A CLUster COUnting Drift Chamber for ILC

…and…

can we adapt this chamber to **SuperB**?

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SuperB

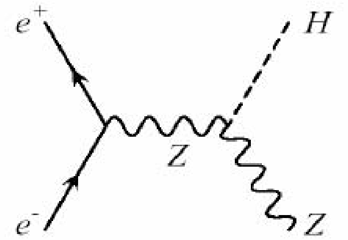
5th Super B Workshop
Paris, May 9-11, 2007

outline

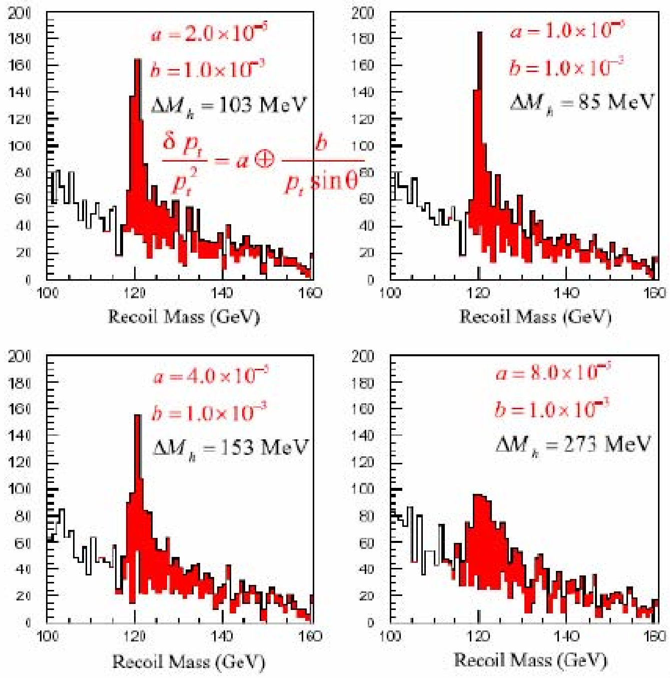
- Requirements for tracking at ILC
- Cluster Counting
- 4thConcept CLUCOU Drift Chamber
- Downscaling to SuperB
- Summary

Higgs Recoil Mass

- Benchmark measurement is the measurement of the Higgs recoil mass in the channel $e^+e^- \rightarrow ZH$
  - Higgs recoil mass resolution improves until $\Delta p/p^2 \sim 2 \times 10^{-5}$
  - Sensitivity to invisible Higgs decays, and purity of recoil-tagged Higgs sample, improve accordingly.



- Example:
  - $\sqrt{s}$ = 300 GeV
  - 500 fb^{-1}
  - beam energy spread of 0.1%
- Goal:
  - $\delta M_{ll} < 0.1 \times \Gamma_Z$
  - δM_H dominated by beamstrahlung



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borrowed from:

Tracking R&D Review, Feb. 5-8, 2007, Beijing, -- M. Demarteau

From Gluckstern:

$$(\delta\kappa)^2 = \left(\frac{\varepsilon_\perp}{L_\perp{}^2}\sqrt{\frac{320}{N+4}}\right)^2 + \left(\frac{0.016\,(GeV/c)}{L\beta p_\perp \sin\theta}\sqrt{\frac{L}{X_0}}\right)^2$$

$$\kappa = {}^{1}\!/_{\rho} \qquad \rho = {}^{p_\perp}\!/_{0.3B}$$

@ ILC, for B = 5 T, $L_\perp$ = 1.5 m

$$\frac{\delta p_\perp}{p_\perp{}^2} = 5.3\frac{\varepsilon_\perp}{\sqrt{N+4}} \oplus \frac{7.2\times10^{-3}}{p_\perp \sin\theta}\sqrt{\frac{L}{X_0}}$$

$$\frac{\varepsilon_\perp}{\sqrt{N+4}} = 4\times10^{-6}$$

$$\frac{L}{X_0} = 2\times10^{-2}$$

N = 150 , L ~ 2m
(1 cm^2 hex. cells)
60.000 sense wires
120.000 field wires

$$\varepsilon_\perp \cong 50\,\mu m\,! \quad X_0 \geq 100m\,!$$

Multiple scattering contribution (equivalent L/X_0):

60.000	20 μm W sense wires	→	1.8×10^{-3}	(X_0 = 0.35 cm)
120.000	80 μm Al field wires	→	2.2×10^{-3}	(X_0 = 8.9 cm)
2 m gas	(90% He + 10% iC_4H_{10})	→	1.5×10^{-3}	(X_0 = 1300 m)

Equivalent L/X_0 = 5.5×10^{-3}

$$\frac{\delta p_\perp}{p_\perp^2} = \frac{0.5 \times 10^{-3}}{p_\perp \sin\theta}$$

