E+00  0.25000000E+03  0.00000000E+00
      3    -11      0      0  0.00000000E+00  0.00000000E+00 -0.25000000E+03  0.00000000E+00
      3     22      0      0 -0.17829929E-02  0.16015685E-02  0.12775856E+03  0.00000000E+00
      3     22      0      0  0.58550442E+00  0.38201003E+00 -0.24608426E+03  0.00000000E+00
      3      6      0      0 -0.24647798E+02 -0.13194629E+02 -0.62364497E+02  0.17467267E+03
      3     -6      0      0  0.25231519E+02  0.13578240E+02 -0.55961203E+02  0.17534621E+03
      3     24      0      0  0.74252779E+00 -0.63110250E+02  0.17110730E+01  0.80533043E+02
      3      5      0      0 -0.25390325E+02  0.49915622E+02 -0.64075570E+02  0.48000000E+01
      3    -24      0      0 -0.24219198E+02  0.56278547E+02 -0.65883854E+02  0.79434259E+02
      3     -5      0      0  0.49450717E+02 -0.42700307E+02  0.99226516E+01  0.48000000E+01
      3     -3      0      0  0.25747972E+01  0.18296894E+02  0.92901511E+01  0.50000000E+00
      3      4      0      0 -0.19043515E+01 -0.80958923E+02 -0.77601768E+01  0.15000000E+01
      3      1      0      0  0.15469427E+02  0.34059998E+02 -0.64044792E+02  0.33000000E+00
      3     -2      0      0 -0.36076792E+02  0.16583274E+02  0.32279444E+01  0.33000000E+00
      1    -11      0      0 -0.58550486E+00 -0.38200963E+00 -0.38840359E+01  0.51000000E-03
      1     11      0      0  0.17834354E-02 -0.16019659E-02  0.12220974E+03  0.51000000E-03
      2     24     31     41  0.67044563E+00 -0.62662029E+02  0.15299742E+01  0.80533043E+02
