A Time Projection Chamber for physics at the International Linear Collider

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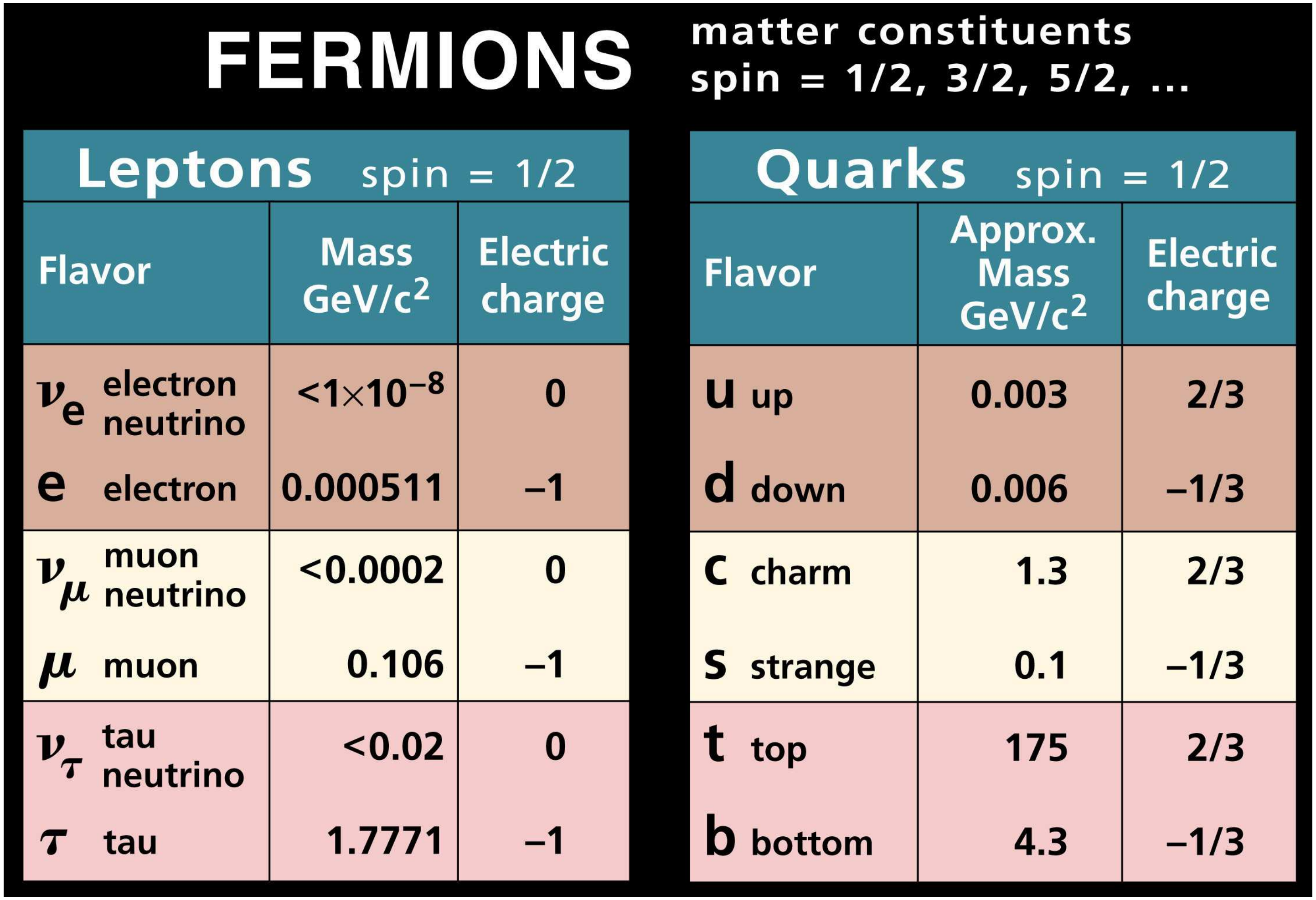
The ILC - the next high energy physics accelerator after the LHC

- New Physics discoveries appear imminent with the startup of the CERN Large Hadron Collider (LHC) this Summer
- ILC will be the next world facility for particle physics after the LHC.
- The ILC physics case & its experiments
- TPC R&D for the ILC charged particle tracker
- Outlook

An overview

- Electromagnetism & the weak nuclear force are unified by the electroweak (EW) Standard Model: $SU(2) \times U(1)_Y$
- Electroweak symmetry is broken to give particles masses. An understanding of EW symmetry breaking could help explain the origin of mass through the existence of the Higgs particle
- Cosmic connections:
  - ❑ solve the dark matter problem through existence of super-symmetry (SUSY)
  - ❑ unify the strong nuclear force and gravity with electroweak force
  - ❑ provide information about additional hidden space-time dimensions
- Many hints for new physics at TeV level. The CERN Large hadron Collider should help unravel some of these mysteries

The Standard Model - The Fundamental Particles



FERMIONS

matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2

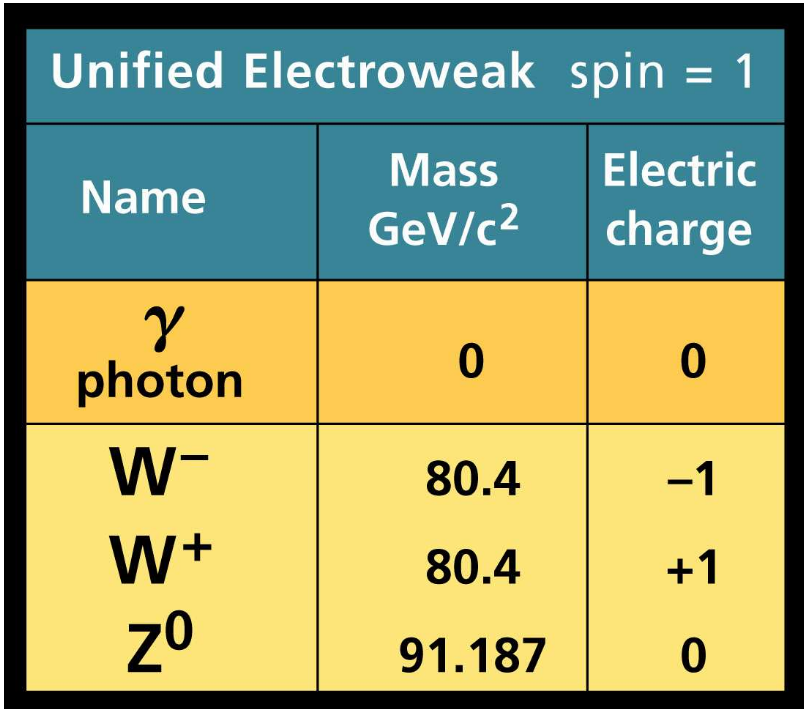
Flavor		Mass GeV/c^2	Electric charge
ν_e	electron neutrino	$<1\times10^{-8}$	0
e	electron	0.000511	–1
ν_μ	muon neutrino	<0.0002	0
μ	muon	0.106	–1
ν_τ	tau neutrino	<0.02	0
τ	tau	1.7771	–1

Quarks spin = 1/2

Flavor		Approx. Mass GeV/c^2	Electric charge
u	up	0.003	2/3
d	down	0.006	–1/3
c	charm	1.3	2/3
s	strange	0.1	–1/3
t	top	175	2/3
b	bottom	4.3	–1/3

The Bosons of the Standard Model

Electroweak force is carried by vector bosons



Unified Electroweak spin = 1		
Name	Mass GeV/c^2	Electric charge
γ photon	0	0
W^-	80.4	–1
W^+	80.4	+1
Z^0	91.187	0

A Scalar Higgs field (spin=0) provides mass to particles

Start with one complex doublet (4 field components)

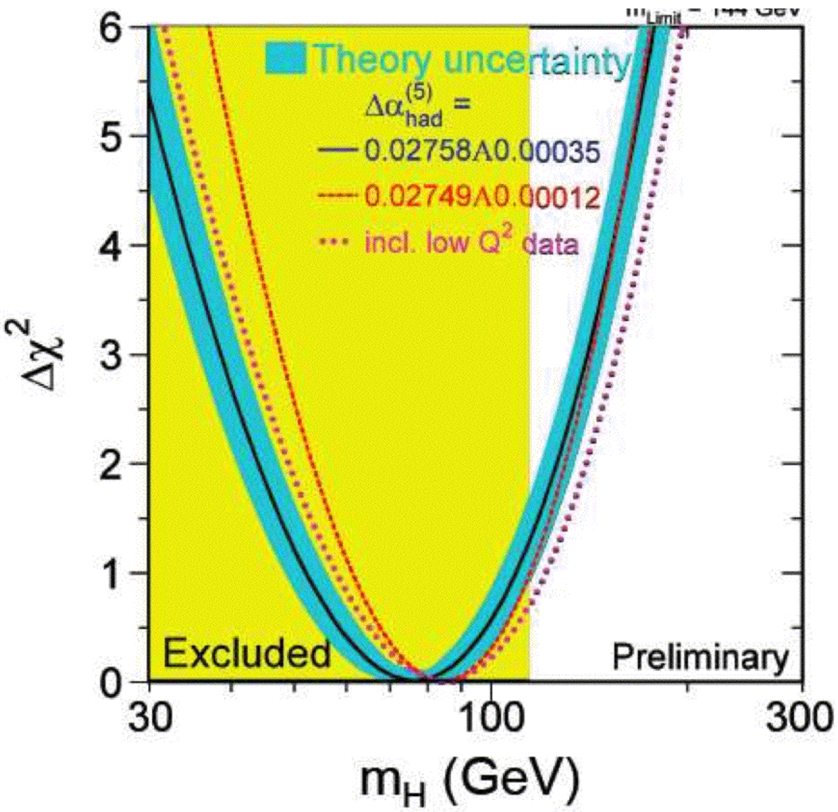
3 field components "eaten" by W^+, W^- & Z^0 to acquire masses

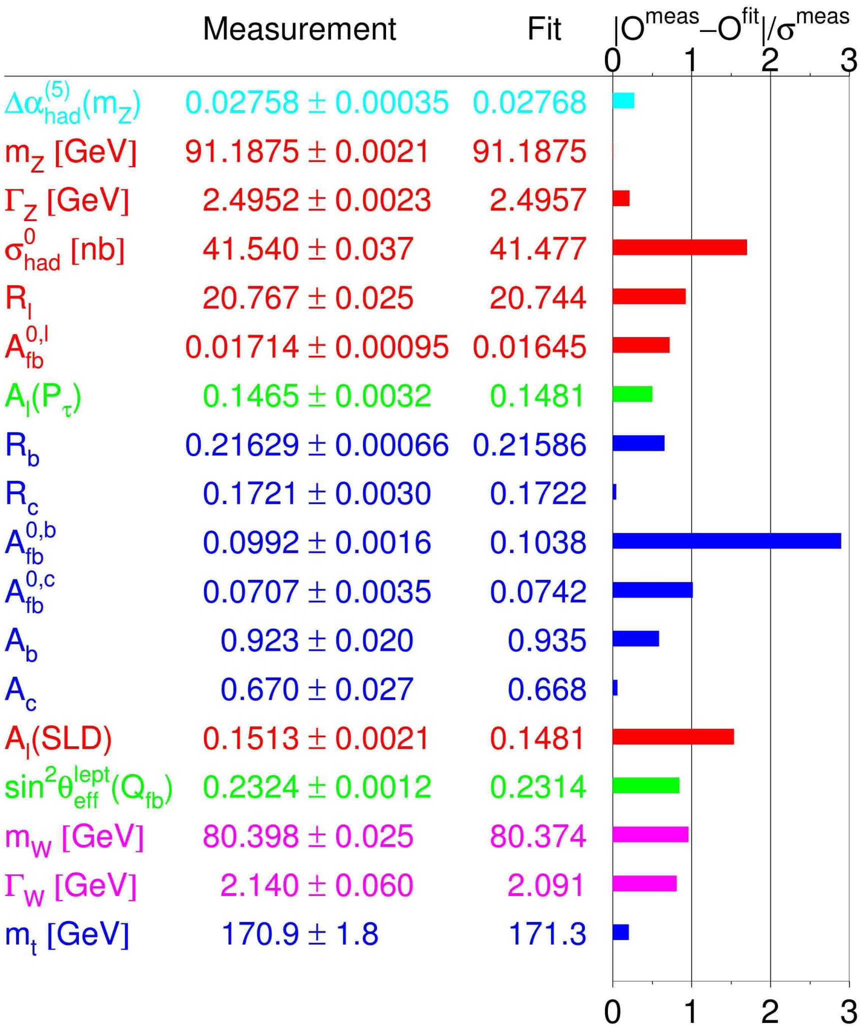
A single neutral scalar particle H^0 remains

SM internally consistent and in agreement with experiments within ~ 0.1%.

The fundamental scalar H^0 responsible for EW symmetry breaking remains undiscovered

Higgs constraints from precision SM fits



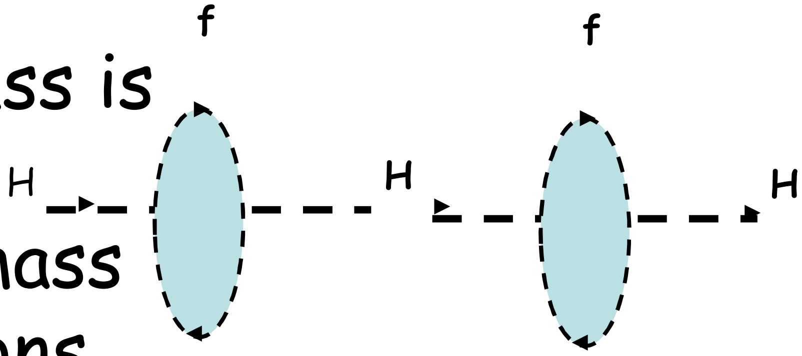


	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02768
m_Z [GeV]	91.1875 ± 0.0021	91.1875
Γ_Z [GeV]	2.4952 ± 0.0023	2.4957
σ^0_{had} [nb]	41.540 ± 0.037	41.477
R_l	20.767 ± 0.025	20.744
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01645
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1481
R_b	0.21629 ± 0.00066	0.21586
R_c	0.1721 ± 0.0030	0.1722
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1038
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1481
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.398 ± 0.025	80.374
Γ_W [GeV]	2.140 ± 0.060	2.091
m_t [GeV]	170.9 ± 1.8	171.3

$114.4 < M_{Hi} < 144$ GeV
from LEP exclusion & SM fits
M_t & M_W from CDF & D0

Indicators of New Physics at TeV level

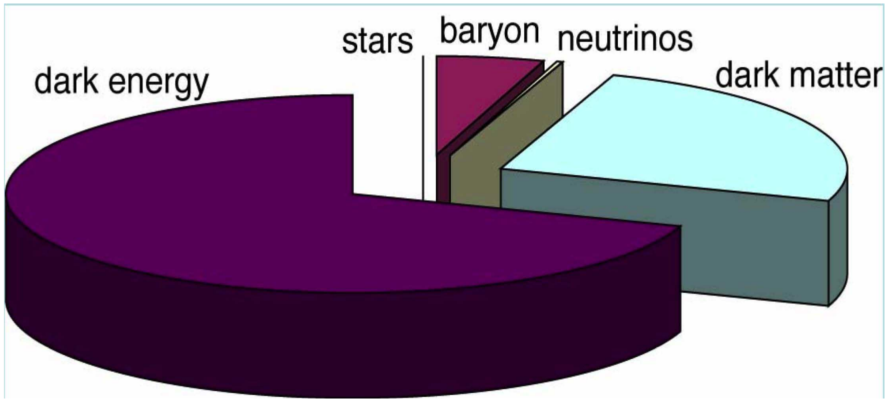
- ☐The predicted SM Higgs mass is unexpectedly low ~ 100 GeV
- ☐M_H ~ 10^{19} GeV near Planck mass from large radiative corrections
- ☐Low Higgs mass requires term by term cancellation of divergences



- ▪Fine-tuning to cancel divergences is unnatural
- ▪With Supersymmetry at ~ 1 TeV, super-particle loops naturally cancel particle loop divergences

- If no Higgs below ~ TeV, New Strong Interactions among W Z bosons needed to restore unitarity.