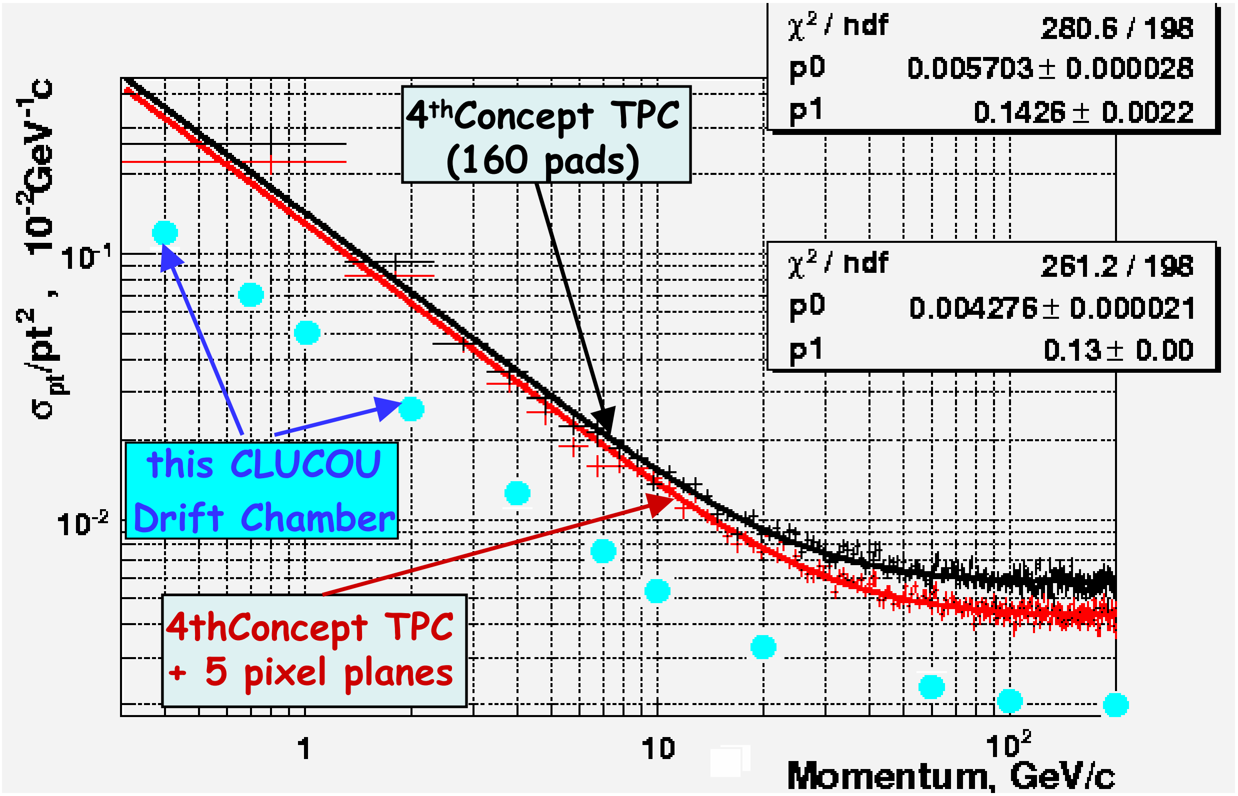
$$X_0 = 360m$$

Sagitta measurement contribution (in ⊥ plane):