      2    -24     42     50 -0.20607365E+02  0.50643273E+02 -0.60816847E+02  0.79434259E+02
      1     22      0      0  0.00000000E+00  0.00000000E+00  0.17986604E-06  0.00000000E+00
      1     22      0      0  0.00000000E+00  0.00000000E+00 -0.84483751E-06  0.00000000E+00
      2      5     51     51 -0.26170538E+02  0.49051848E+02 -0.62902817E+02  0.48000000E+01
      2     21     51     51  0.13561144E+00  0.23695952E+00 -0.17238231E+00  0.00000000E+00
      2     21     51     51  0.71668288E+00  0.17859279E+00 -0.81927132E+00  0.00000000E+00
      2     21     51     51  0.34317243E+01  0.11748970E+01 -0.18083539E+01  0.00000000E+00
      2     -2     51     51  0.83372946E+01  0.86743504E+00 -0.66501210E+01  0.33000000E+00
      2     -5     56     56  0.27073362E+02 -0.39470102E+02  0.14309414E+02  0.48000000E+01
      2     21     56     56  0.20473655E+01 -0.73216317E+00 -0.38089648E+00  0.00000000E+00
      2      2     56     56  0.49491384E+01  0.10949010E+01 -0.61439770E+00  0.33000000E+00
      2     -3     61     61  0.16403154E+00  0.14181192E+02 -0.25862490E+01  0.50000000E+00
      2     21     61     61  0.75413396E+00  0.21859169E+01  0.25141042E+00  0.00000000E+00
      2     21     61     61  0.10576886E+01  0.20983988E+00  0.49343197E+00  0.00000000E+00
      2     21     61     61  0.51459828E+00 -0.63271234E+01  0.45635009E+01  0.00000000E+00
      2     21     61     61 -0.68726978E+00 -0.27932701E+01  0.31055057E+01  0.00000000E+00
      2     21     61     61  0.46687514E+00 -0.13775133E+01  0.22304701E+01  0.00000000E+00