Cosmological indicators of New Physics at Tev level



❑Existence of Dark Matter (DM) is well established.

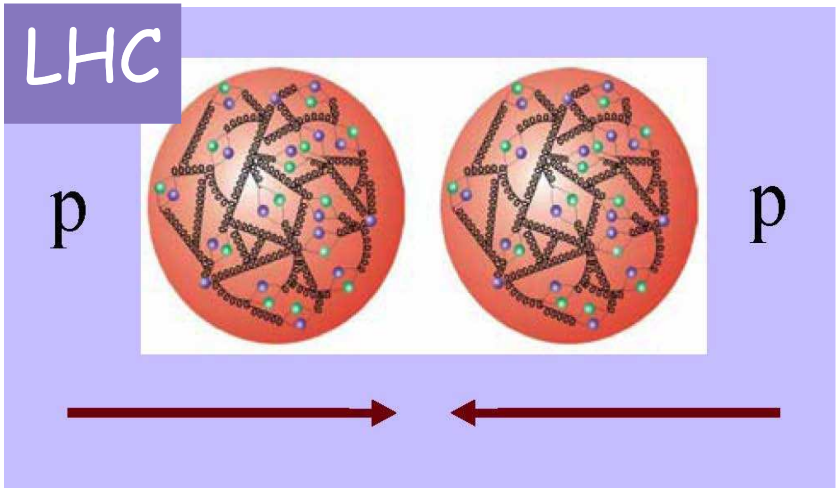
~ 1 TeV Weakly Interacting Massive particles (WIMP) could account for the observed DM density.
Can WIMP be the lowest mass SuperSymmetric particle?

❑How to Unify gravity with other forces?

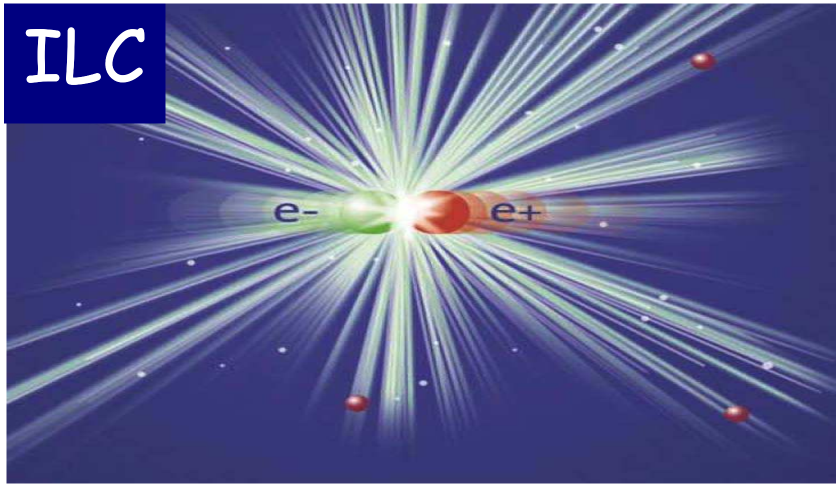
Motivates String theory & Extra Dimensions

TeV physics with the LHC & with the ILC

- Parton-parton (quarks & gluons) collisions at 14 TeV
- Centre of mass collision energy & quantum numbers ill defined.
- High backgrounds, but with higher mass reach, can discover new physics directly

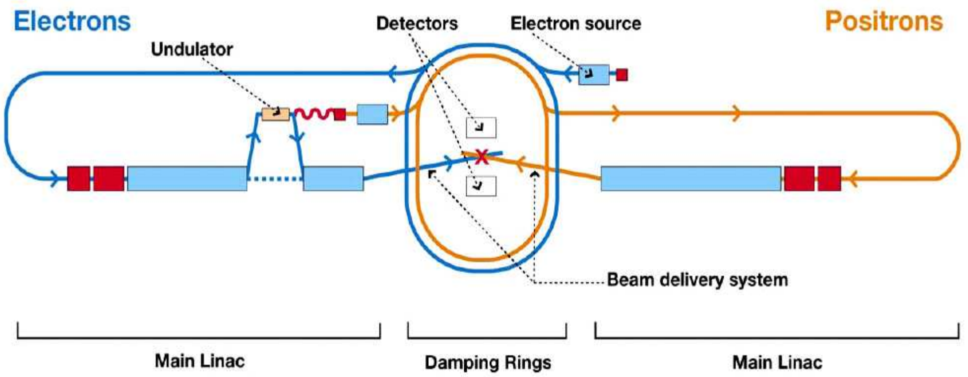


- Clean 0.5-1 TeV $e^+ e^-$ collisions
- E_{CM} & initial state quantum numbers well defined & tunable
- Polarization to select specific states & suppress backgrounds
- A powerful tool to probe New Physics



The International Linear Collider ILC

ILC



$e^+ e^-$ Linear Collider E_{cm} adjustable from 200 – 500 GeV

Two experiments, complementary & contrasting technologies

Single interaction region, 14 mrad crossing angle

Luminosity → $\int Ldt = 500\ \text{fb}^{-1}$ in 4 years

Ability to scan between 200 and 500 GeV

Energy stability and precision below 0.1%

Electron polarization at least 80%

The machine upgradeable to 1 TeV

ILC sensitivity to New Physics

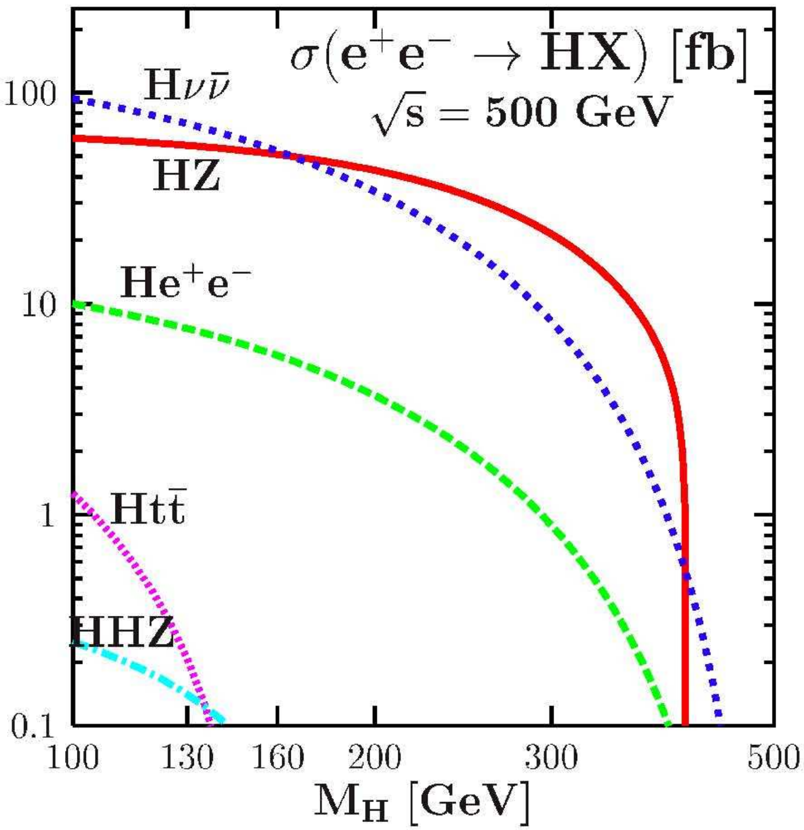
The LHC has higher mass reach, but precision makes ILC the ultimate probe of new physics

- ILC physics menu:
  - The nature of electromagnetic symmetry breaking & detailed study of the Higgs
  - Supersymmetry, its mass spectrum & parameters
  - New gauge interactions
  - Extra dimensions
  - Precision measurements
    - $\Delta M_{Top} \approx$ 100 MeV, $\Delta\Gamma_{Top} \approx 2\%$
    - ΔM_Z & $\Delta M_W \approx$ 5 MeV (from 30 MeV)
    - $\Delta(\sin^2\vartheta) \approx 10^{-5}$ (from $2 \cdot 10^{-4}$)
- LHC & ILC Complementary
- Essential to understanding the New Physics

Model independent Higgs studies at ILC

- Detailed precision measurements
- Establish spin, parity (SM Higgs 0^+)
- Measure decay modes to discriminate between SM and SuperSymmetric Higgs
- Higgs couplings to gauge bosons & to itself to confirm its role in EW symmetry breaking

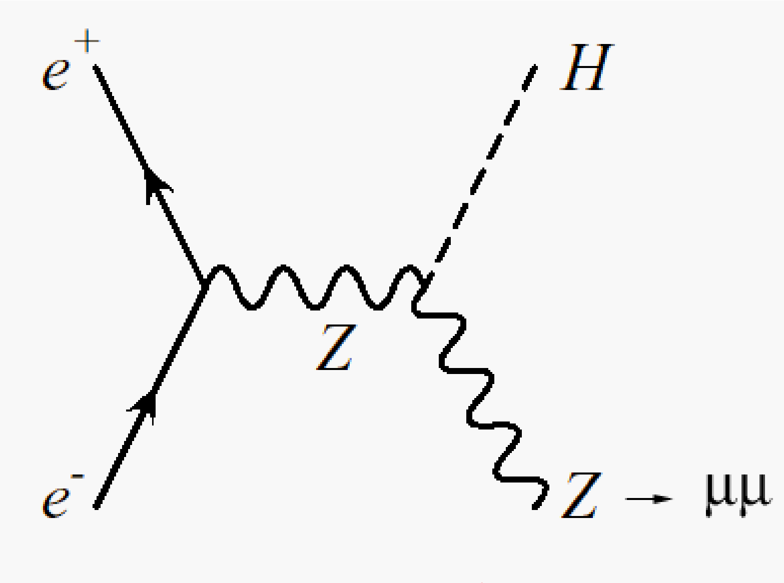
Higgs production at the ILC



ILC RDR, arXiv:0709.1893

ttH kinematically limited at 500 GeV ILC

Higgsstraulung - the Golden channel for Higgs studies



$e+ \; e- \to ZH$

$Z \to \mu+ \; \mu- \; ; \; e+ \; e-$

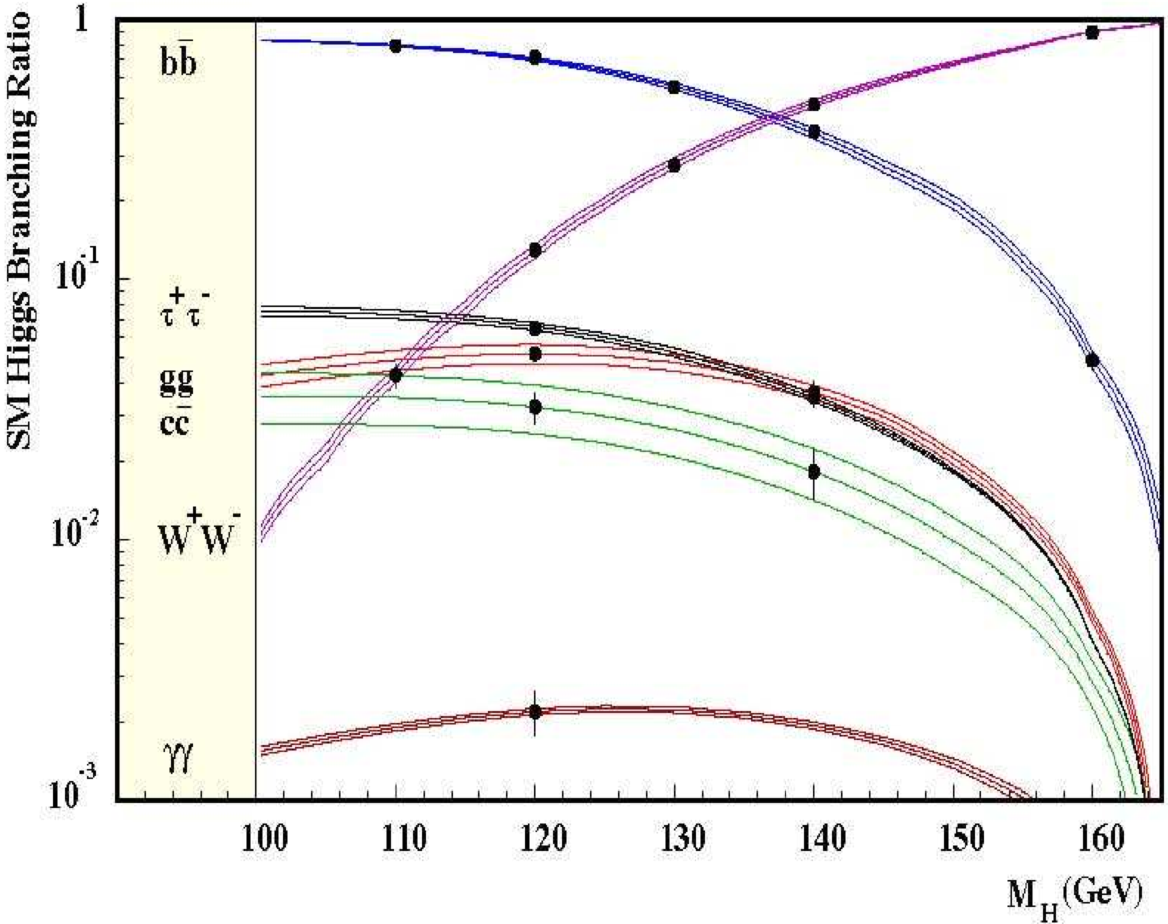
Evidence of new physics if the Higgs production rate differs from the Standard Model prediction

I. Measure Higgs mass & production rates independent of decay modes - includes even invisible Higgs decays
II. Enables detailed studies with tagged Higgs
III. Fully establish Higgs mechanism!
IV. The ultimate Higgs factory

Some examples….