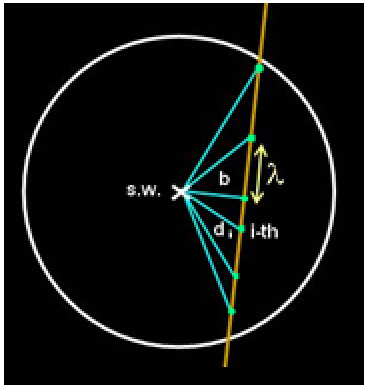
$$\sigma_{xy} = 50\mu m$$

Momentum Resolution

$$2\times10^{-5} \oplus \frac{5\times10^{-4}}{p_\perp \sin\theta}$$



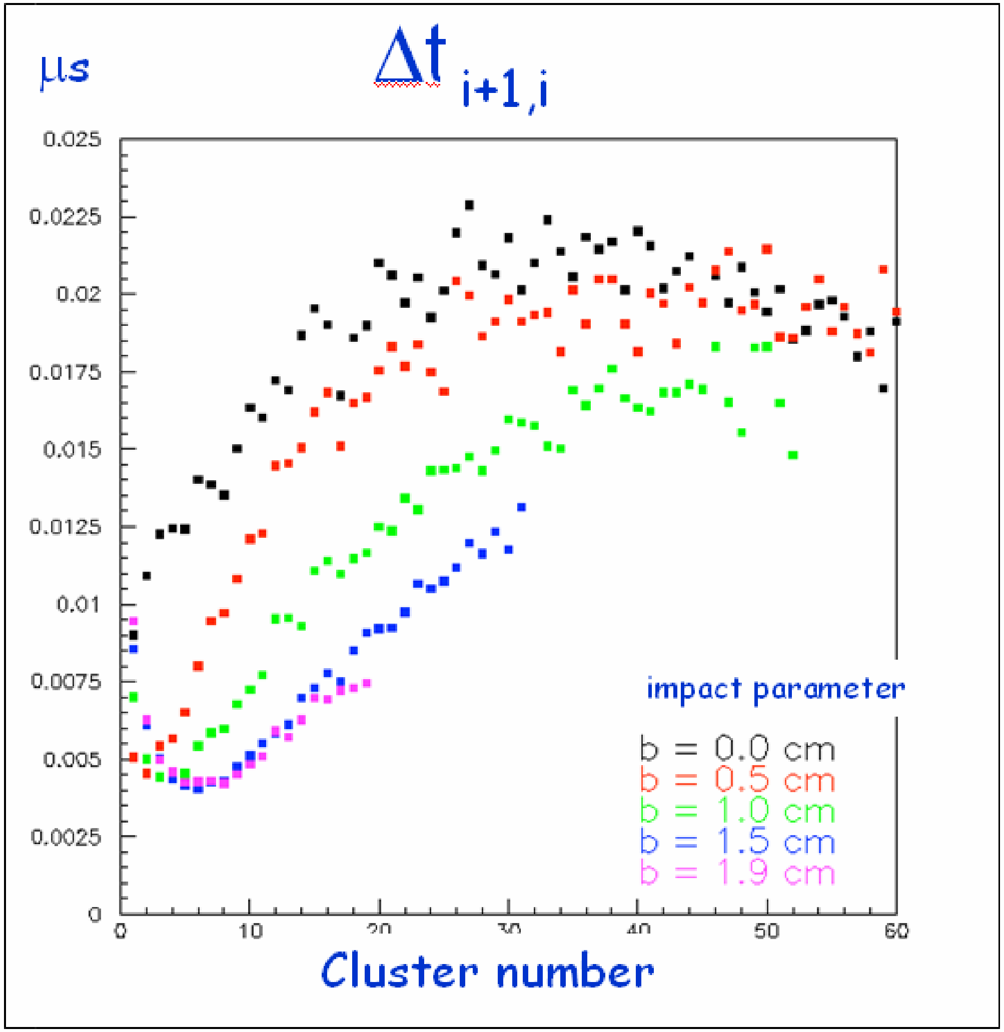
CLUster COUnting



2 cm drift tube

90%He-10%iC_4H_{10}

few x 10^5 gain

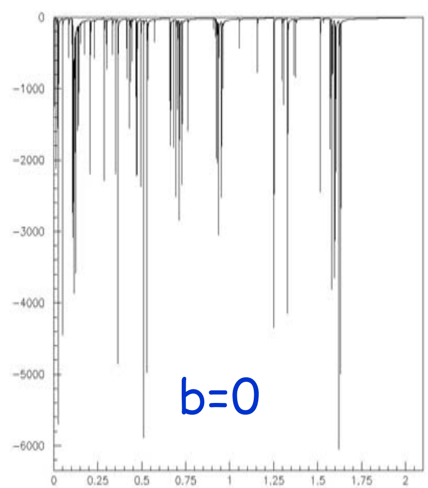


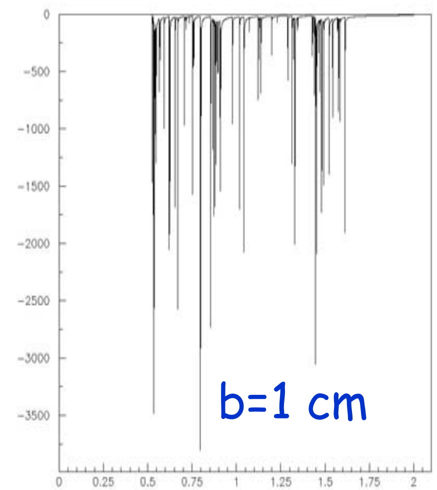
$\Delta t_{i+1,i}$: time separation between consecutive ionization clusters, as a function of their ordered arrival time, for different impact parameters. (caveat: electrons!)

In this He mixture , **provided that:**
sampling frequency of signals > 2 Gsa/s
and rise (and fall) time of single electron signals < 1ns
single electron counting is possible.

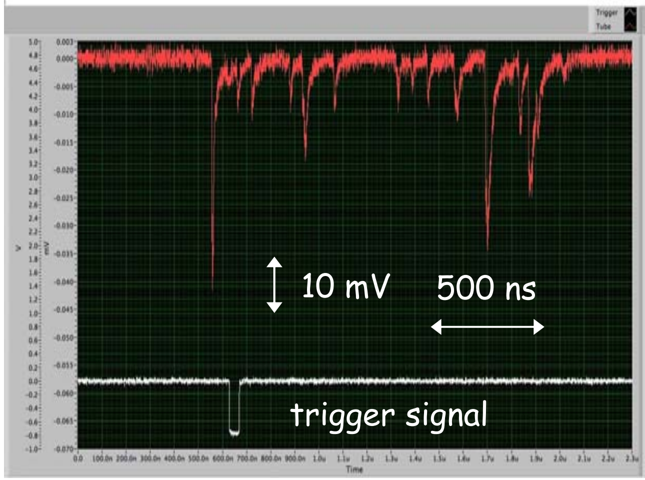
CLUster COUnting

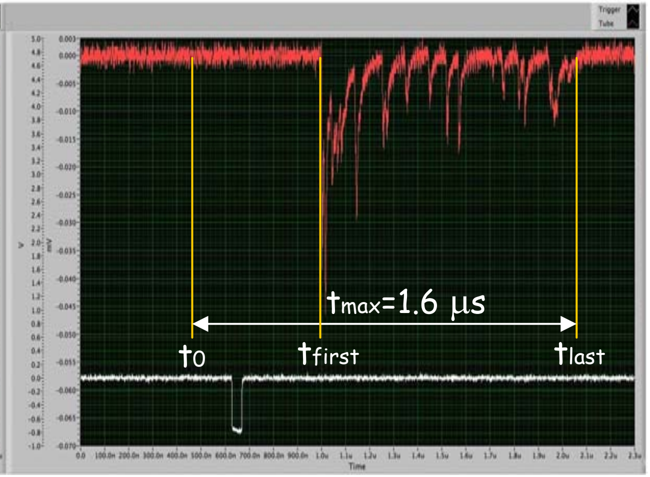
MC generated events:
2cm diam. drift tube
gain = few x 10
gas: $90\%He-10\%iC_4H_{10}$
no electronics simulated
vertical arbitrary units





cosmic rays triggered by scintillator telescope and readout by:
8 bit, 4 GHz, 2.5 Gsa/s digital sampling scope through a 1.8 GHz, x10 preamplifier





CLUster COUnting

For a given set up, and a digitized pulse (t_{last} is constant with a spread < 20 ns)

$t_0 = t_{last} - t_{max}$ gives the trigger time

$b_f = \int_{t_0}^{t_{first}} v(t)\,dt$ first approx. of impact parameter b

$(c/2)^2 = r^2 - b_f^2$ length of chord

$N_{cl} = c \,/\, (\lambda(\beta\gamma) \times \sin\theta)$ expected number of cluster