      2     21     61     61  0.49682220E+00 -0.24272274E+01 -0.11632552E+01  0.00000000E+00
      2     21     61     61  0.21349508E+00 -0.10469929E+01 -0.18651725E+00  0.00000000E+00
      2     21     61     61  0.36517099E+00 -0.57230713E+01 -0.56185679E+00  0.00000000E+00
      2     21     61     61 -0.41118582E+00 -0.16109961E+02 -0.84867029E+00  0.00000000E+00
      2      4     61     61 -0.22639146E+01 -0.43433818E+02 -0.37677963E+01  0.15000000E+01
      2      1     81     81  0.12842476E+02  0.27006145E+02 -0.51183746E+02  0.33000000E+00
      2     21     81     81  0.21387675E+01  0.60106322E+01 -0.10888082E+02  0.00000000E+00
      2     21     81     81 -0.27060817E+01  0.28763146E+00 -0.11089709E+01  0.00000000E+00
      2     21     81     81 -0.20388544E+01  0.92396742E+00 -0.16125419E+00  0.00000000E+00
      2     21     81     81 -0.12295991E+02  0.72331893E+01  0.40071606E+01  0.00000000E+00
      2     21     81     81 -0.86683864E+01  0.59412562E+01  0.18620327E+01  0.00000000E+00
      2     21     81     81 -0.61692551E+00  0.70082263E+00  0.17196584E+00  0.00000000E+00
      2     21     81     81 -0.63373538E+00  0.46903131E+00  0.26900318E+00  0.00000000E+00
      2     -2     81     81 -0.86286351E+01  0.20705974E+01 -0.37849561E+01  0.33000000E+00
      2     92     52     55 -0.13549224E+02  0.51509732E+02 -0.72352946E+02  0.44527218E+02
      2   -513    100    101 -0.24822642E+02  0.47052483E+02 -0.60212356E+02  0.53248000E+01
      2   -213    102    103 -0.11967437E+01  0.19600567E+01 -0.32728246E+01  0.75288755E+00