Measurements of Higgs production couplings, decay branching ratios (from ILC RDR)

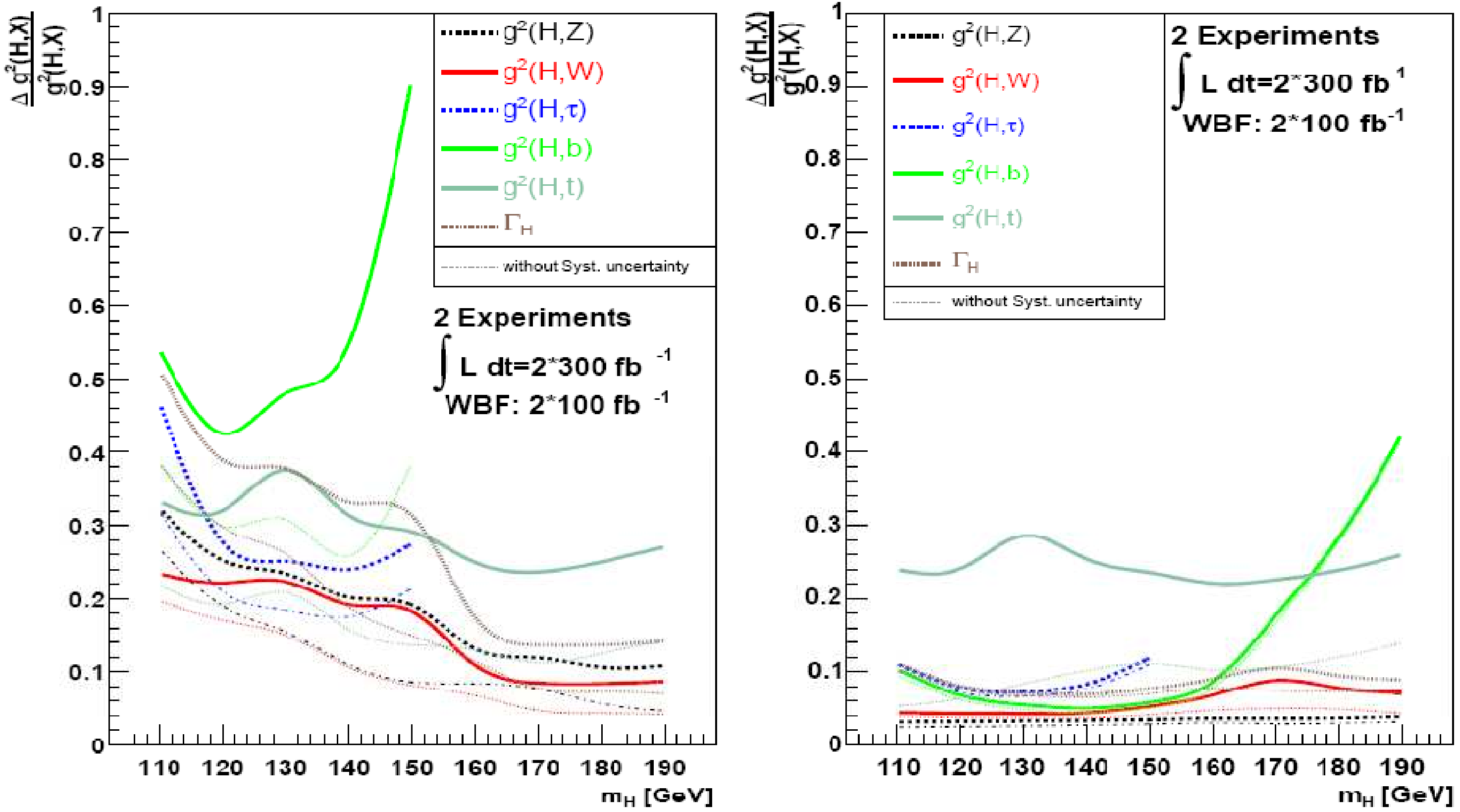
Decay	Rel. precision (%)
b b	1.0-2.4
c c	8.1-12.3
τ τ	4.6-7.1
g g	4.8-10
W W	3.6-5.3
γ γ	23 - 35



Makes possible model independent extraction of Higgs couplings, constraining non SM Higgs - not possible at LHC

LHC-ILC interplay on Higgs couplings

LHC + mild model assumptions **LHC+ILC model independent**



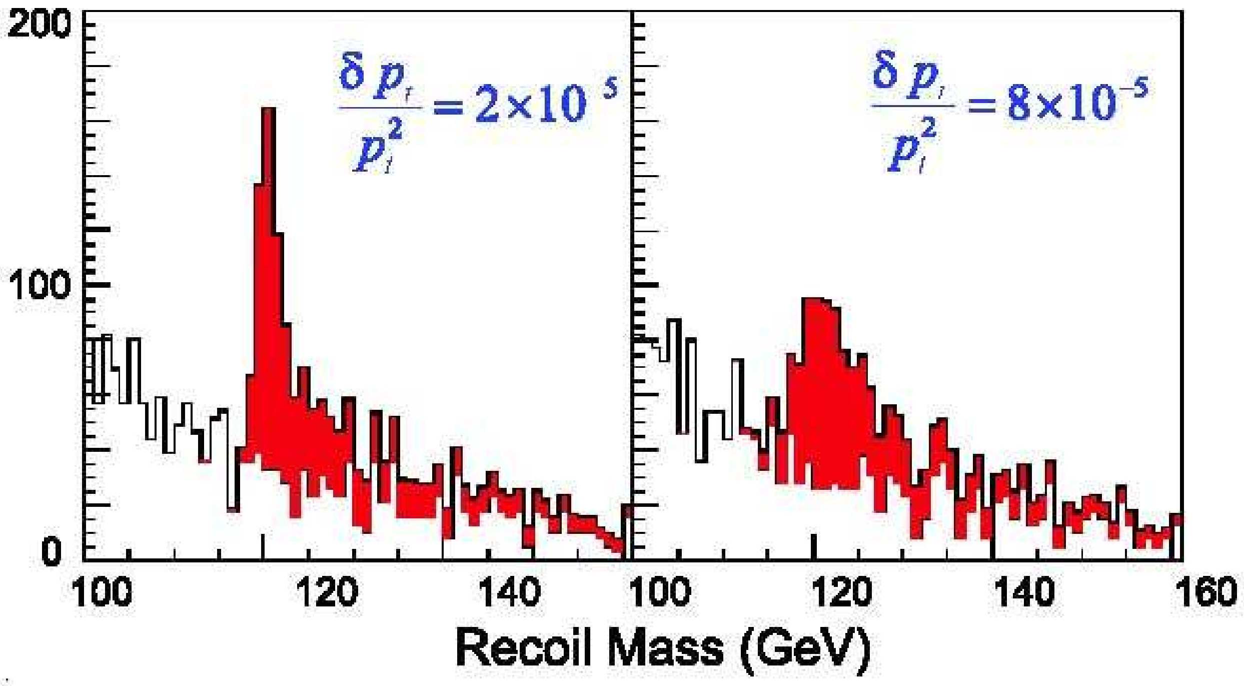
KD, Dührssen, Heinemyer, Logan, Rainwater, Weiglein, Zeppenfeld - preliminary

Precision mostly dominated by ILC. ttH coupling better than LHC alone due to ILC input to LHC fit.

The ILC goal is to measure Higgs with precision limited only by the knowledge of beam energy

Puts unprecedented demands on the tracker momentum resolution

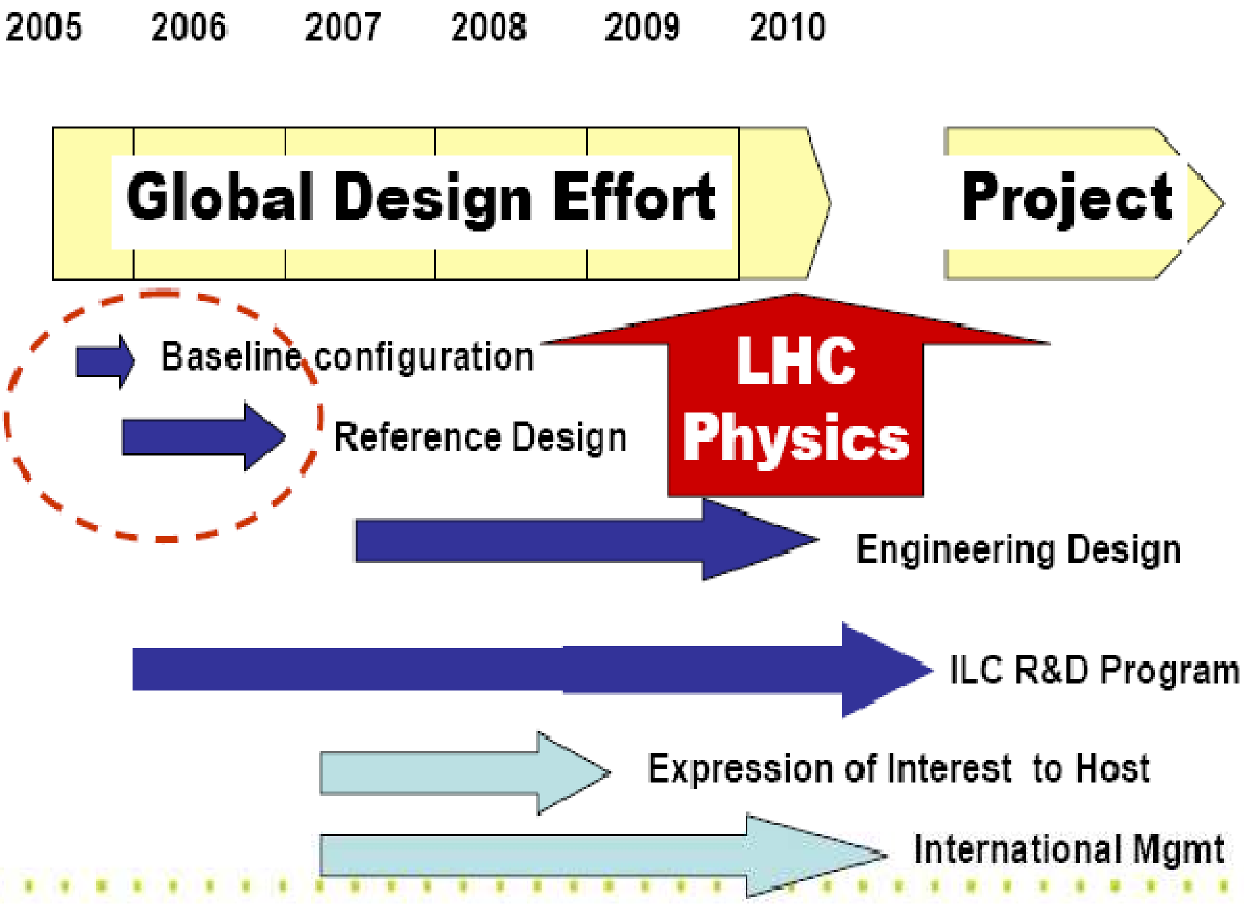
$\Delta(1/p_T)$ ~ 2 to 3 x10^{-5} $(GeV/c)^{-1}$ more than 10 times better than at LEP!



$\mu^+ \mu^-$ recoil mass at $\sqrt{s}$ = 500 GeV. M_H = 120 GeV, for two values of the tracker resolution.

Original

The GDE Plan and Schedule



2005 2006 2007 2008 2009 2010

Global Design Effort

Project

LHC Physics

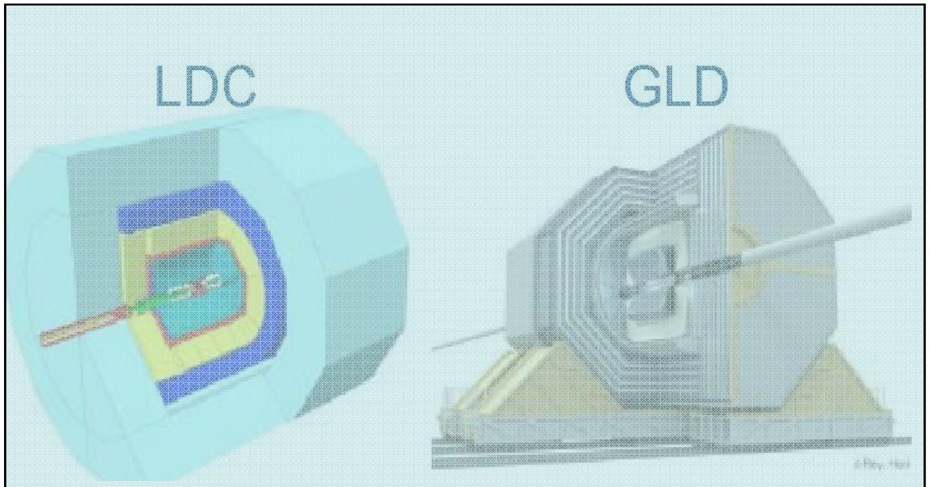
- Baseline configuration
- Reference Design
- Engineering Design
- ILC R&D Program
- Expression of Interest to Host
- International Mgmt

Including Detectors

December, 2007

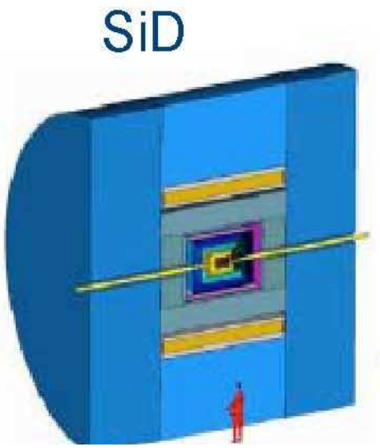
- The UK terminates ILC R&D support
- The US ILC budget reduced by Conngress to 25% of President's request. Money already spent.
- Aftermath: Cutbacks & layoffs at Fermilab & SLAC
  - Revised ILC schedule
  - How to maintain momentum
  - Focus on critical R&D items
  - Prepare for LHC results
  - Scientific case for ILC still valid

The three ILC Detector Concepts
2 propose using Time Projection Chamber Trackers

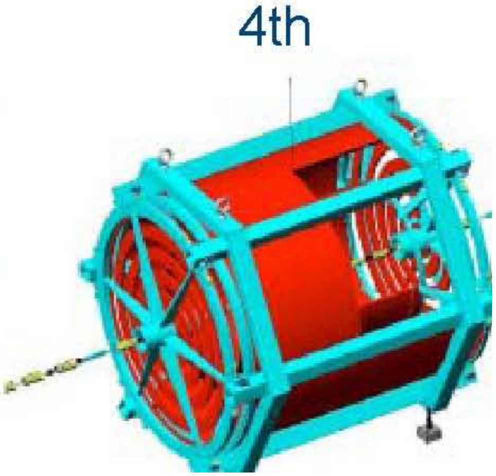


TPC (B=4T)

TPC (B=3T)



Silicon (B=5T)



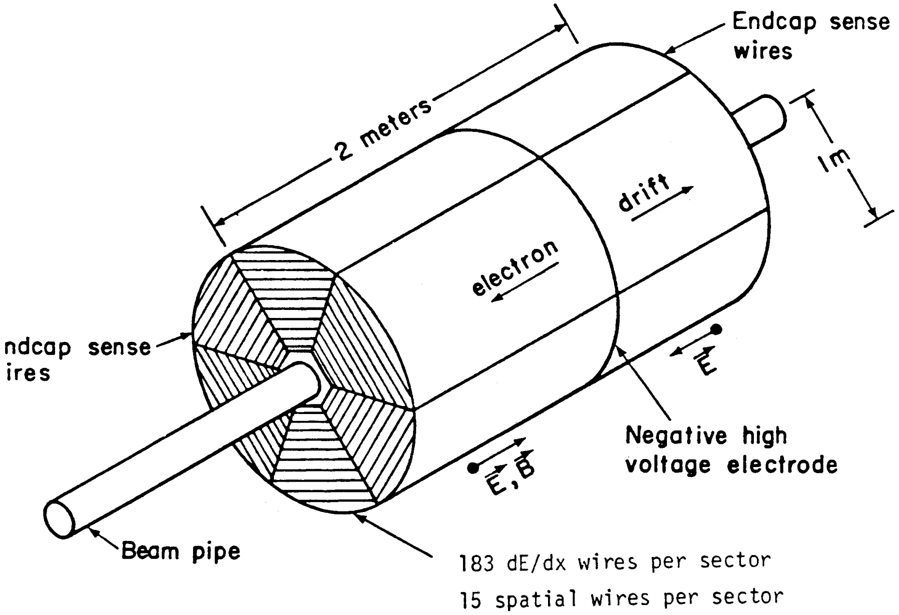
TPC (B=3.5 T)

International Large Detector (ILD)

- LOI (Letters of Intent) by 31 March 2009
- LsOI evaluated by IDAG for a Technical Design Proposal
- The collaborations to produce Engineering Design Reports (EDRs) by 2012

MWPC Readout Time Projection Chamber (TPC)

Nygren (1984)



(M.D. Shapiro, thesis, 1984)

- Large gas filled cylinder with parallel **B** and **E** fields along axis
- Ionization trail along particle tracks
- Ionization electrons drift at constant speed under electric field to both ends of TPC
- TPC endcap proportional wires read out the signal
- z => electron drift time

r => anode wire position

ϕ =>cathode pads

A TPC tracker for the ILC

TPC an ideal central tracker for ILC

- Low mass, minimal photon conversion
- High efficiency, high granularity continuous tracking,
- Excellent pattern recognition,
- Particle ID
  - $\Delta(1/p_T) \sim 1 \times 10^{-4}$ (GeV-1) (TPC alone)
  - $\sim 3.10^{-5}$ (GeV-1) (vertex + Si inner tracker + TPC)

TPC parameters:

- 200 track points
- **$\sigma(r, \varphi) \leq 100\ \mu m$ includes stiff 90° tracks ~ 2 m drift**
- $\sigma(z) \sim 1$ mm
- $\sigma_{2\ track}(r, \varphi) \sim 2$ mm
- $\sigma_{2\ track}(z) \sim 5$ mm
- dE/dx ~ 5%

Conventional TPCs never achieve their potential!