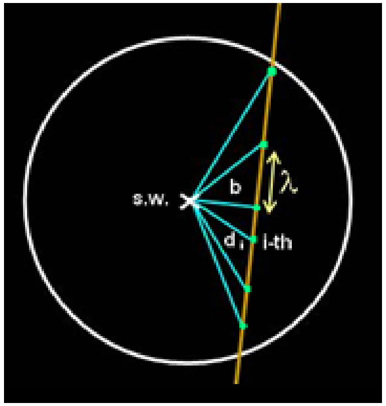
$N_{ele} = 1.6 \times N_{cl}$ expected number of electrons (to be compared with counted one)

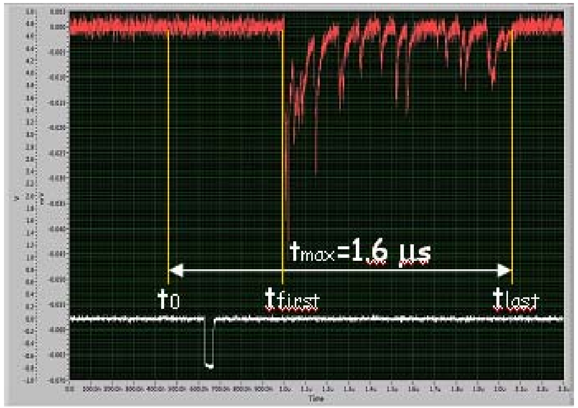
$\{t_i\}$ and $\{A_i\}$, $i=1,N_{ele}$ ordered sequence of ele.drift times and their amplitudes

$P(i,j)$, $i=1,N_{ele}$, $j=1,N_{cl}$ probability i-th ele. $\in$ to j-th cl.

$$D_i^{N_{cl}}(x) = \frac{N_{cl}!}{(N_{cl}-i)!\,(i-1)!}(1-x)^{N_{cl}-i}\,x^{i-1}$$

probability density function of ionization along track



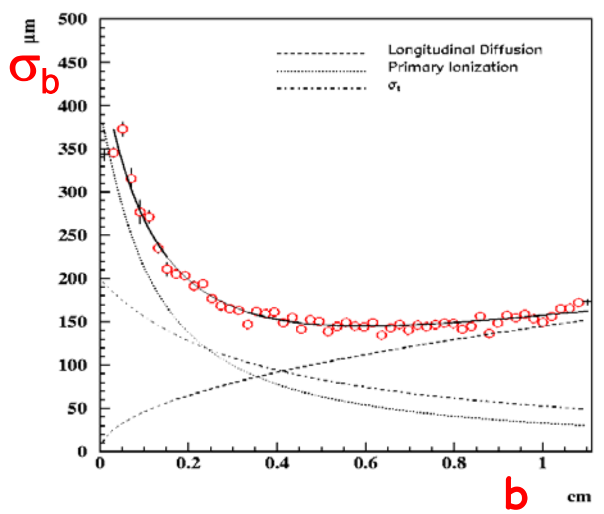


Each cluster contributes to the measurement of the impact parameter with an independent estimate weighted according to the Poisson nature of the process and the electron diffusion along the drift path.

The resolution on the impact parameter, σ_b, improves with the addition of each cluster beyond the first one.

It, however, saturates at a value of 30-35 μm, convolution of:

- spread in mechanical tolerances (position of sense wire; gravitational sag; electrostatic displacement)
- timing uncertainties (trigger timing; electronics calibration; t_0)
- degree of knowledge of time-to-distance relation
- instability of working parameters (HV, gas temperature and pressure, gas mixture composition)

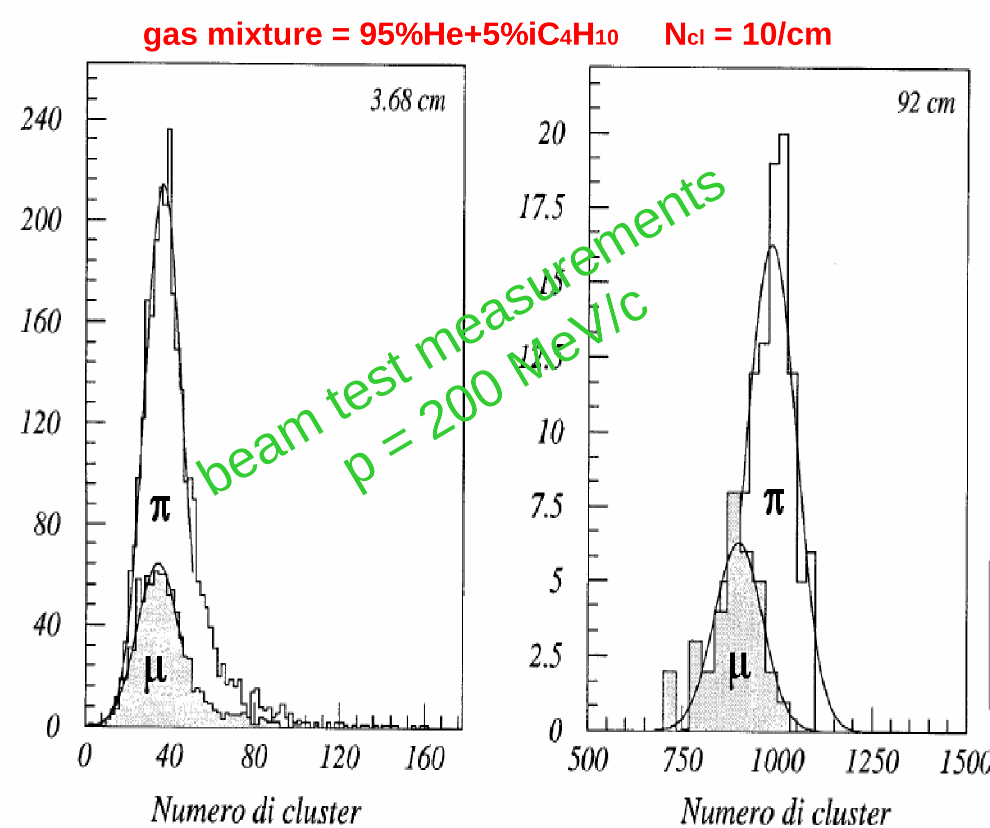


Fit to resolution function:
(from KLOE data)