      2    213    104    105  0.51623618E+01  0.16936354E+01 -0.28984172E+01  0.79660301E+00
      1   -211      0      0  0.73077994E+01  0.80355710E+00 -0.59693484E+01  0.13957000E+00
      2     92     57     60  0.34069865E+02 -0.39107365E+02  0.13314119E+02  0.20976595E+02
      2  -5122    106    108  0.26937291E+02 -0.38428739E+02  0.14241915E+02  0.56410000E+01
      1   2212      0      0  0.15613661E+01 -0.12961988E+01 -0.23054947E+00  0.93827000E+00
      1   -211      0      0  0.14179357E+01 -0.50434508E+00  0.11552937E+00  0.13957000E+00
      1    211      0      0  0.41532728E+01  0.11219186E+01 -0.81277536E+00  0.13957000E+00
      2     92     62     80  0.67044563E+00 -0.62662029E+02  0.15299742E+01  0.80533043E+02
      2    323    109    110  0.42971771E+00  0.90970890E+01 -0.14995297E+01  0.88274324E+00
      1  -2212      0      0  0.10901986E+00  0.36950425E+01 -0.52813110E+00  0.93827000E+00
      2    213    111    112  0.36904958E+00  0.16236714E+01 -0.31036045E+00  0.83879962E+00
----:---F1  fort.3          (Nroff)--L5--Top-------------------------------------------
```

Detector Simulation: Mokka and Geant

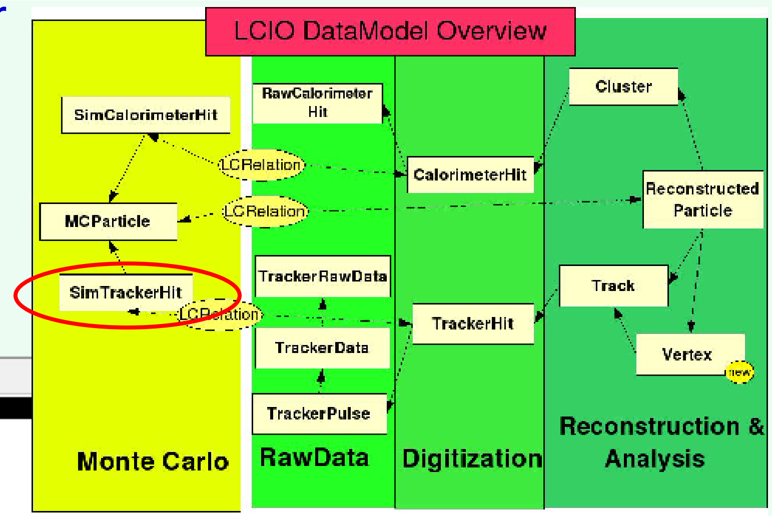






MySQL geometry database describes detector (using a custom geometry, includes tpc07)

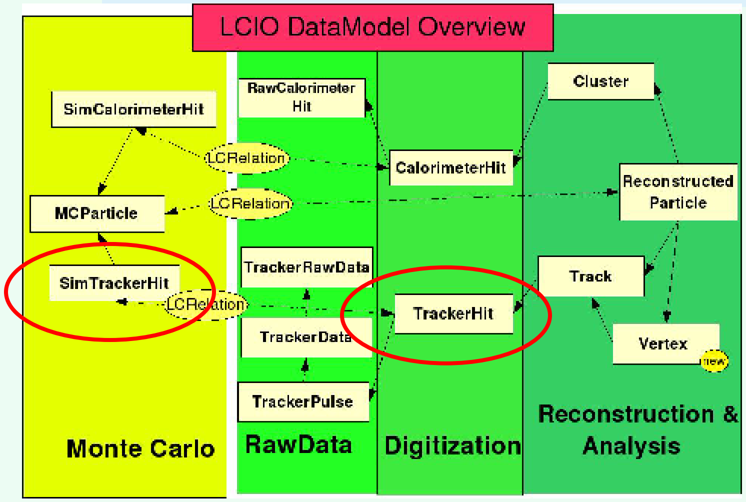
Mokka requires the geometry, HEPEvt file outputs to LCIO, SimTrackerHit simplified geometry GEAR file




```
File Edit View Terminal Tabs Help
File Edit Options Buffers Tools SGML Help
<gear>
    <!--Gear XML file automatically created with GearXML::createXMLFile ....-->