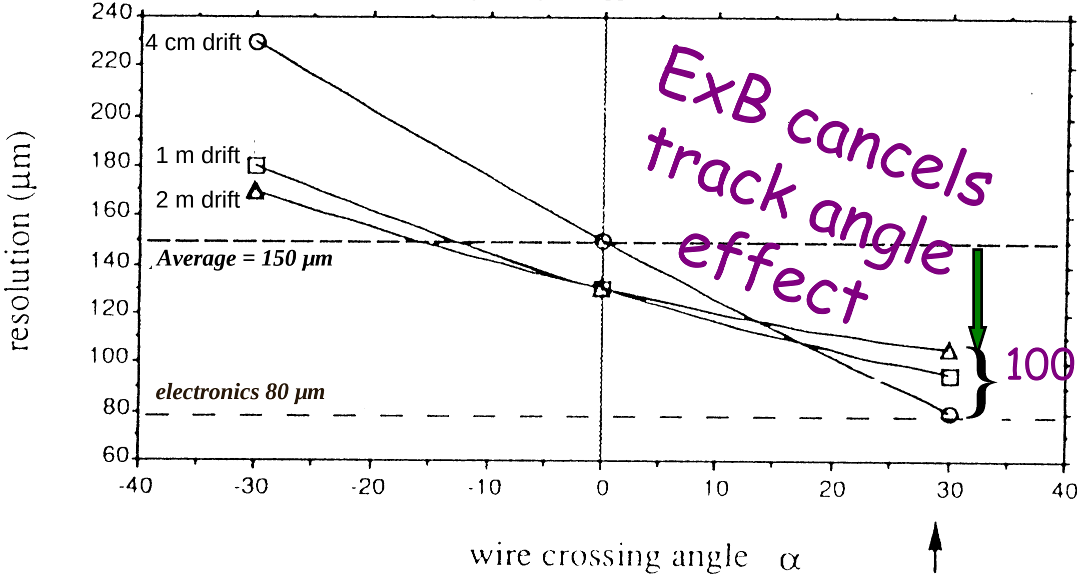
Example:Systematic effects in Aleph TPC at LEP

S.R. Amendolia et al. / The spatial resolution of the ALEPH TPC

Nuclear Instruments and Methods in Physics Research A283 (1989) 573–577

North-Holland, Amsterdam

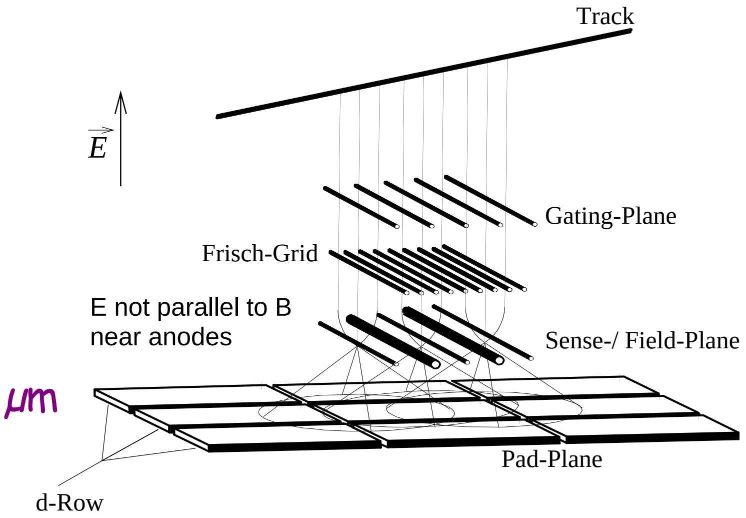
ExB and wire crossing angle effects dominate TPC resolution



ExB cancels track angle effect

100 μm

TPC wire/pad readout



- Average Aleph resolution ~ 150 μm
- About 100 μm best for all drift distances
- Limit from diffusion σ (10 cm drift) ~ 15 μm; σ (2 m drift) ~ 60 μm
- 100 μm limit for all drift distances comes from wide pad response

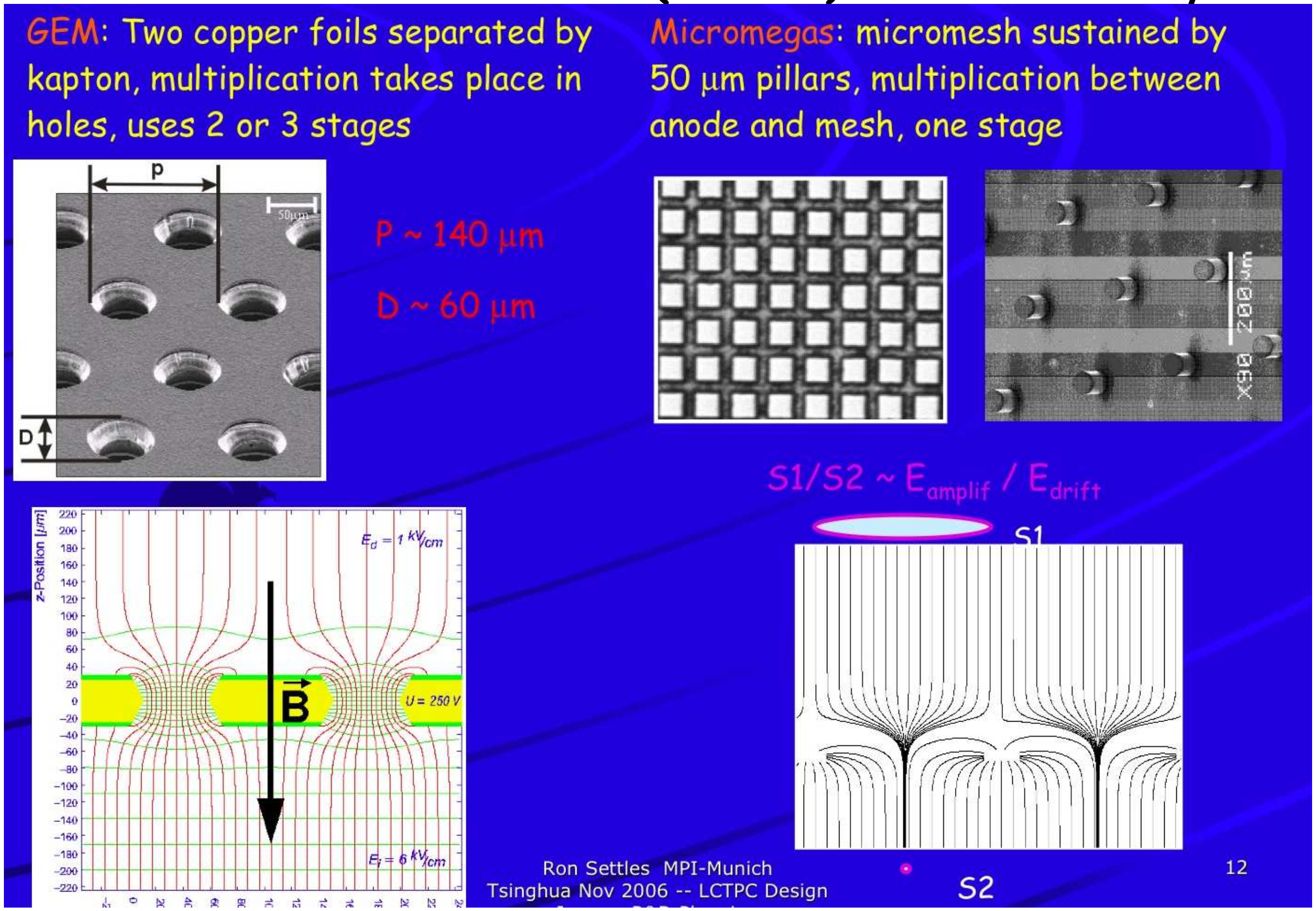
An improved high performance TPC for ILC

- Large systematic effects cannot be avoided in a conventional wire readout TPC
- Even when systematics cancel, resolution worse than diffusion
- A micro-pattern gas detector (MPGD*) readout TPC has
  - Negligible ExB effects
  - Feasibility of achieving resolution close to the fundamental limit from physics of diffusion

* Such as Gas Electron Multiplier (GEM), Micromegas

ILC challenge: σ_{Tr} ~ 100 μm (all tracks 2 m drift)

Classical anode wire/cathode pad TPC limited by ExB effects
Micro Pattern Gas Detectors (MPGD) not limited by ExB effect



GEM: Two copper foils separated by kapton, multiplication takes place in holes, uses 2 or 3 stages

P ~ 140 μm

D ~ 60 μm

Micromegas: micromesh sustained by 50 μm pillars, multiplication between anode and mesh, one stage

S1/S2 ~ E_{amplif} / E_{drift}

Ron Settles MPI-Munich
Tsinghua Nov 2006 -- LCTPC Design

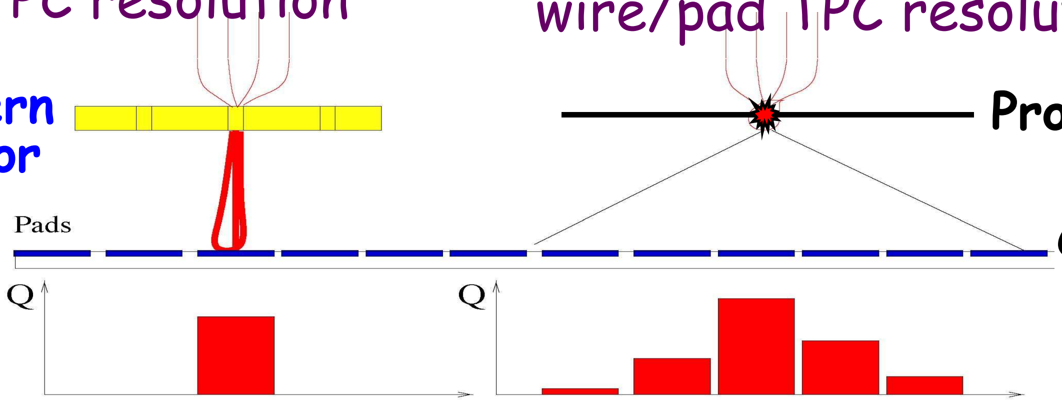
Worldwide R&D to develop MPGD readout for the ILC TPC

Limits on achievableTPC resolution

- The physics limit of TPC resolution comes from transverse diffusion: $\sigma_x{}^2 \approx \frac{D_{Tr}^2 \cdot z}{N_{eff}}$ N_{eff} = effective electron statistics.
- For best resolution, choose a gas with smallest diffusion in a high B field

Pad width limits the MPGD TPC resolution

ExB systematics limits wire/pad TPC resolution



Micro Pattern Gas Detector

Anode pads width w

Proportional wire

Cathode pads width w

Direct signal on MPGD anode pads

Induced cathode signal determined by geometry

For small diffusion, less precise centroid for wide pads

Accurate centroid determination possible with wide pads

$$\sigma_x{}^2 \approx \sigma_0{}^2 + \frac{1}{N_{eff}}\left[D_{Tr}^2 z + w^2/12\right]$$

$$\sigma_x{}^2 \approx \sigma_0{}^2 + \frac{D_{Tr}^2 \cdot z}{N_{eff}}$$

Micro-Pattern Gas Detector development for the ILC TPC

- TESLA TPC TDR : 2 mm x 6 mm pads (1,500,000 channels) with GEMs or Micromegas
- LC TPC R&D: 2 mm pads too wide with conventional readout
- For the GEM ~ 1 mm wide pads (~3,000,000 channels)
- Even narrower pads would be needed for the Micromegas

Improving MPGD resolution without resorting to narrower pads

- Disperse track charge after gas gain to improve centroid determination with wide pads.
- For the GEM, large transverse diffusion in the transfer & induction gaps provides a natural mechanism to disperse the charge.
- No such mechanism for Micromegas
- The GEM readout will still need ~ 1 mm wide pads to achieve ~ 100 μm ILC resolution goal

Charge dispersion on a resistive anode - a mechanism to disperse the MPGD avalanche charge. It makes position sensing insensitive to pad width.

The technique works for both the GEM and the Micromegas

Finding the avalanche position on a proportional wire

Charge division on a proportional wire

Telegraph equation (1-D):

$$\frac{L}{R}\frac{\partial^2 Q}{\partial t^2} + \frac{\partial Q}{\partial t} = \frac{1}{RC}\frac{\partial^2 Q}{\partial x^2}$$

Deposit point charge at t=0

Solution for charge density (L ~ 0)

$$Q(x,t) = \sqrt{\frac{RC}{4\pi t}}\, e^{\frac{-x^2 RC}{4t}}$$

Generalize charge division to charge dispersion in 2D

Finding the avalanche location on a MPGD resistive anode surface

Telegraph equation 2-D generalization

$$\frac{\partial Q}{\partial t} = \frac{1}{RC}\left[\frac{\partial^2 Q}{\partial r^2} + \frac{1}{r}\frac{\partial Q}{\partial r}\right]$$

Solution for charge density in 2-D

$$Q(r,t) = \frac{RC}{2t}\, e^{\frac{-r^2 RC}{4t}}$$

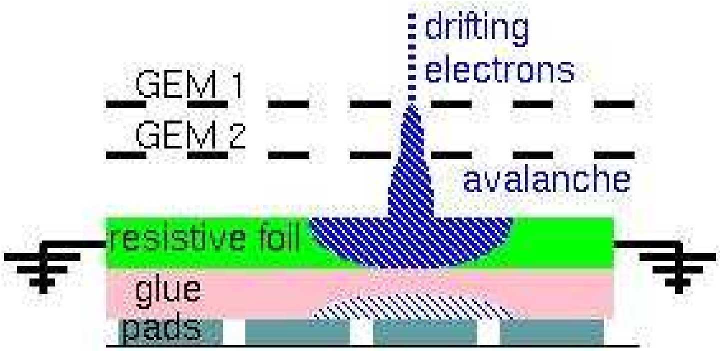
Charge dispersion in a MPGD with a resistive anode

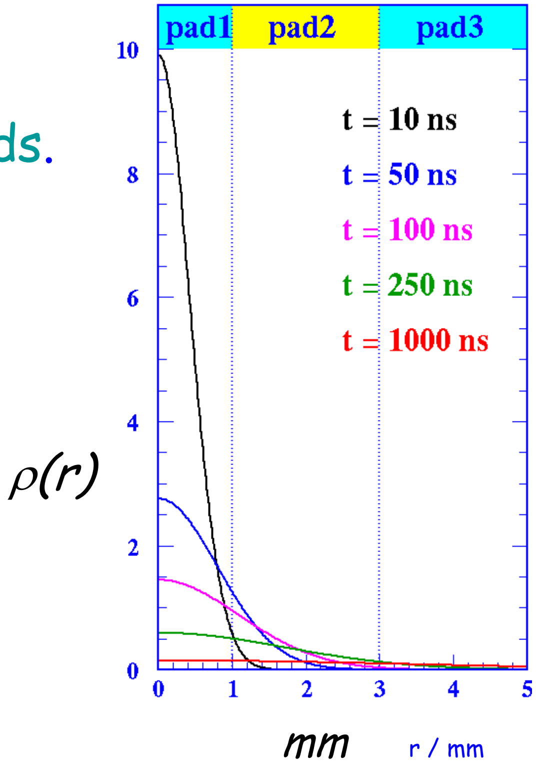
- Modified GEM anode with a high resistivity film bonded to a readout plane with an insulating spacer.
- 2-dimensional continuous RC network defined by material properties & geometry.
- Point charge at r = 0 & t = 0 disperses with time.
- Time dependent anode charge density sampled by readout pads.