$\lambda = 770 \pm 14$ μm
$n_p = 12.9 \pm 0.1$ cm^{-1}
$\sigma_D = 140$ μm cm$^{-1/2}$
$\sigma_t = 4.8 \pm 0.2$ ns

Reasonable to assume σ_b = 50 μm per sense wire

Particle Identification



experiment:

$\pi/\mu = 1.3\ \sigma$

theory: $\pi/\mu = 2.0\ \sigma$

trunc. mean: $\pi/\mu = 0.5\ \sigma$

		statistica		fit	
	traccia	N_{cl}	r.m.s.	N_{cl}	σ
π	3.7 cm	41.17	15.91	36.34	8.83
	92.0 cm	978.20	60.53	982.50	65.08
μ	3.7 cm	38.45	16.39	34.07	9.69
	92.0 cm	882.30	70.82	896.20	63.39

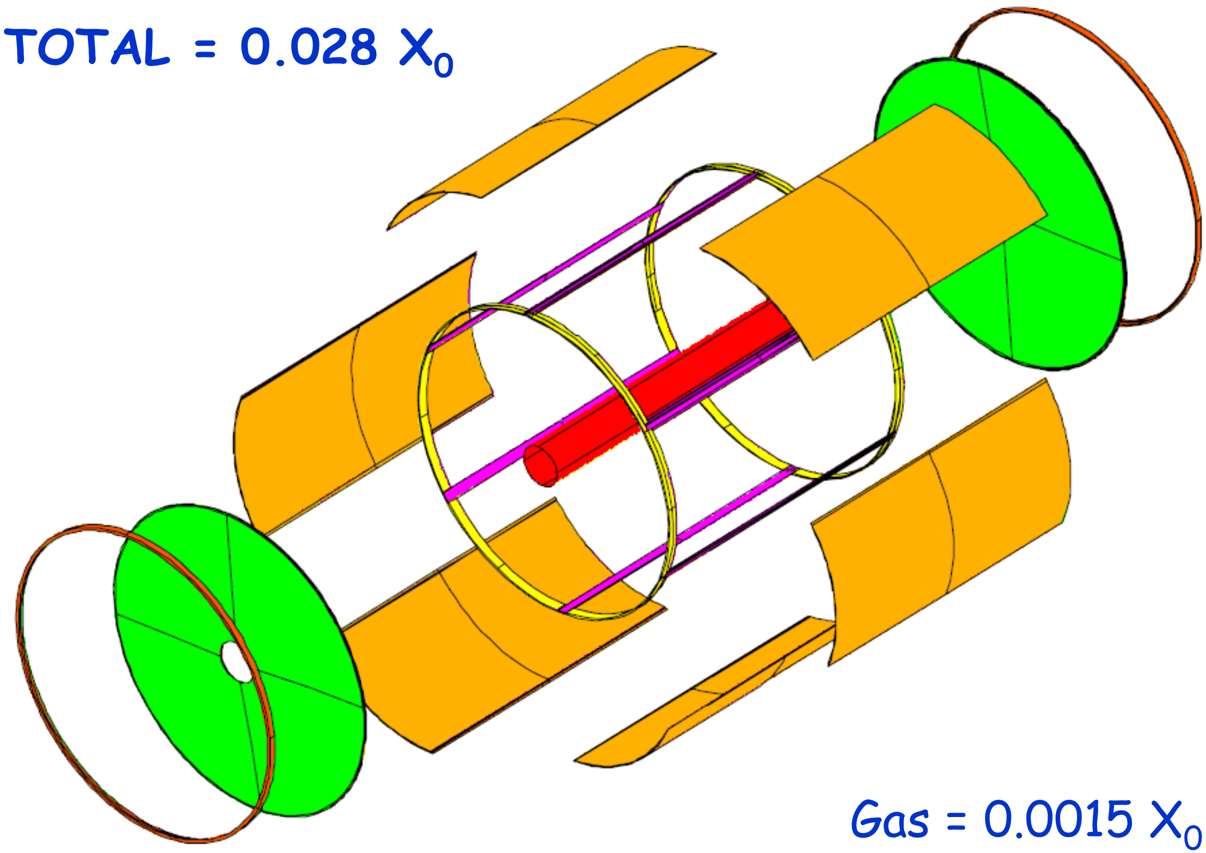
CLUCOU chamber expected dN_{cl}/dx resolution for a 2 m m.i.p. at 13 cluster/cm:

$\sigma(dN_{cl}/dx)/(dN_{cl}/dx) = 2.0\ \%$

4thConcept ILC Drift Chamber

Layout and assembly technique

TOTAL = 0.028 X_0



Gas = 0.0015 X_0
Wires = 0.0040 X_0

Length:
3.4 m at r = 22.5 cm
3.0 m at r = 147.0 cm

Spherical end plates:
C-f. 12 mm + 30 μm Cu
(0.047 X_0)

Inner cylindrical wall:
C-f. 0.2 mm + 30 μm Al
(0.001 X_0)