    <detectors>
        <detector name="TPC" geartype="TPCParameters">
            <driftVelocity value="0.000000" />
            <maxDriftLength value="2497.500000" />
            <readoutFrequency value="0.000000" />
            <PadRowLayout2D type="FixedPadSizeDiskLayout" rMin="386.000000" rMax="1626.000000" padHeight="6.000000" padWidth="2.000000" maxRow="206" padGap="0.000000" />
        </detector>
    </detectors>
</gear>
```

CORNELL UNIVERSITY LEPP
LABORATORY FOR ELEMENTARY-PARTICLE PHYSICS

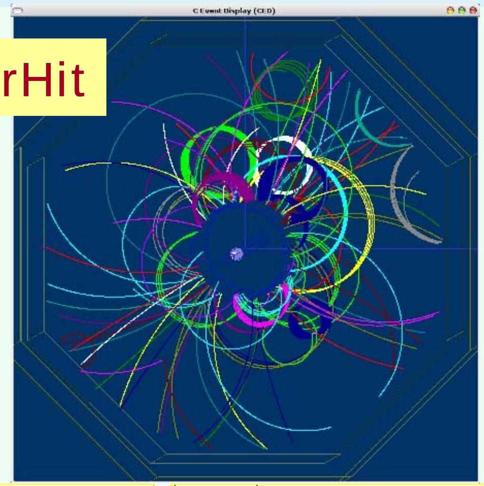
Reconstruction, Analysis, Visualization: Marlin

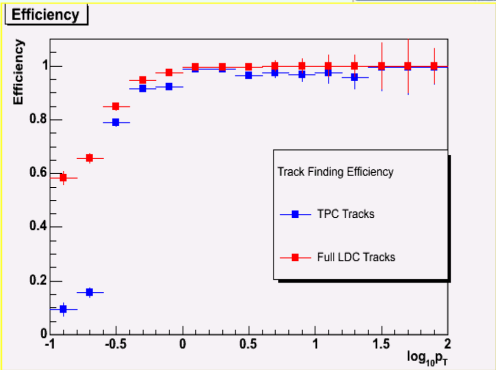


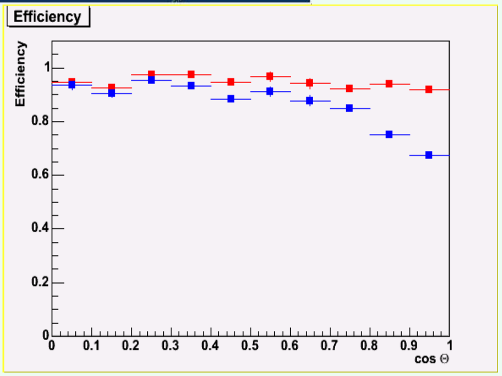
Marlin requires
  LCIO and GEAR files
  specification of processors

```
File  Edit  View  Terminal  Tabs  Help
File Edit Options Buffers Tools SGML Help
<marlin>
 <execute>
  <processor name="GenericViewer"/>
 </execute>

 <global>
  <parameter name="LCIOInputFiles"> ttbar_large_step.slcio  </parameter>
  <parameter name="SupressCheck" value="true" />
  <parameter name="GearXMLFile"> gear_ldc.xml </parameter>
 </global>

 <processor name="GenericViewer" type="GenericViewer">
 <!--Drawing Utility-->
  <!--Layer for Sim Tracker Hits-->
  <parameter name="LayerSimTrackerHit" type="int">1</parameter>
  <parameter name="SimTrackerHitCollections" type="StringVec">tpc07_TPC STpc01_TPC </parameter>
</processor>

</marlin>
```

SimTrackerHit







TPCDigiProcessor (Gaussian smearing)

TPCTrackerHits

Full reconstruction,
95% efficiency in TPC