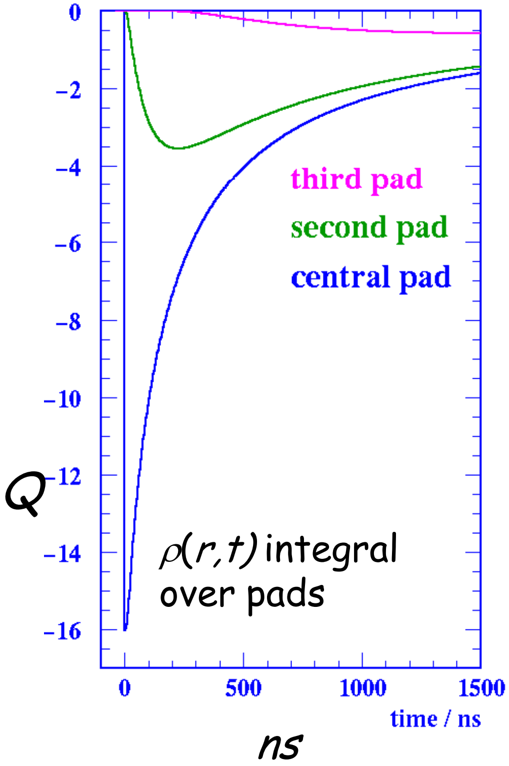
Equation for surface charge density function on the 2-dim. continuous RC network:

$$\frac{\partial\rho}{\partial t}=\frac{1}{RC}\left[\frac{\partial^2\rho}{\partial r^2}+\frac{1}{r}\frac{\partial\rho}{\partial r}\right]$$

$$\Rightarrow \rho(r,t)=\frac{RC}{2t}e^{\frac{-r^2RC}{4t}}$$

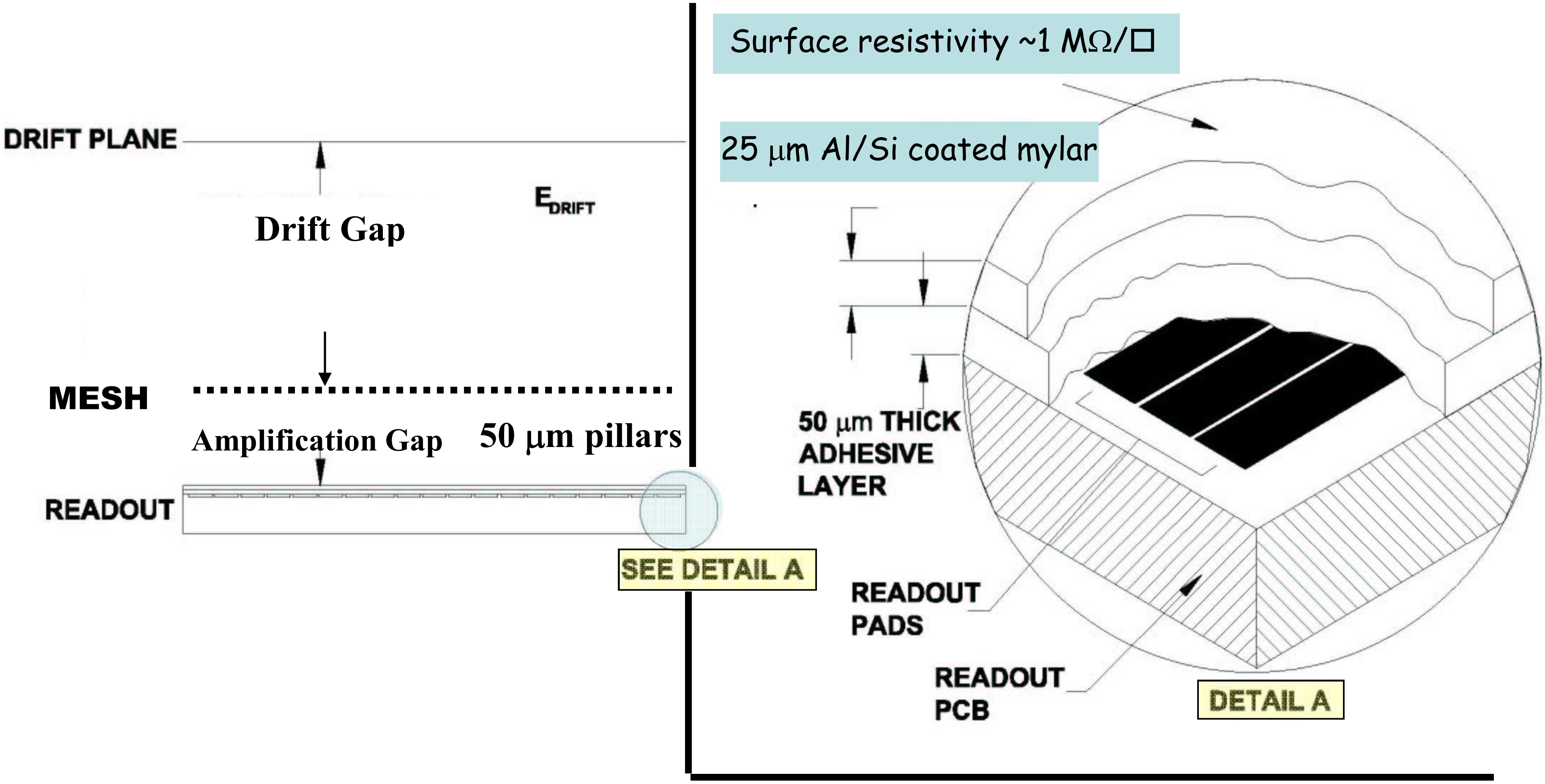






M.S.Dixit et.al., Nucl. Instrum. Methods A518 (2004) 721.

Micromegas resistive anode readout structure



Readout PCB with resistive anode

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

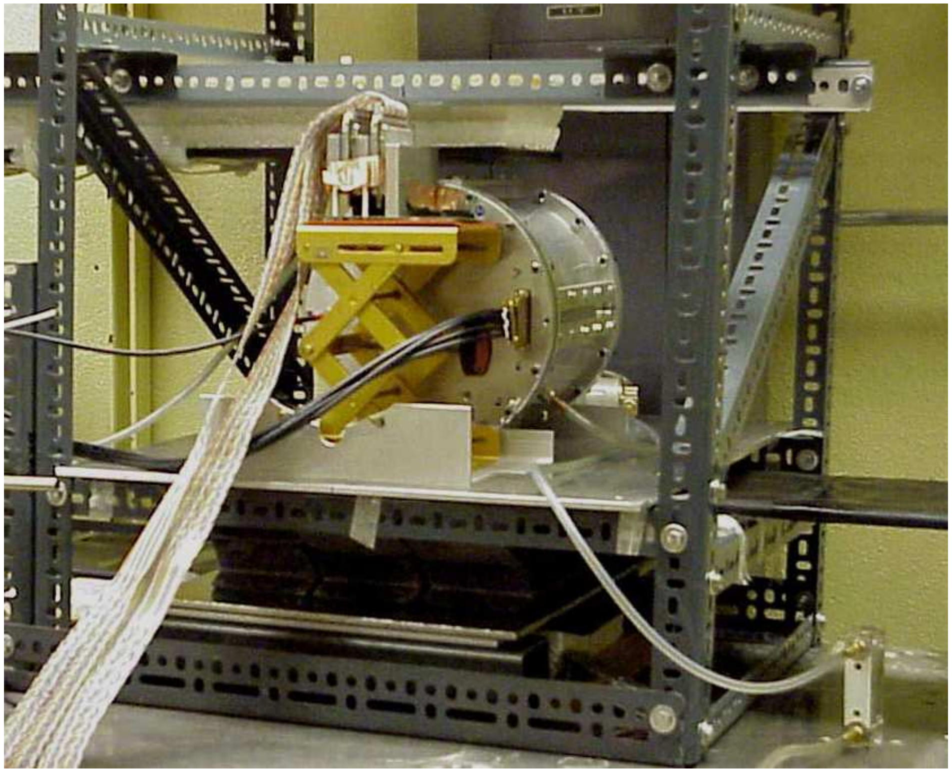
Cosmic ray TPC tests with MPGD charge dispersion readout

- 15 cm drift length with GEM or Micromegas readout
- B=0
- Ar+10% CO_2 chosen to simulate low transverse diffusion in a magnetic field.
- Aleph charge preamps.

τ_{Rise}= 40 ns, τ_{Fall} = 2 μs.

- 200 MHz FADCs rebinned to digitization effectively at 25 MHz.
- 60 tracking pads (2 x 6 mm^2)

\+ 2 trigger pads (24 x 6 mm^2).



The GEM-TPC resolution was first measured with conventional direct charge TPC readout.

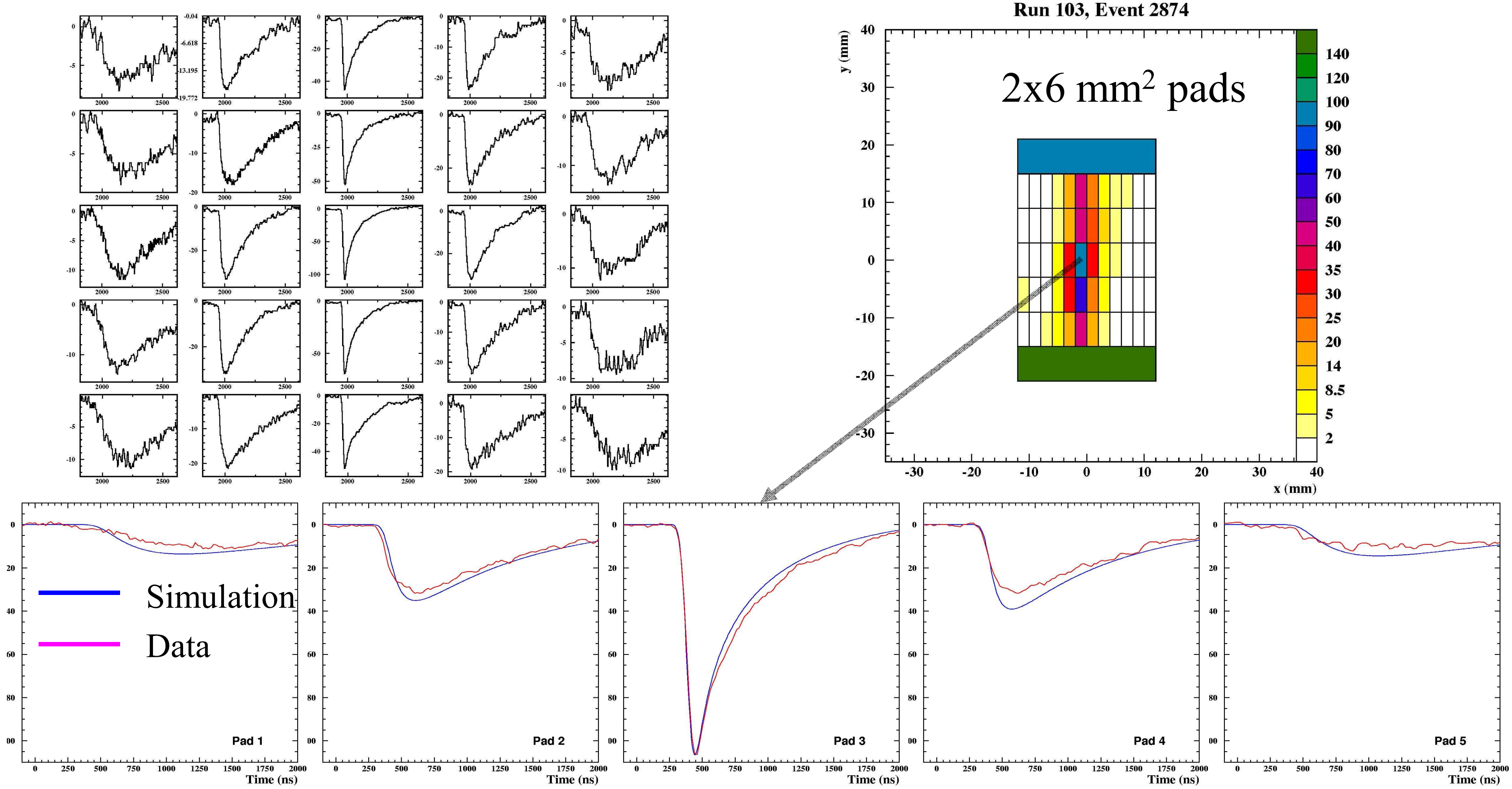
The resolution was next measured with a charge dispersion resistive anode readout with a double-GEM & with a Micromegas.

Simulating the charge dispersion phenomenon

M.S.Dixit and A. Rankin, Nucl. Instrum. Methods* A566 *(2006) 281.

- The charge dispersion equation describe the time evolution of a point like charge deposited on the MPGD resistive anode at $t = 0$.
- For improved understanding & to compare to experiment, one must include the effects of:
  - Longitudinal & transverse diffusion in the gas.
  - Intrinsic rise time T_{rise} of the detector charge pulse.
  - The effect of preamplifier rise and fall times t_r & t_f.
  - And for particle tracks, the effects of primary ionization clustering.

GEM TPC charge dispersion simulation (B=0)
Cosmic ray track, Z = 67 mm Ar+10%CO_2



Centre pulse used for normalization - no other free parameters.

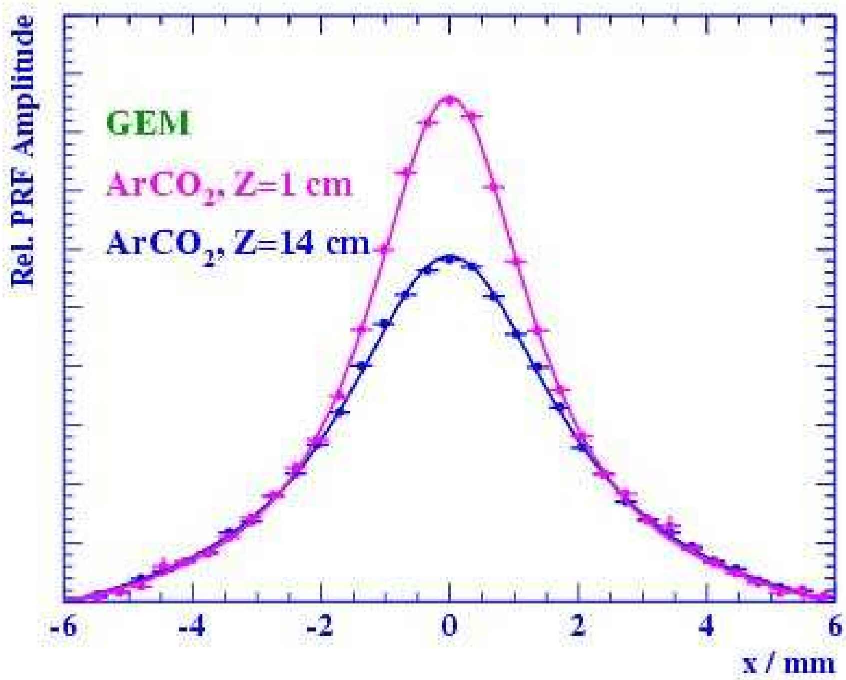
Charge dispersion pulses & pad response function (PRF)

- Non-standard variable pulse shape; both the rise time & pulse amplitude depend on track position.
- The PRF is a measure of signal size as a function of track position relative to the pad.
- We use pulse shape information to optimize the PRF.
- The PRF can, in principle, be determined from simulation.
- However, system RC non-uniformities & geometrical effects introduce bias in absolute position determination.
- The position bias can be corrected by calibration.
- PRF and bias determined empirically using a subset of data used for calibration. Remaining data used for resolution studies.