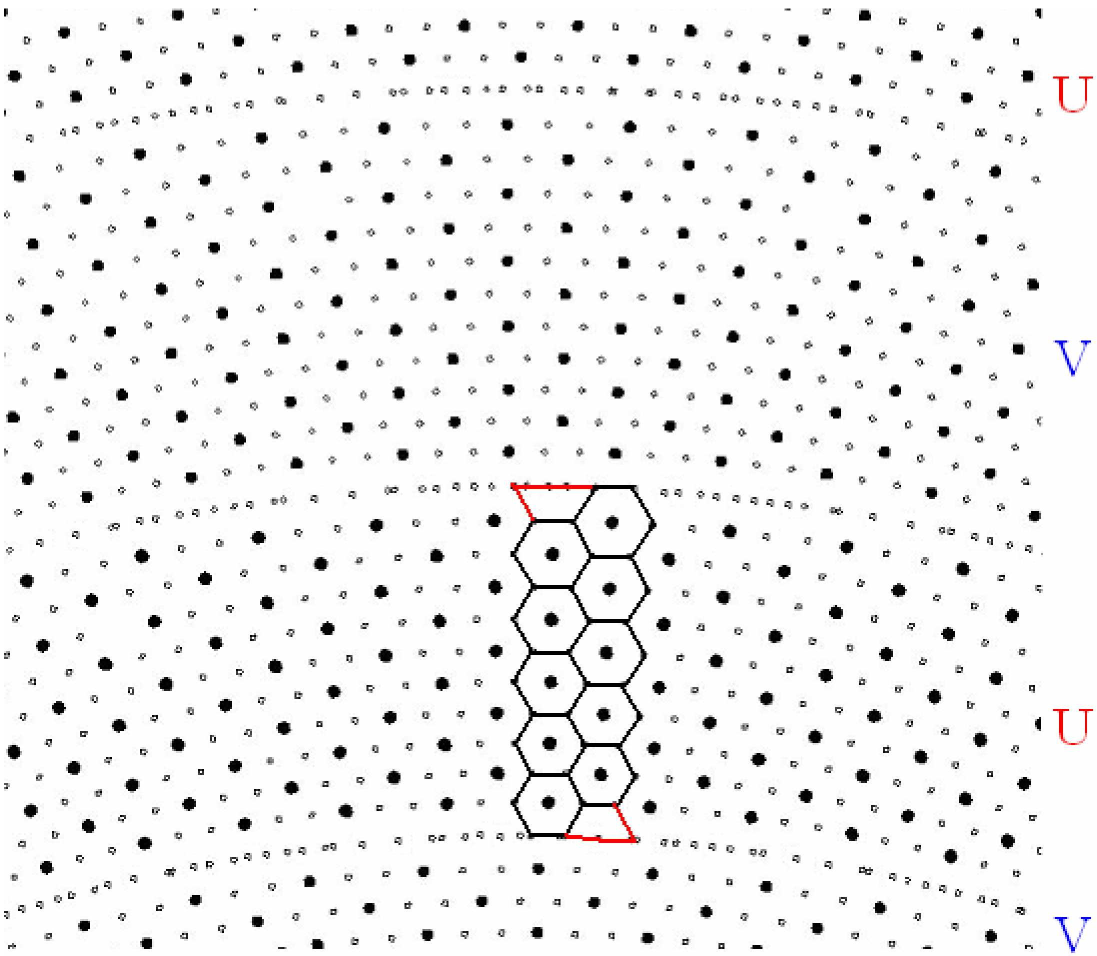
Outer cylindrical wall:
C-f./hex.cell. sandwich
held by 6 unidir. struts
0.020 X_0)

Retaining ring

Stiffening ring

4thConcept ILC Drift Chamber

Layout



Hexagonal cells f.w./s.w.=2:1

cell height: 1.00 ÷ 1.20 cm
cell width: 6.00 ÷ 7.00 mm

(max. drift time < 300 ns !)

20 superlayers at alternating
stereo angles ±72 ÷ ±180 mrad
(constant stereo drop = 2 cm)

60000 sense w. 20 μm W
120000 field w. 80 μm Al

“easy” t-to-d r(t) (few param.)

>90% sampled volume

Summary for ILC

A drift chamber à la KLOE with cluster counting (≥ 1GHz, ≥ 2Gsa/s, 8bit)

- uniform sampling throughout >90% of the active volume
- 60000 hexagonal drift cells in 20 stereo superlayers (72 to 180 mrad)
- cell width 0.6 ÷ 0.7 cm (max drift time < 300 ns)
- 60000 sense wires (20 μm W), 120000 field wires (80 μm Al)
- high efficiency for kinks and vees
- spatial resolution on impact parameter σ_b = 50 μm (σ_z = 300 μm)
- particle identification $\sigma(dN_{cl}/dx)/(dN_{cl}/dx) = 2.0\%$
- transverse momentum resolution $\Delta p_\perp/p_\perp = 2\cdot10^{-5}\, p_\perp \oplus 5\cdot10^{-4}$
- gas contribution to m.s. 0.15% X_0, wires contribution 0.40% X_0
- high transparency (barrel 2.8% X_0, end plates 5.4%/cosθ X_0+electronics)
- easy to construct and very low cost

is realistic, provided:

- cluster counting techique is at reach (front end VLSI chip)
- fast and efficient counting of single electrons to form clusters is possible
- 50 μm spatial resolution has been demonstrated

A CMOS high-speed front-end for cluster counting techniques in ionization detectors

A. Baschirotto[1], S. D'Amico[1], M. De Matteis[1], F. Grancagnolo[2], M. Panareo[1,2], R. Perrino[2], G. Chiodini[2], G. Tassielli[2,3]