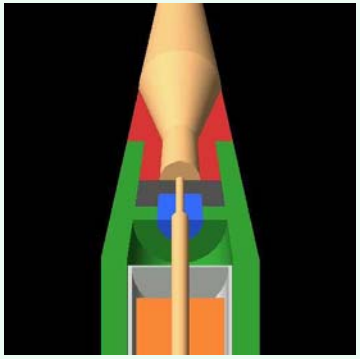
A. Raspereza, MPI, Valencia 2006

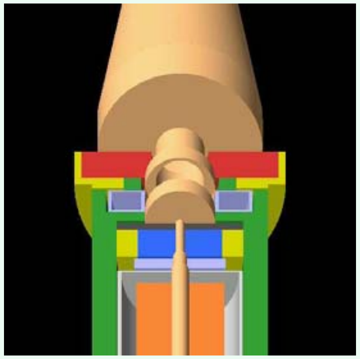
S. Alpin, DESY, Cambridge 2006

Simulate radiation in the TPC **in Mokka**

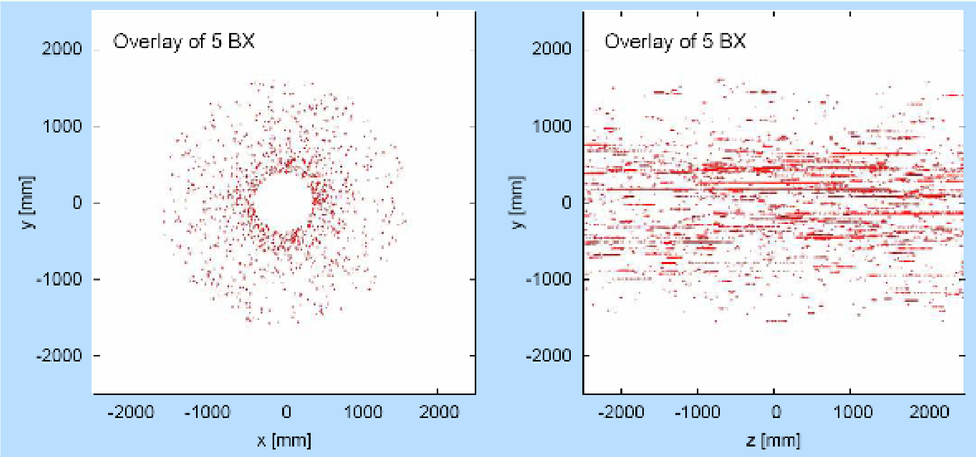
Realistic noise

Input
- TESLA TDR/Stahl beam parameters
- Guinea Pig pairs from 5 simulated beam crossings
- different geometries and magnetic fields
- neutron production enabled in Geant 4



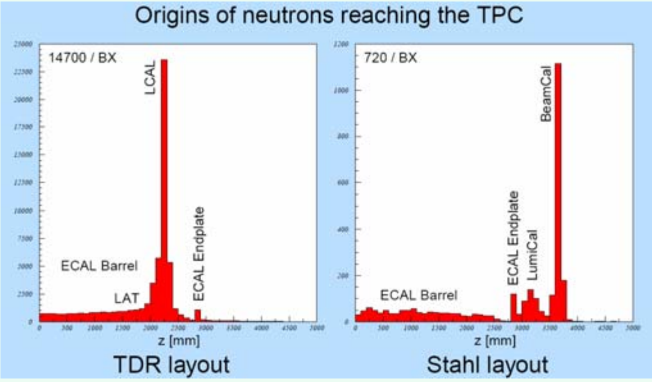


Output
- write out hits on all detectors to LCIO files
- monitor all particles entering the TPC



future:
- overlay beam background hits
  - on physics events

A. Vogel, DESY, Vienna 2005

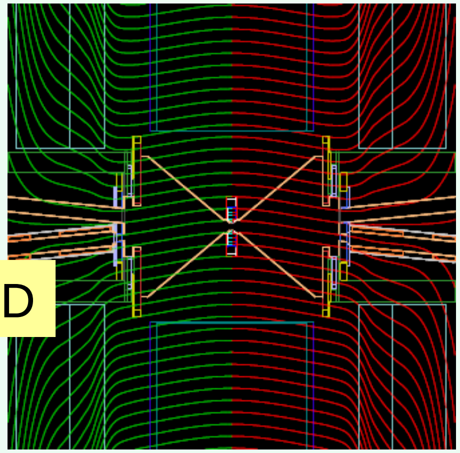


Magnetic Field Distortions

Magnetic field distortions
 change the trajectory of particles
 Primary Particles
 drifting electrons in the TPC

The field must be mapped -
 Hall probe
 Then use data to find corrections.

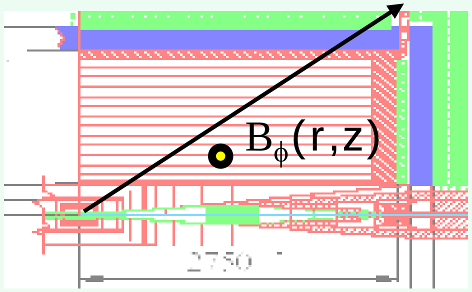
distortions due to DID



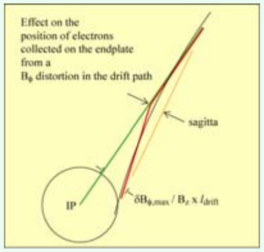
J. Abernathy, Victoria, Vancouver 2006

$dB/B_z < 2 \times 10^{-5}$ is required

Simulation is implemented using Mokka
 Allows parameters to be stored in a MySQL database
 and accessed with drivers
 Gas composition, Geometry, Field distortion

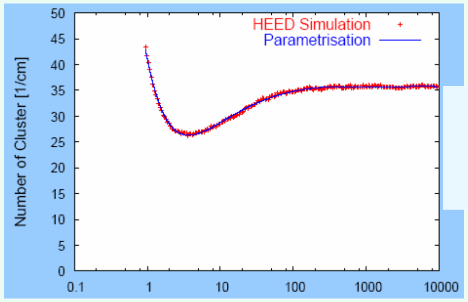


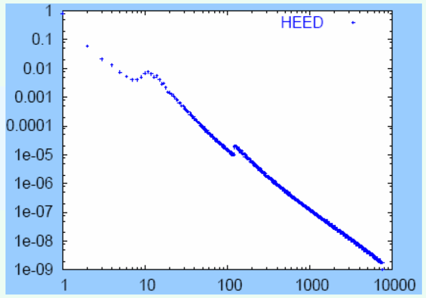
Reconstruction is within Marlin
 Modular pieces are being developed in parallel
 Signal calibration
 Pattern recognition / Seed Track
 TrackFitterLikelihood (Victoria)



D. Peterson, Cornell, Snowmass 2005