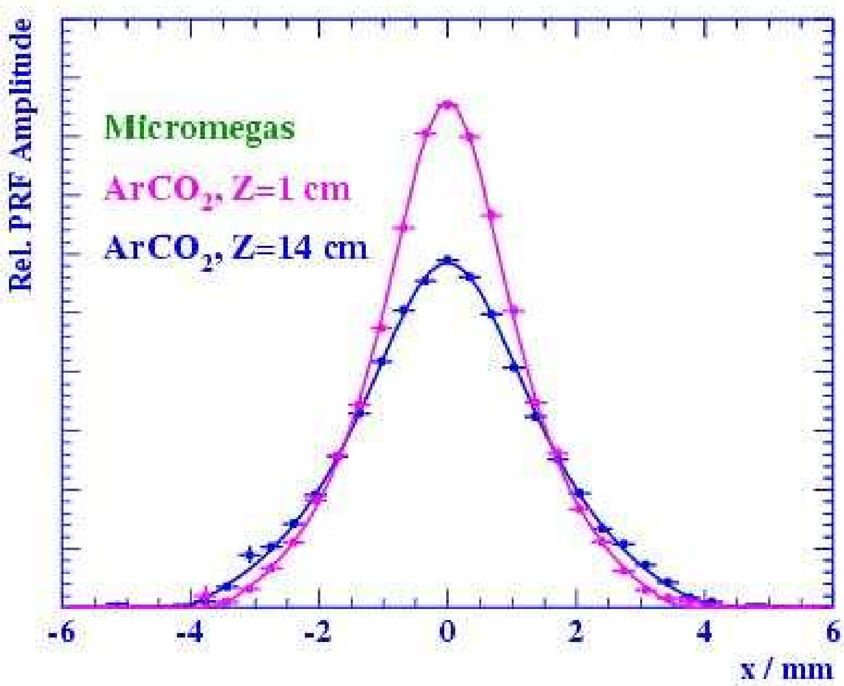
GEM & Micromegas track Pad Response Functions

Ar+10%CO_2 2x6 mm^2 pads

The pad response function (PRF) amplitude for longer drift distances is lower due to Z dependent normalization.



GEM PRFs



Micromegas PRFs

Micromegas PRF narrower due to higher resistivity anode & smaller diffusion than in GEM after avalanche gain.

Track PRFs with GEM & Micromegas readout

The PRFs are not Gaussian.

The PRF depends on track position relative to the pad.

PRF = PRF(x,z)

PRF can be characterized by FWHM $\Gamma(z)$ & base width $\Delta(z)$.

PRFs determined from the data parameterized by a ratio of two symmetric 4th order polynomials.

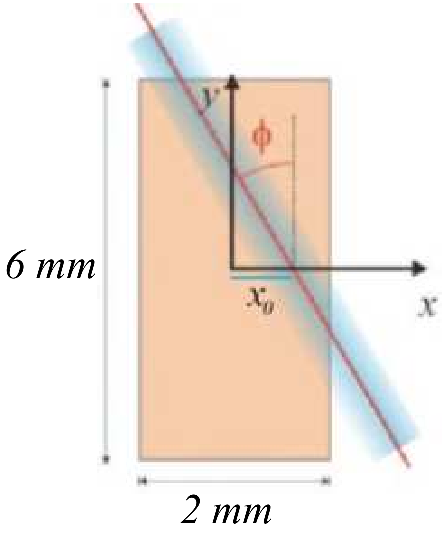
$$PRF[x,\Gamma(z),\Delta(z),a,b]=\frac{(1+a_2x^2+a_4x^4)}{(1+b_2x^2+b_4x^4)}$$

a_2 a_4 b_2 & b_4 can be written down in terms of Γ and Δ & two scale parameters a & b.

Track fit using the the PRF

Track at: $x_{track} = x_0 + \tan(\phi)\, y_{row}$

$$\chi^2 = \sum_{rows} \sum_{i=pads} \left(\frac{A_i - PRF_i}{\partial A_i} \right)^2$$

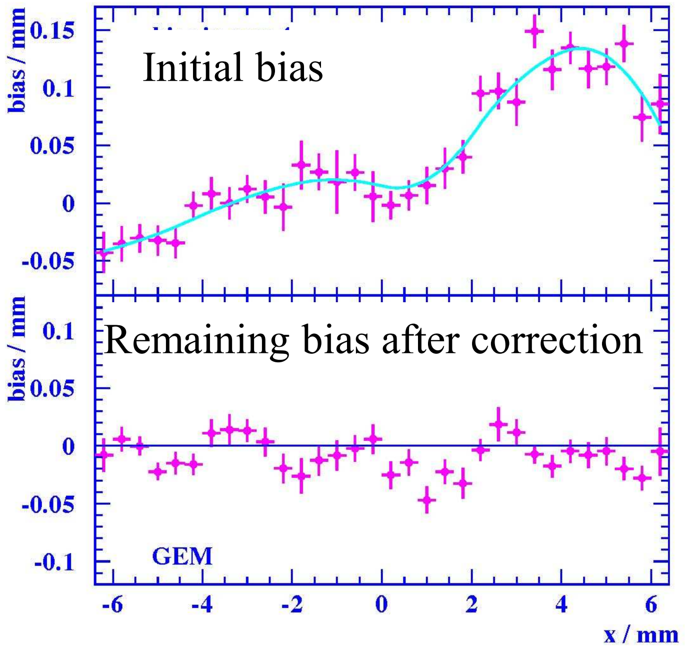


Determine x_0 & ϕ by minimizing χ^2 for the entire event

Definitions:

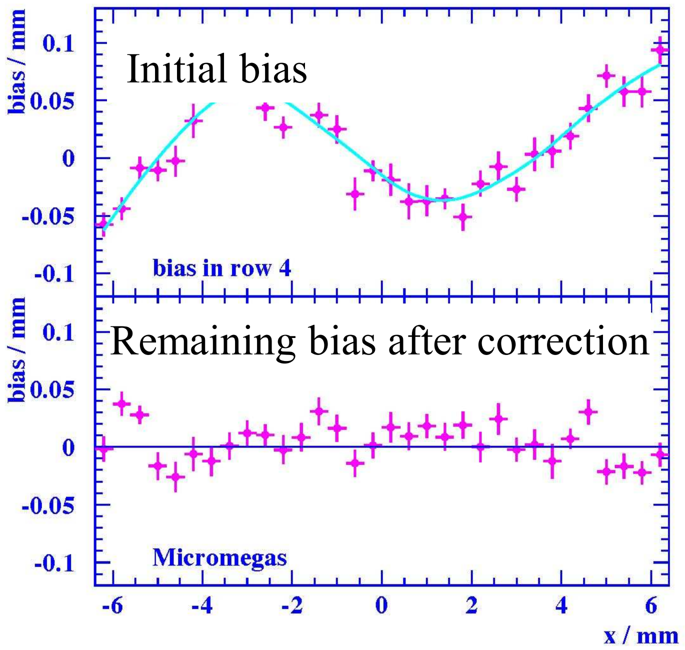
- residual: $x_{row} - x_{track}$
- bias: mean of $x_{row} - x_{track} = f(x_{track})$
- resolution: standard deviation of residuals

Bias corrections for the GEM & for Micromegas



2x6 mm^2 pads

GEM

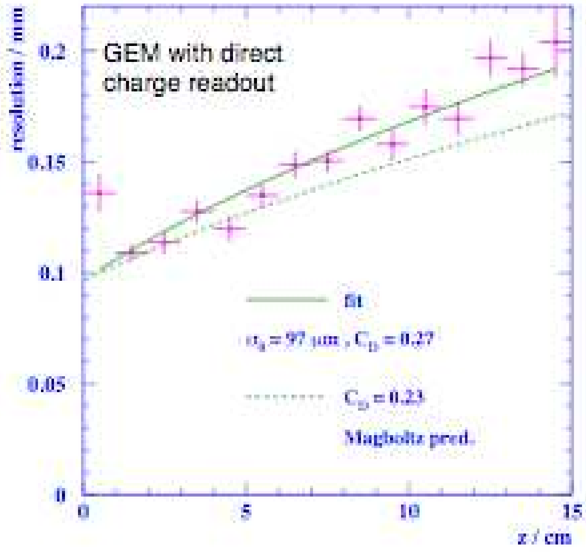


2x6 mm^2 pads

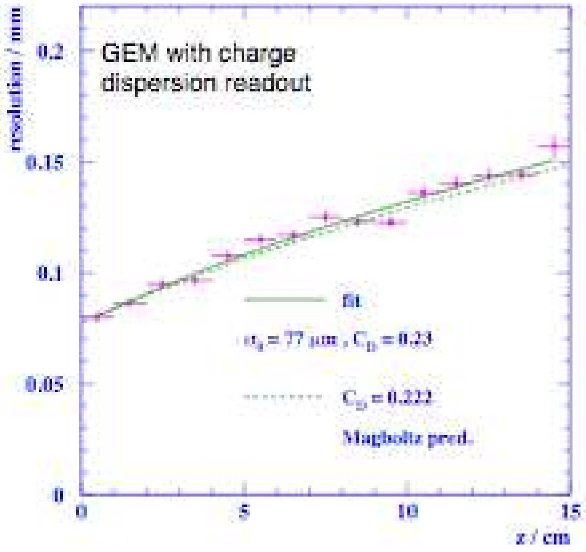
Micromegas

Transverse resolution (B=0) - Cosmic Rays $Ar+10\%CO_2$

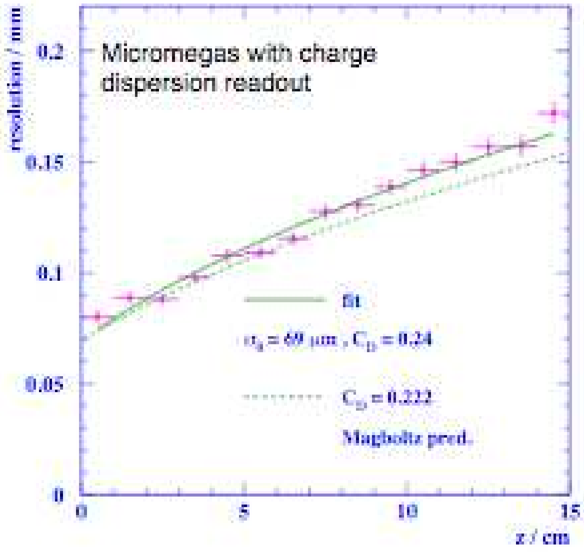
R.K.Carnegie et.al.,
NIM A538 (2005) 372



K. Boudjemline et al.,
NIM. A574, 22 (2007).



A. Bellerive et al,
LCWS 2005, Stanford

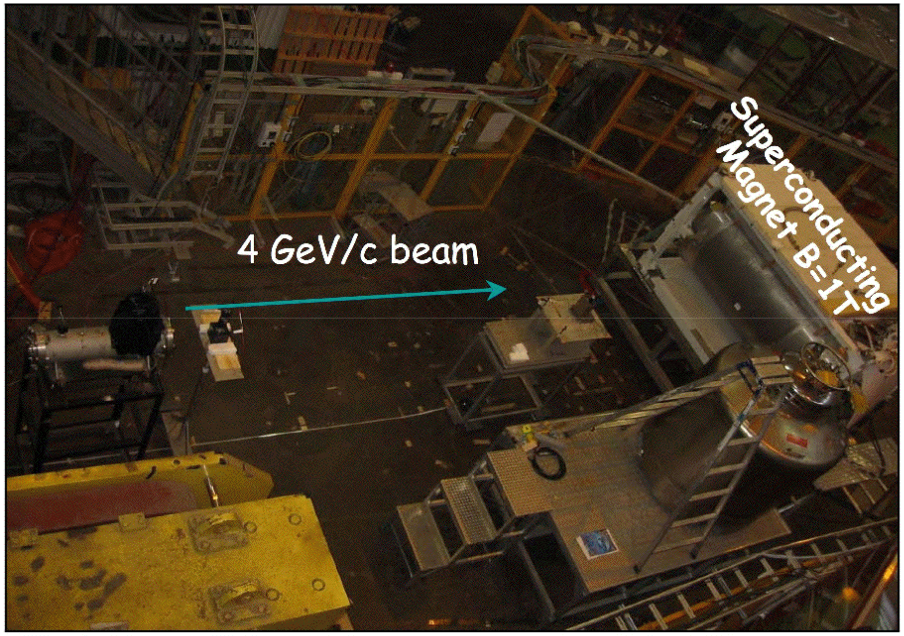


....

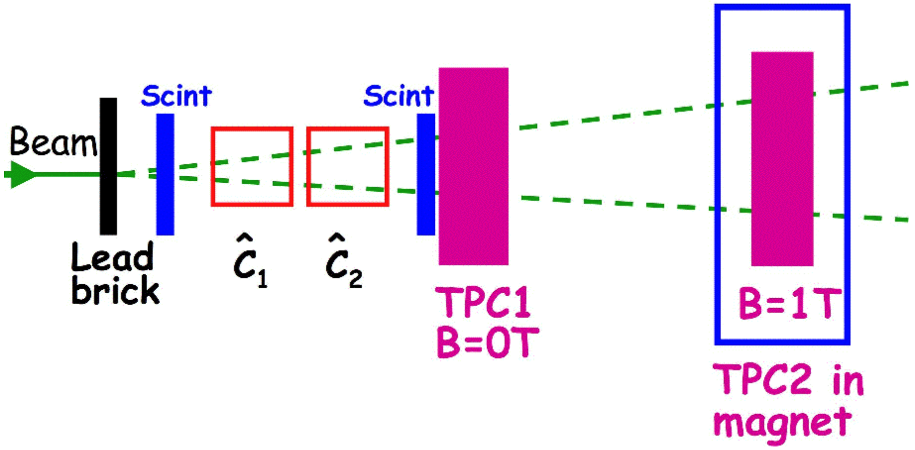
$$\sqrt{\sigma_0^{\,2} + \frac{C_D^{\,2}}{N_e} z}$$

Compared to conventional readout, charge dispersion gives better resolution for the GEM and the Micromegas.