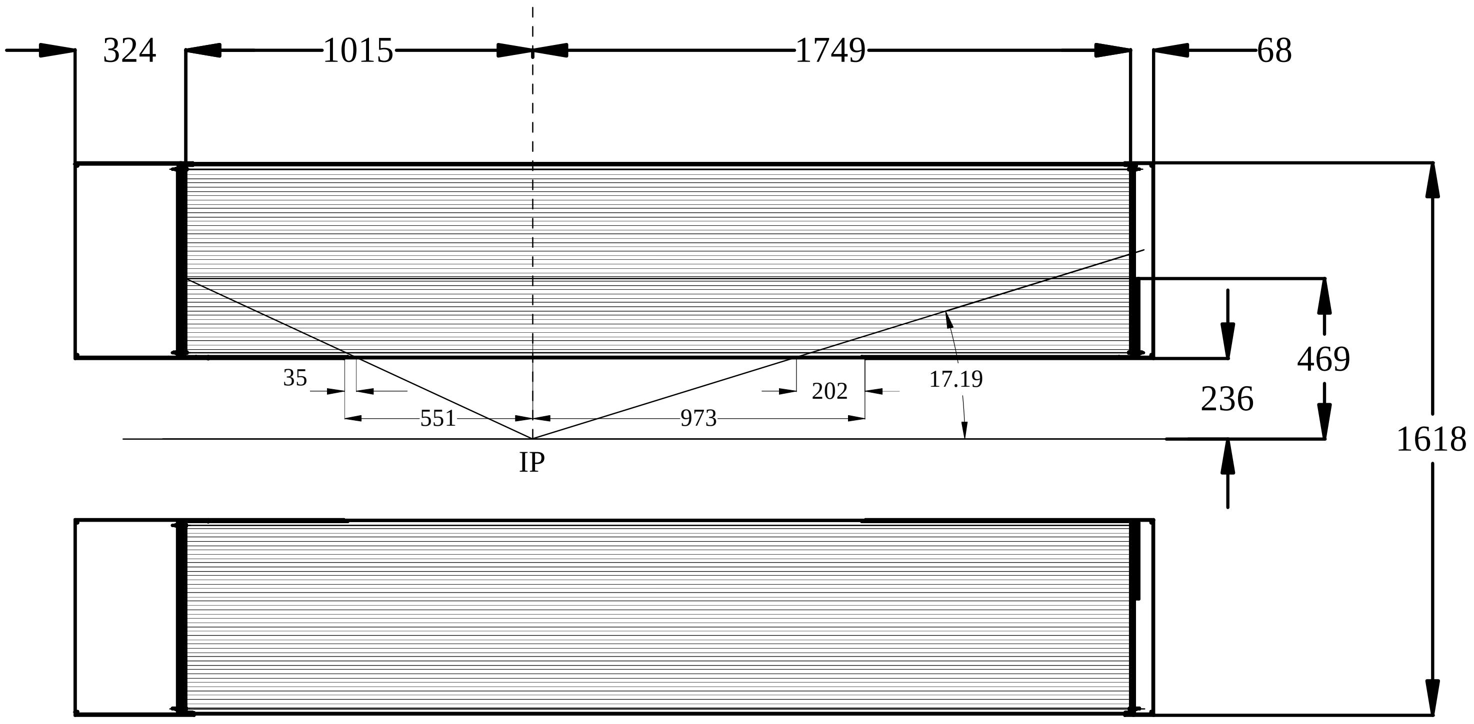
to be presented at

IWASI 2007

2nd IEEE International Workshop On
Advances in
Sensors and Interfaces
26/27 June 2007 - Bari, Italy
http://iwasi.poliba.it