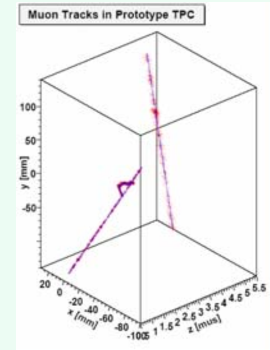
Detector response and digitization full simulation

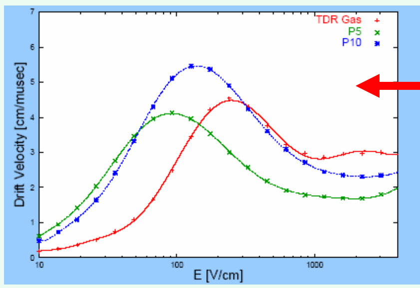




(1) primary ionization:
clusters and cluster size,
track trajectory

ionization in drift volume

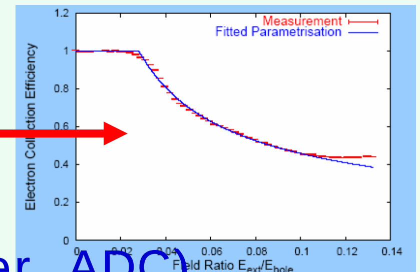


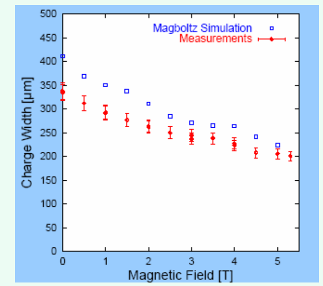


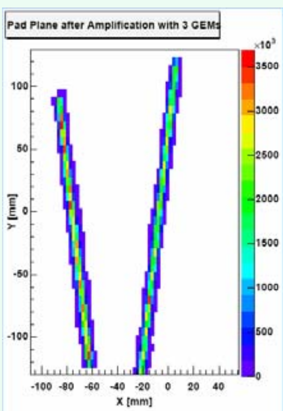
(2) drift the electrons to the readout

(3) properties of GEM
gas amplification
transmission, width

(4) electronics (shaper, ADC)





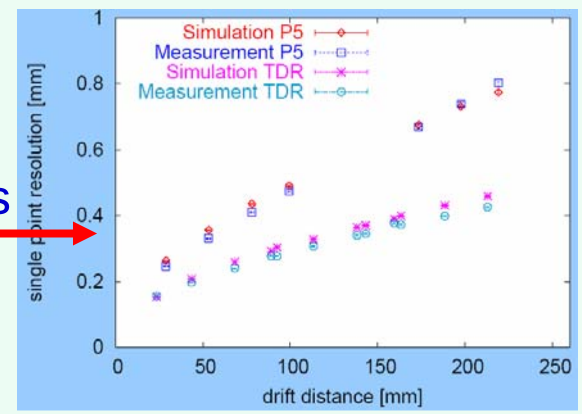


resulting simulated pad response

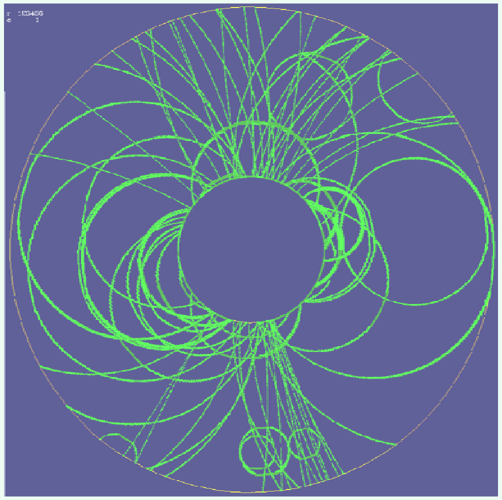
duplication of prototype measurements

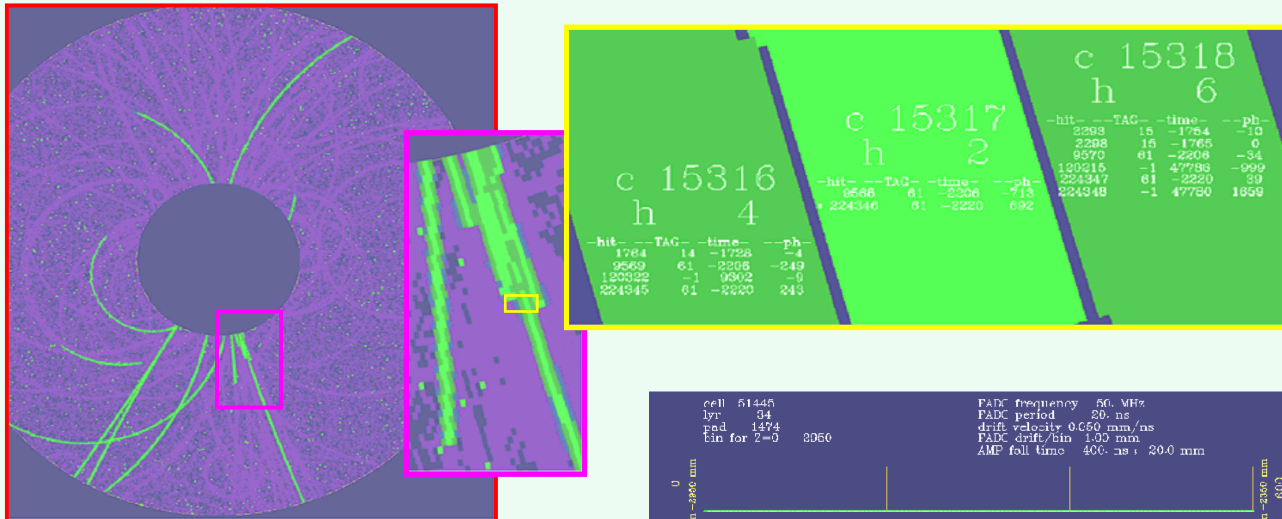
future parameterization in Mokka

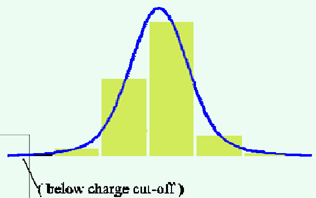
A. Münnich, Aachen, Valencia 2006

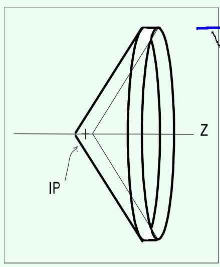


Simulation of signal overlap

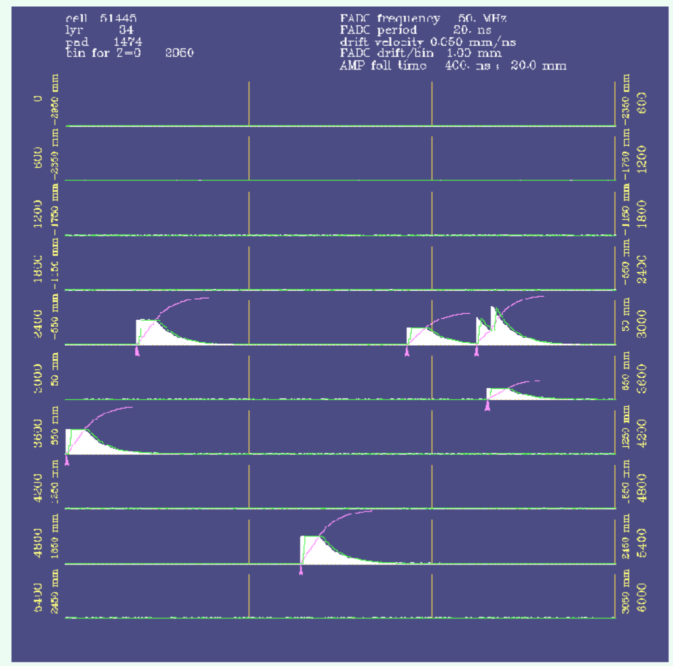






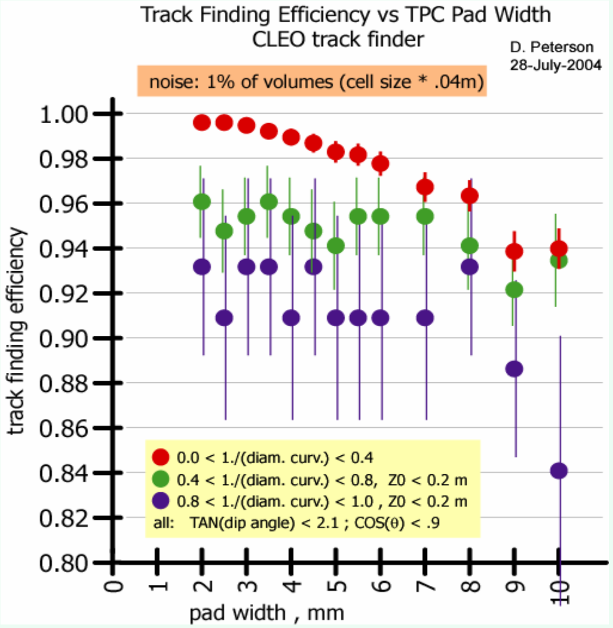


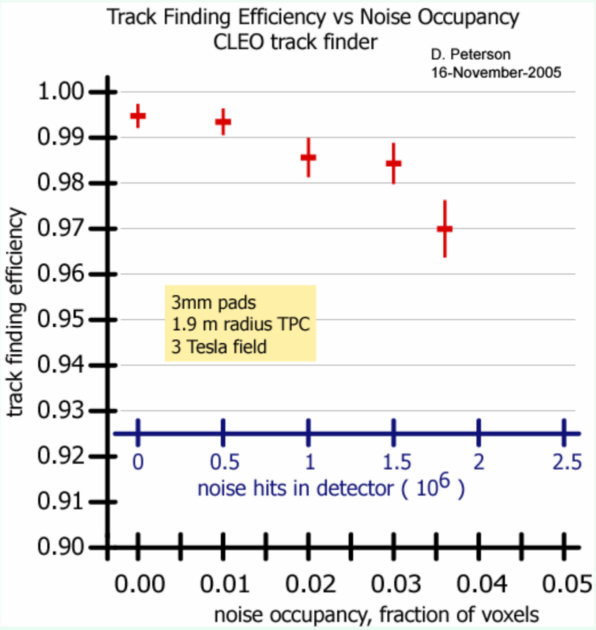
A cone with +/- 4.7 cm is "active"



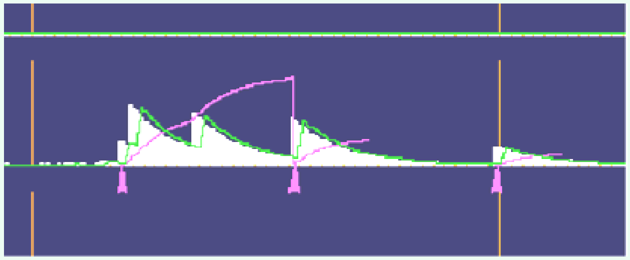
Simulated "ionization centers"
Gaussian spreading pad distribution function
Multiple hits on pads
Create FADC time response for each pad
  Future: implementation in Marlin

Results of reconstruction



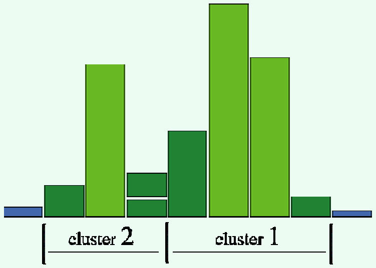


Reconstruction …
in time
in rϕ



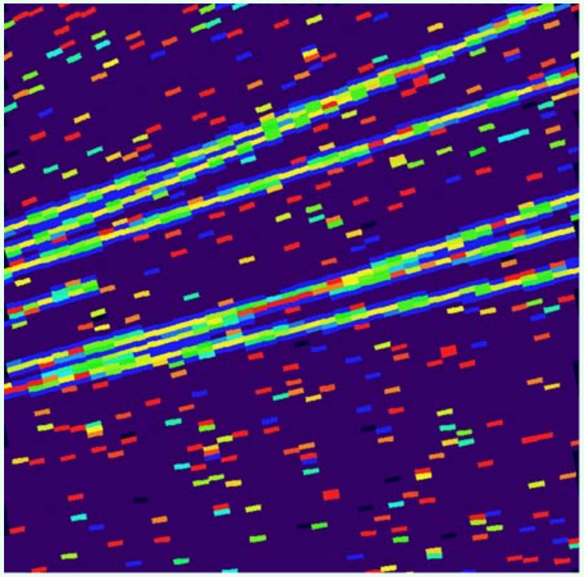
99.5% efficiency

3 mm pads sufficient
(Resolution is the determining factor for pad size)



2.5% loss in efficiency
with
3.6% voxel occupancy

~21% of hits