KEK beam test at 1 Tesla Canadian/French & Japan/German TPCs



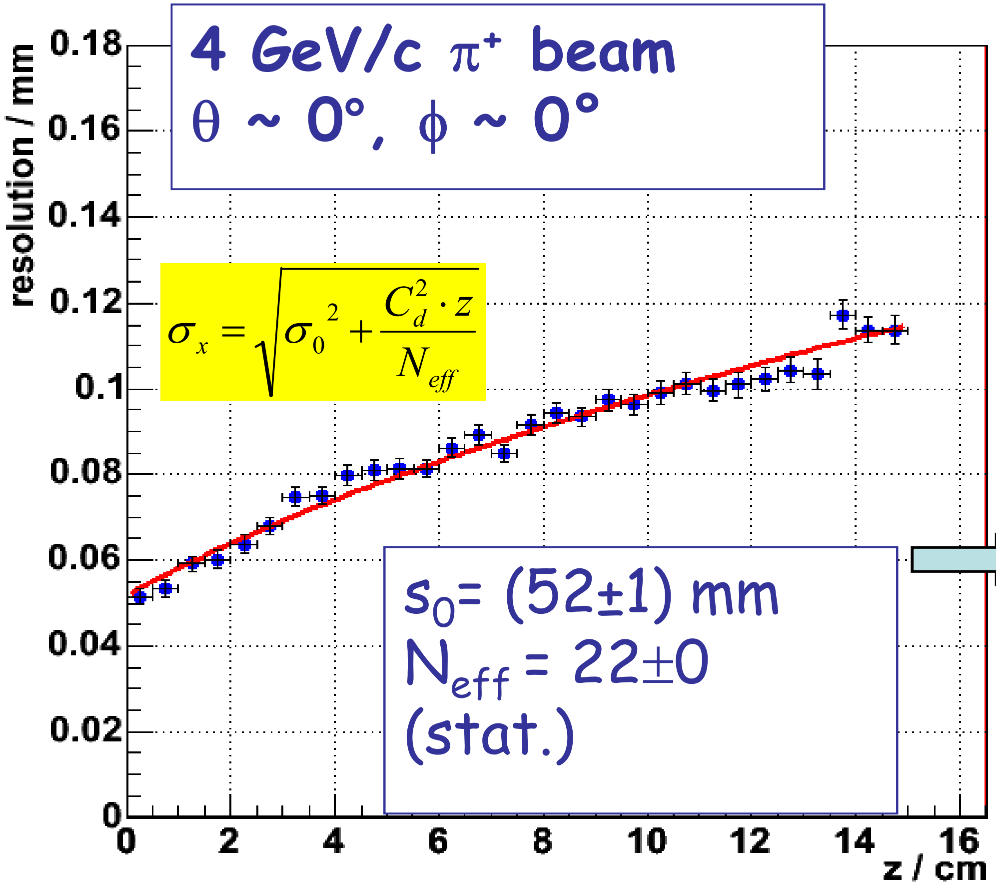
- 4 GeV/c hadrons (mostlyπs)
- 0.5 & 1 GeV/c electrons
- Super conducting 1.2 T magnet without return yoke
- Inner diameter : 850 mm
- Effective length: 1 m



Canadian TPC in the beam outside the magnet

Transverse spatial resolution Ar+5%iC4H10
E=70V/cm D_{Tr} = 125 μm/√cm (Magboltz) @ B= 1T

Micromegas TPC 2 x 6 mm² pads - Charge dispersion readout



4 GeV/c π^+ beam
θ ~ 0°, ϕ ~ 0°

$$\sigma_x = \sqrt{\sigma_0^{\,2} + \frac{C_d^2 \cdot z}{N_{eff}}}$$

s_0= (52±1) mm
N_{eff} = 22±0
(stat.)

- Strong suppression of transverse diffusion at 4 T.

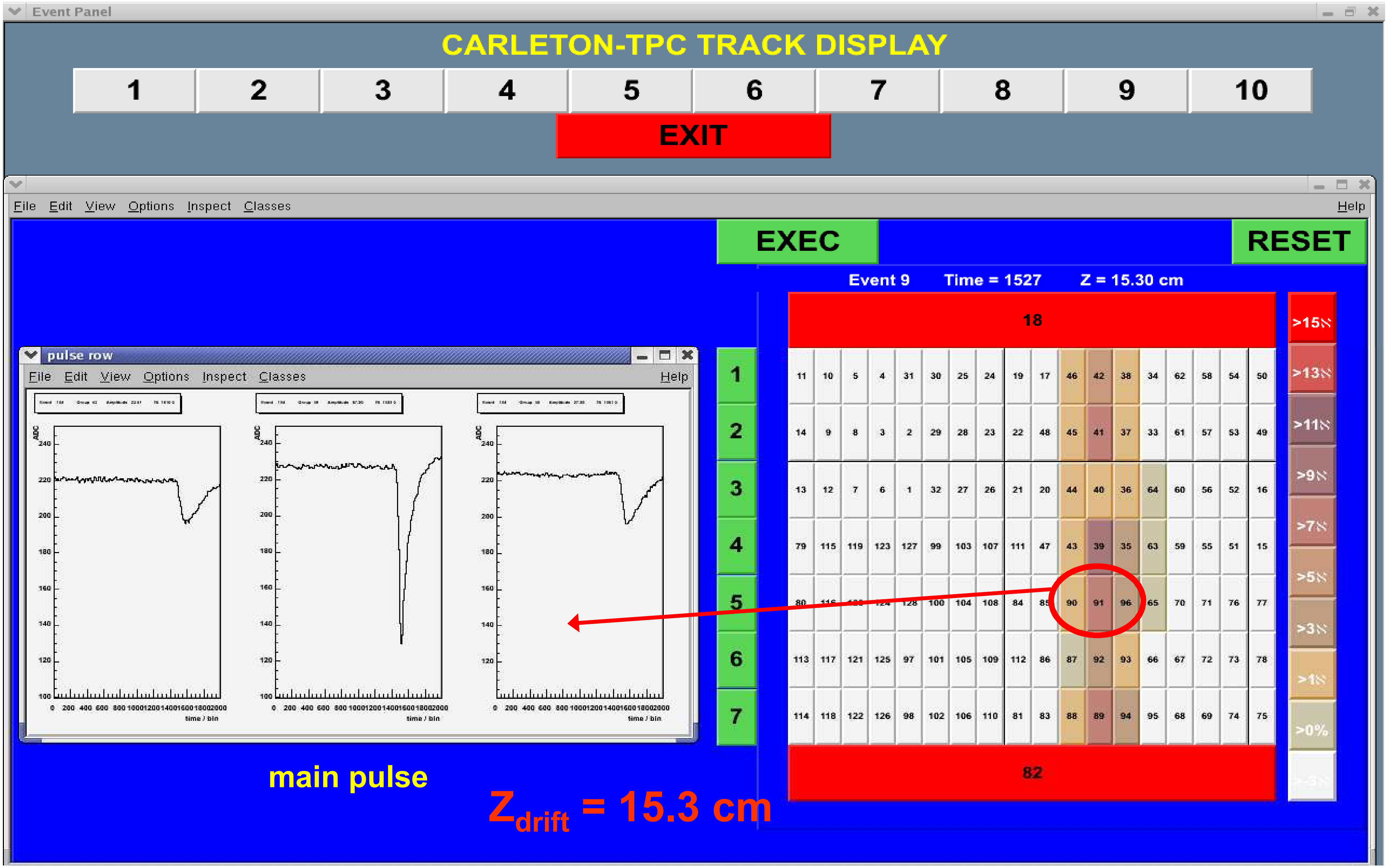
Examples:

D_{Tr}~ 25 μm/√cm (Ar/CH4 91/9)
Aleph TPC gas
~ 20 μm/√cm (Ar/CF4 97/3)

Extrapolate to B = 4T
Use D_{Tr} = 25 μm/√cm
Resolution (2x6 mm² pads)
σ_{Tr} ≈ 100 μm (2.5 m drift)

Track display - Ar+5%iC$_4$H$_{10}$ KEK 4 GeV/c hadrons

Micromegas 2 mm x 6 mm pads B = 1 T



Event 9 Time = 1527 Z = 15.30 cm

11	10	5	4	31	30	25	24	19	17	46	42	38	34	62	58	54	50
14	9	8	3	2	29	28	23	22	48	45	41	37	33	61	57	53	49
13	12	7	6	1	32	27	26	21	20	44	40	36	64	60	56	52	16
79	115	119	123	127	99	103	107	111	47	43	39	35	63	59	55	51	15
80	116	120	124	128	100	104	108	84	85	90	91	96	65	70	71	76	77
113	117	121	125	97	101	105	109	112	86	87	92	93	66	67	72	73	78
114	118	122	126	98	102	106	110	81	83	88	89	94	95	68	69	74	75

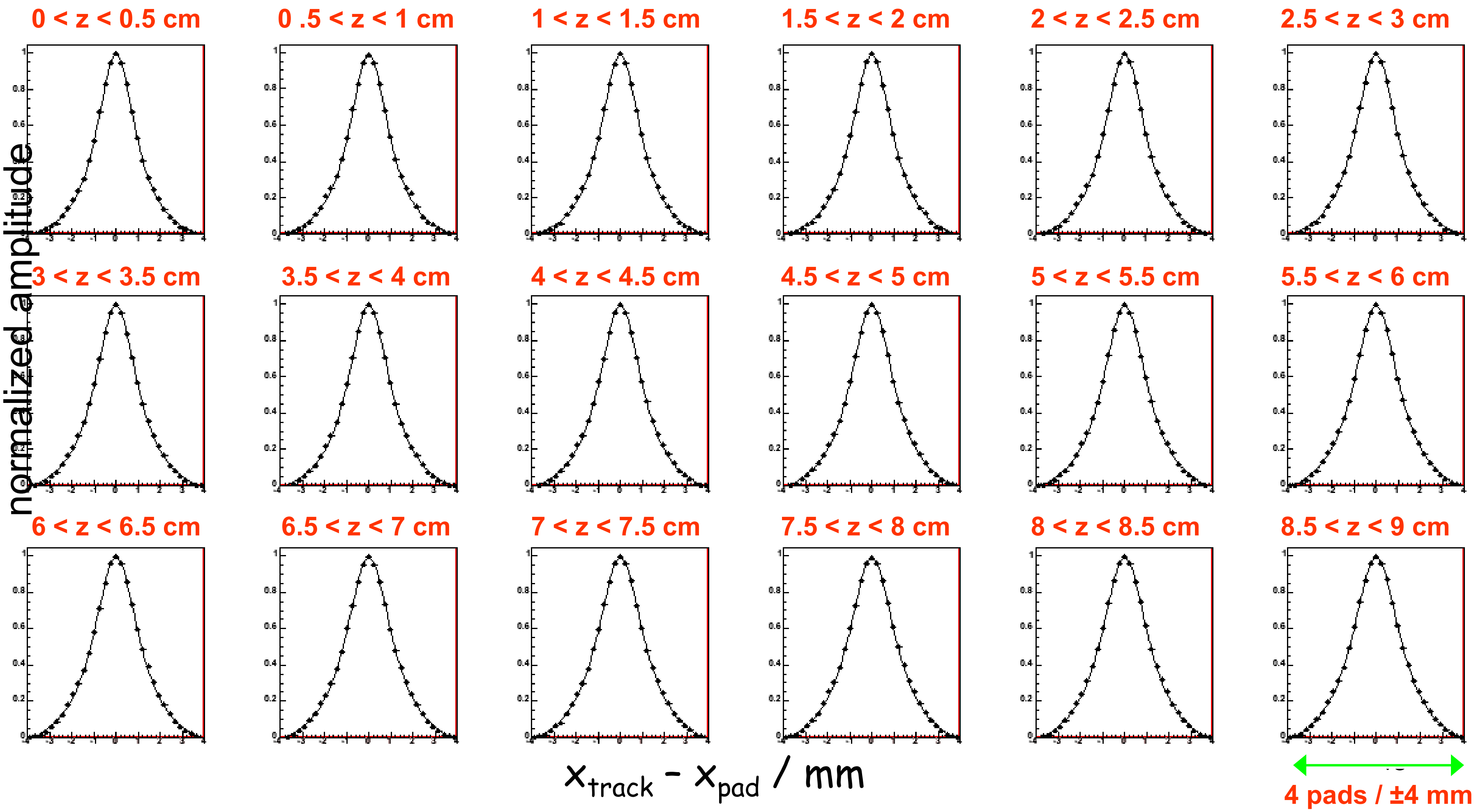
main pulse

Z_{drift} = 15.3 cm

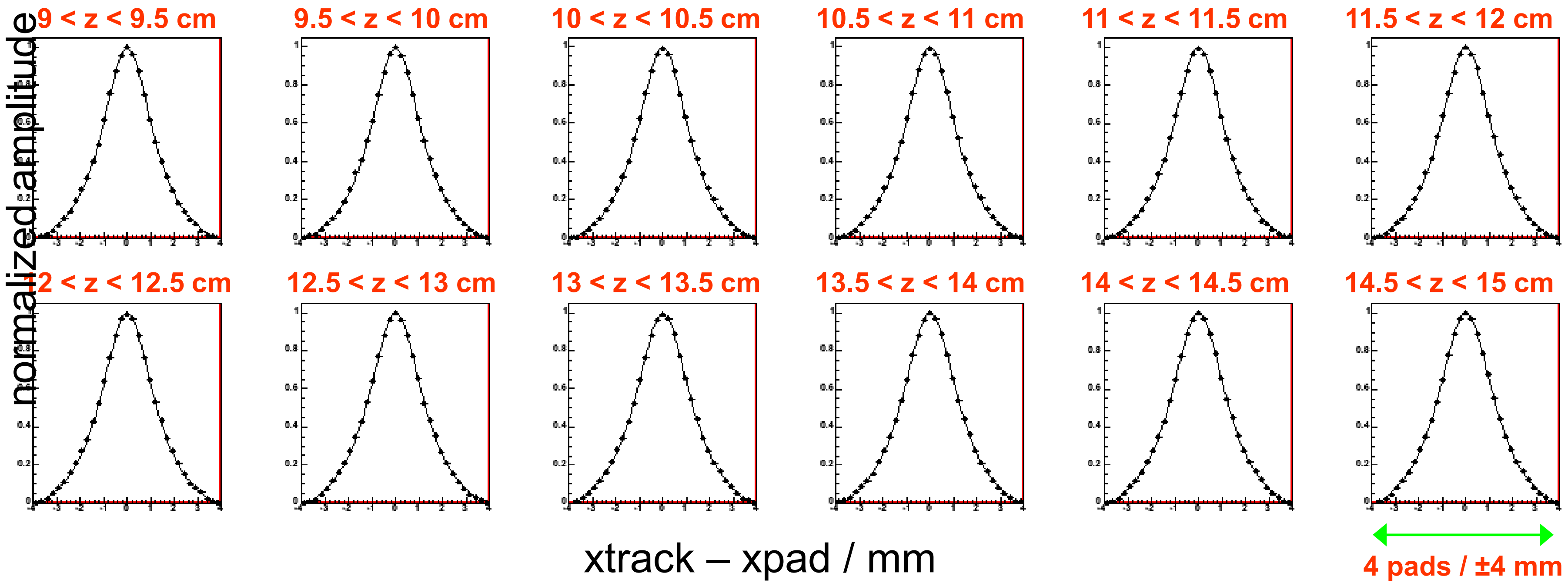
Pad Response Function / Ar+5%iC_4H_{10}

Micromegas+Carleton TPC 2 x 6 mm^2 pads, B = 1 T

30 z regions /
0.5 cm step



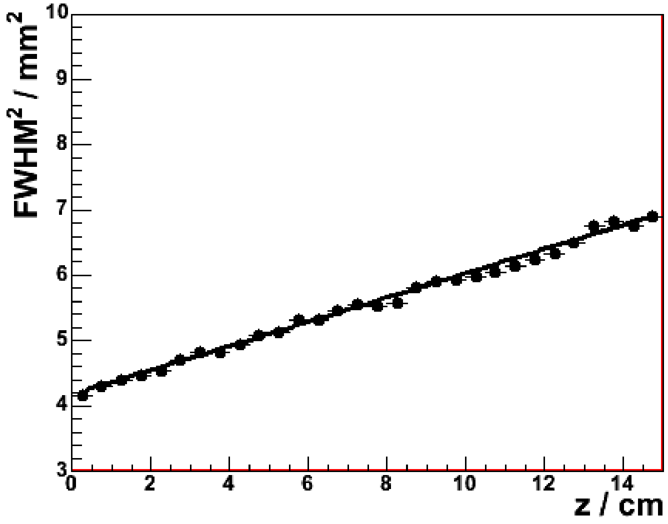
Pad Response Function Ar+5%iC_4H_{10}



PRF parameters

- a = b = 0
- Δ = base width = 7.3 mm
- Γ = FWHM = f(z)