IWASI 2007

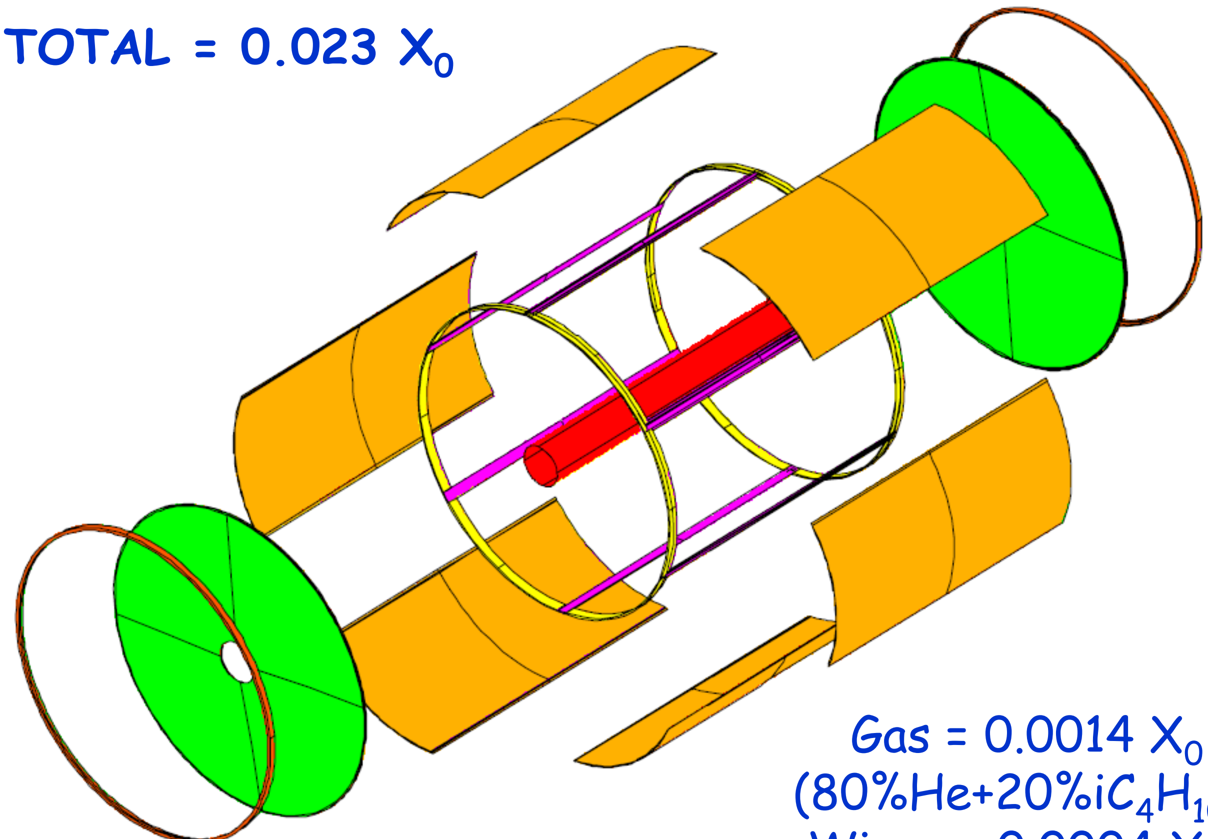
Downscaling to SuperB



SuperB Drift Chamber

Layout and assembly technique

TOTAL = 0.023 X_0



Gas = 0.0014 X_0
($80\%He+20\%iC_4H_{10}$)
Wires = 0.0004 X_0

Length × Diameter :
~ 2.8 m × 0.8 m

Spherical end plates:
C-f. 6 mm equivalent
+ 30 μm Cu (0.024 X_0)

Inner cylindrical wall:
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SuperB Drift Chamber

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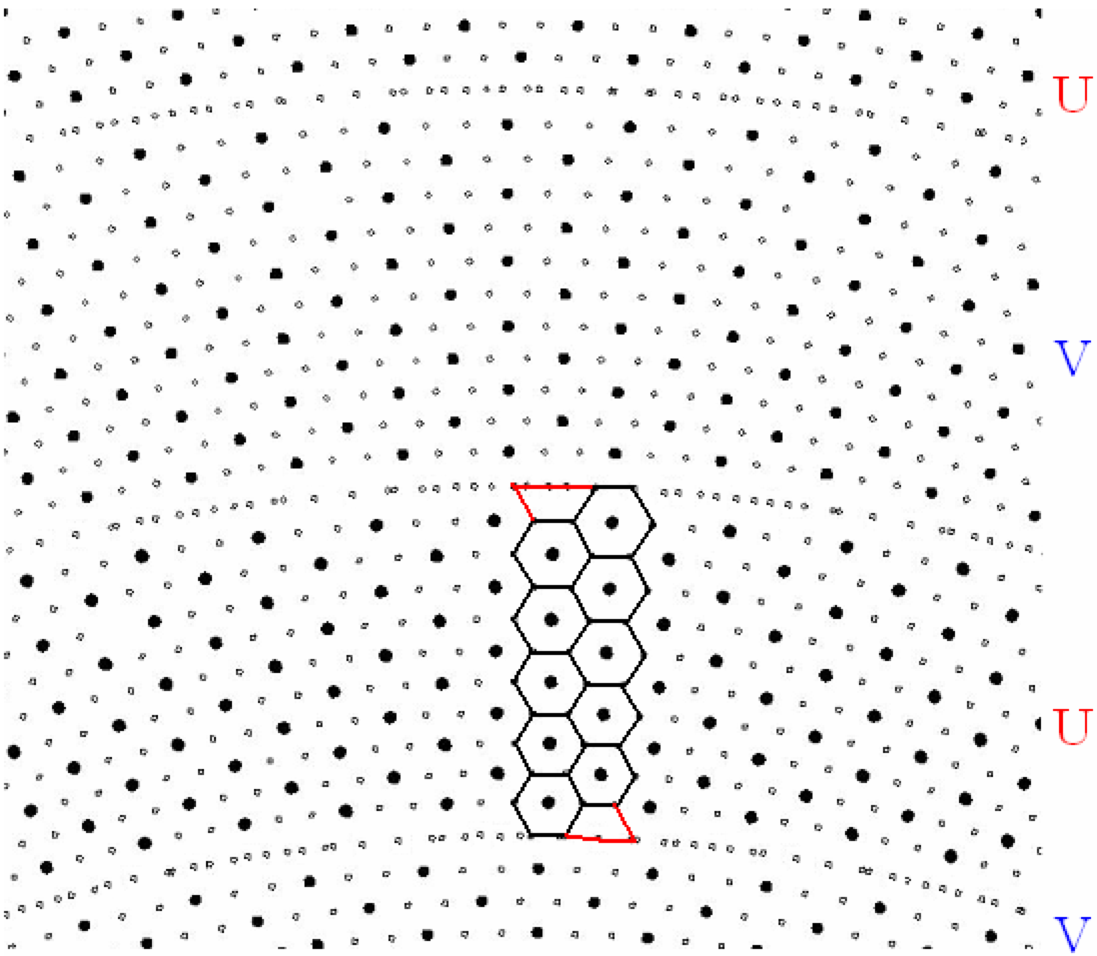

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- 36000 sense wires (20 μm W), 36000 field wires (80 μm Al)
- high efficiency for kinks and vees
- spatial resolution on impact parameter σ_b = 50 μm (σ_z = 400 μm)
- particle identification $\sigma(dN_{cl}/dx)/(dN_{cl}/dx) = 2.3\%$
- transverse momentum resolution $\Delta p_\perp / p_\perp = 0.9 \cdot 10^{-3}\, p_\perp \oplus 1.5 \cdot 10^{-3}$
- gas contribution to m.s. 0.14% X_0, wires contribution 0.04% X_0
- high transparency (barrel 2.3% X_0, end plates 2.7%/cosθ X_0+electronics)
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