are touched by noise



D. Peterson, Cornell, Vienna 2005

Improvements in hit creation: Mokka

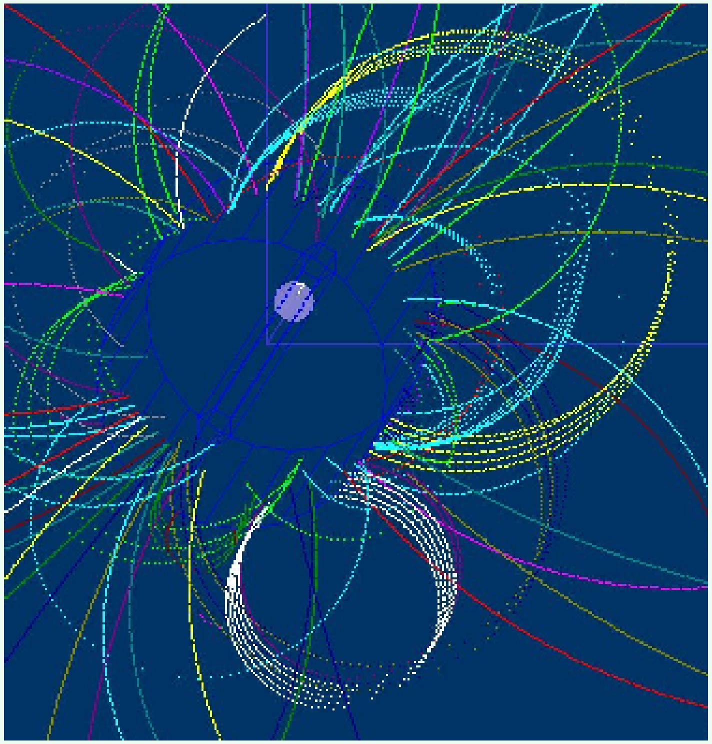
Mokka creates TPC hits

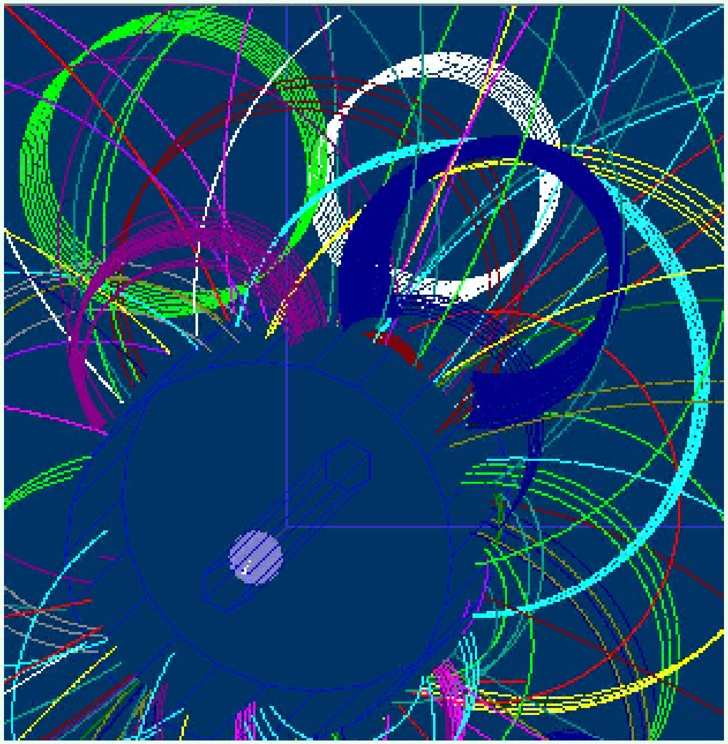
A. Vogel, DESY

previously intersections of track helixes with idealized detector cylinders

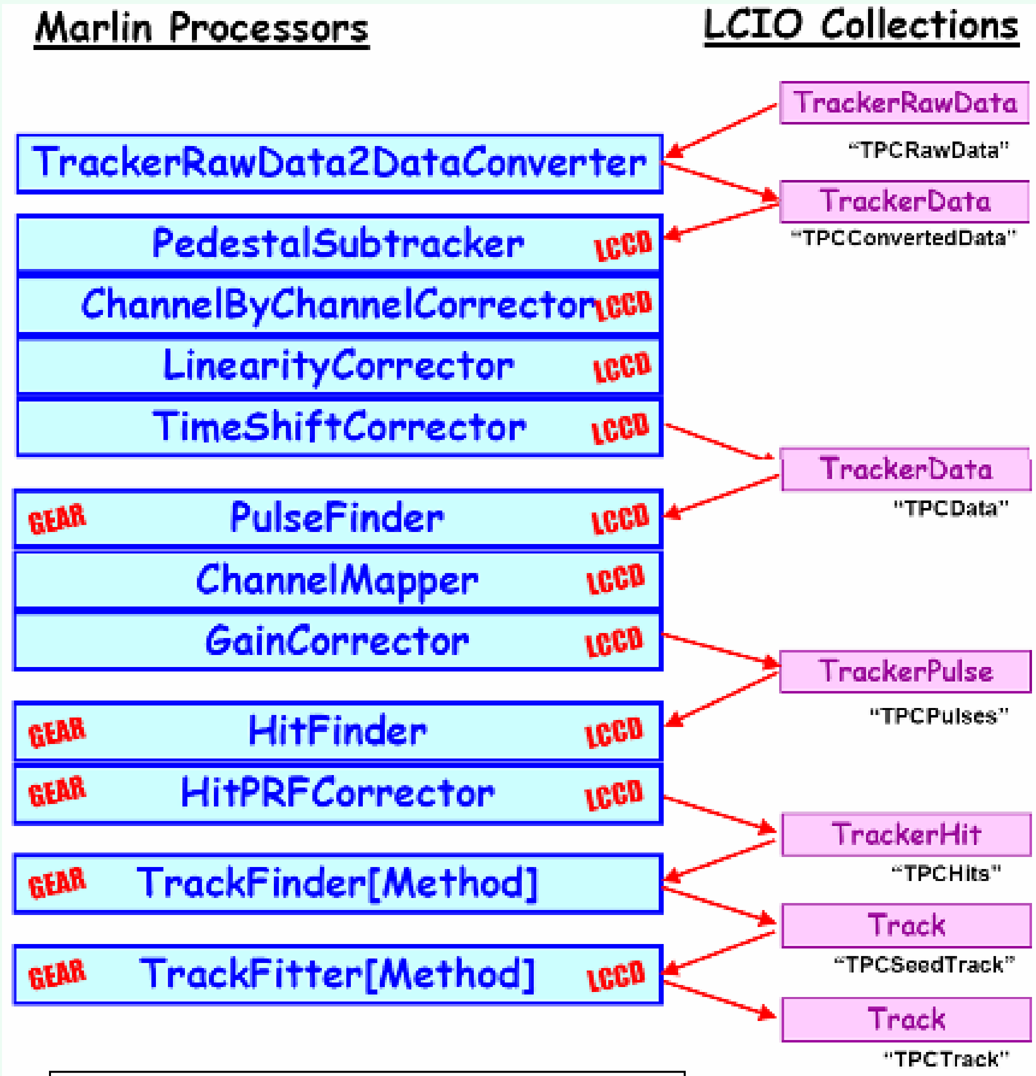
now equally spaced points in material, true “ionization centers”

needed for implementation of the signal overlap treatment in Marlin, which has been started





Beginnings of an Organized Analysis



C. Hansen, Victoria, Vancouver 2005

Currently:
within the TPC community
diversity of simulation
reconstruction
analysis

Starting a common framework
for Large Prototype
to some extent, small prototypes

Large effort with groups in
Germany and Canada

Marlin Processors
GEAR for static information
LCCD for conditions data
(the things we often call
"constants", which are not)

Conclusions

GEM readout:

- resolution goal demonstrated with 1.2 mm pads,
  probably 1.5 mm pads can be used with more diffusion defocusing
- resolution goal at full drift requires a gas mixture
  with lower transverse diffusion in the drift field
- consider a gate to reduce the ion feedback
- consideration of a GEM gate requires understanding of the transparency

GEM endcap tracker

- tests of a large prototype and development of curved foils, this year

Software

- developed frameworks for simulation and reconstruction
  in both Europe and Asia
- working on sophisticated simulations to address detailed TPC design
- organized analysis in development