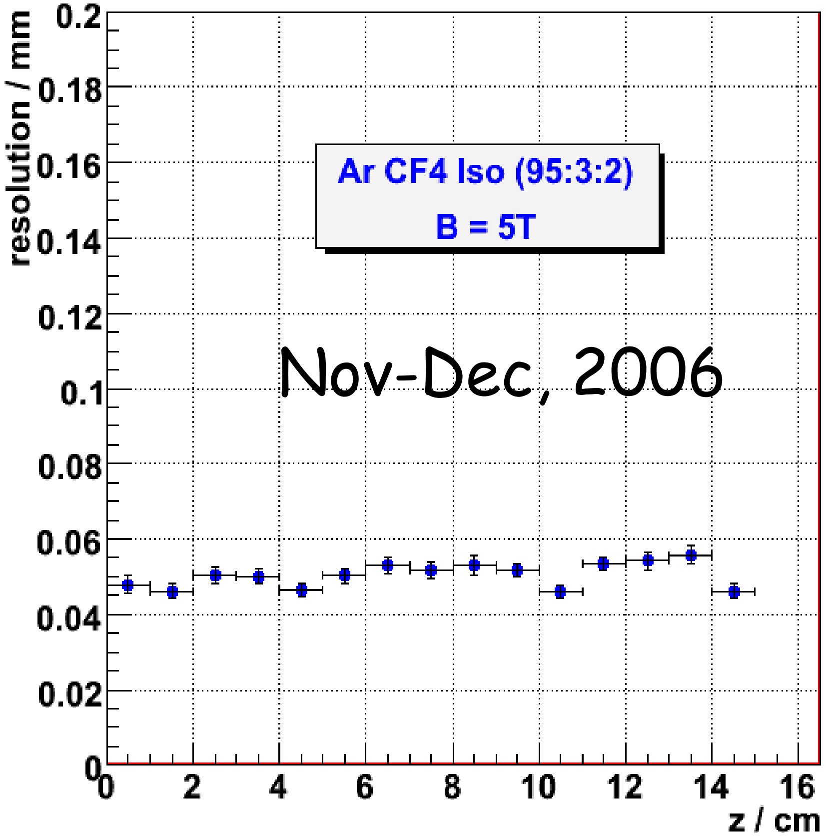
The parameters depend on TPC gas & operational details



Extrapolation confirmed 5 T cosmic tests at DESY

COSMo (Carleton, Orsay, Saclay, Montreal) Micromegas TPC

D_{Tr} = 19 μm/√cm, **2 × 6 mm² pads**

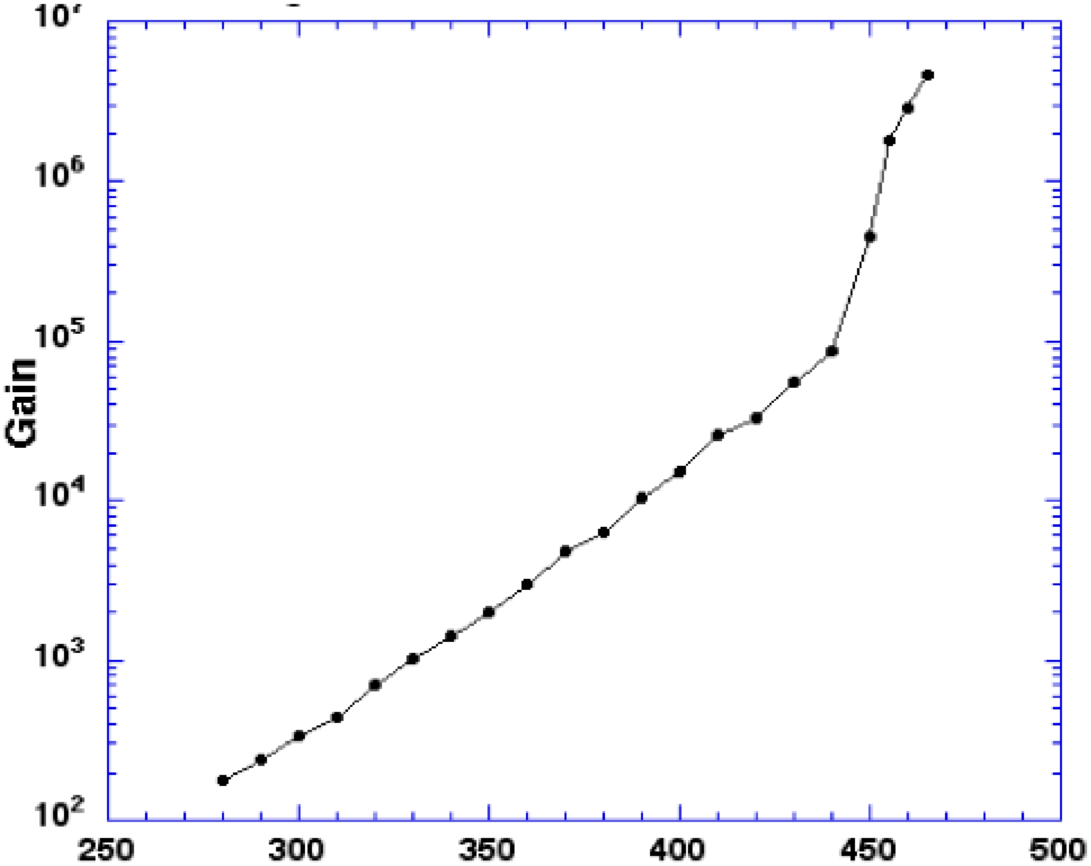


M. Dixit et. al, NIM A 581, 254 (2007)

~ 50 μm av. resolution over 15 cm (diffusion negligible) 100 μm over 2 meters looks within reach!

Micromegas gain with a resistive anode

Argon/Isobutane 90/10



Resistive anode suppresses sparking & improves Micromegas HV stability

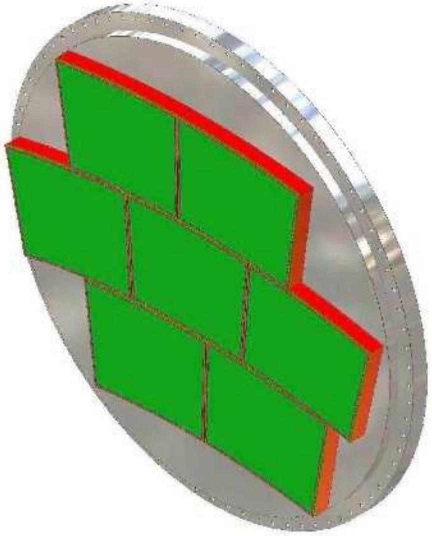
Preparing the TPC for ILC

- A formal Linear Collider TPC (LC-TPC) collaboration recently formed
- Goal - construct a 1 meter prototype & comprehensive beam tests in a 4 T magnet in a beam with ILC like time structure with **realistic electronics** by 2010(12)
- Two possible readout options being developed
  - 1) GEM with 1 mm pads
  - 2) Micromegas with ~ 2 mm pads with charge dispersion readout

1 m Large Prototype TPC for tests at DESY (2007-2010)

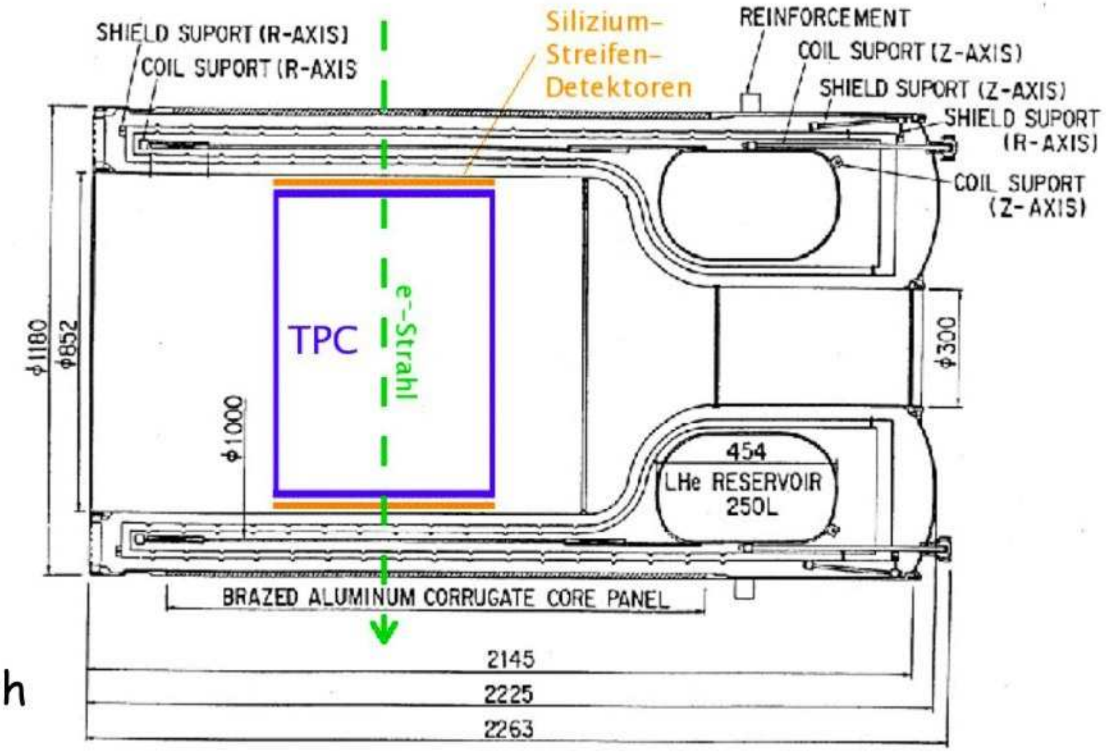
7 panels GEMs with 1 mm pads & Micromegas with 2 mm wide pads

Up to 10,000 instrumented channels



TPC endplate: 7 modules with Micromegas with charge dispersion readout.

To be built by Canada and France



Large prototype in the 1 T magnet PCMAG. The 6 GeV electron beam will enter through the magnet coil transverse to the drift direction. The magnet has no iron.

GDE Timeline

- TDP I : 2010
  - Technical risk reduction
  - Cost risk reduction
  - Global design
- TDP II : 2012
  - RD unit test (KEK)
  - Complete necessary technical designs (exceptions)
  - Project plan by consensus
- Detailed engineering will follow before construction

Detector Timeline

- Detector Design Phase I : 2010
  - Focus on critical R&Ds
  - LOI validation by IDAG

    (March 31 09 LOI deadline)
  - Update physics performance
  - MDI
- Detector Design Phase II : 2012
  - React to LHC results
  - Confirm physics performance
  - Complete necessary R&Ds
  - Complete technical designs
  - Cost (reliable)

Summary

- The physics case for the ILC is compelling
- Expect to gain momentum after LHC results
- At 5 T, an unprecedented flat ~ 50 μm resolution has been demonstrated with 2 x 6 mm^2 readout pads for drift distances up to 15 cm. The ILC-TPC resolution goal ~100 μm for all tracks up to 2 m drift appears feasible.
- The MPGD readout concept of charge dispersion a serious candidate for the ILC TPC readout.
- Canadian responsibilities for large 1 m prototype tests to 2010
    - Construct seven large Micromegas panels with charge dispersion shared with France
    - Calibration
- Possible applications in other areas,e.g. T2K

Simulation of T2K Micromegas TPC with resistive anode readout

Madhu Dixit & Stephen Turnbull
Carleton University

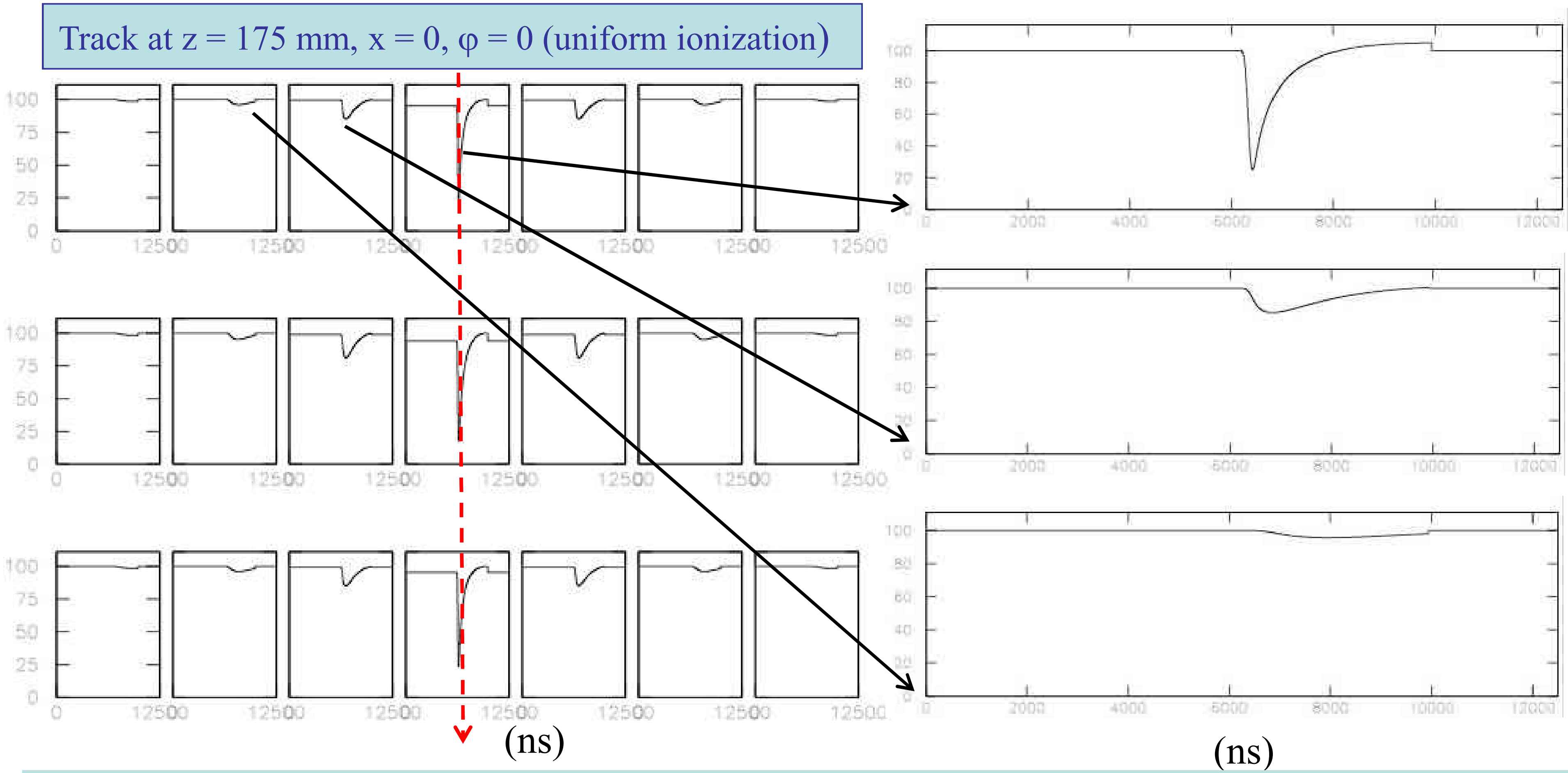
11 August, 2006

Simulated pulses with resistive readout (8 x 8 mm^2 pads)

Ar+10% CO_2 , v_{Drift} = 28 μm/ns (E = 300 V/cm) Aleph preamp t_{Rise} = 40 ns, t_{Fall} = 2 μs

Anode surface resistivity 150 KΩ/□, dielectric gap = 75 μm, K = 2

Track at z = 175 mm, x = 0, φ = 0 (uniform ionization)



Pulses with very similar rise/fall times give $\sigma_0 \approx 50$ μm for 2 x 6 mm^2 pads

Micromegas TPC with resistive readout - Simulated PRF

8 x 8 mm^2 pads, Ar+10% CO_2@ 300 V/cm, 175 mm drift distance