The CLUster COUnting Drift Chamber of the ILC – 4thConcept

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2007 INTERNATIONAL
LINEAR COLLIDER WORKSHOP
May 30 until June 3, 2007

Worldwide Study of
the Physics and Detectors
for Future Linear
e+e- Colliders

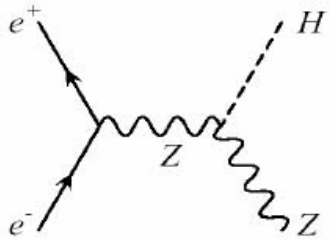
DESY

outline

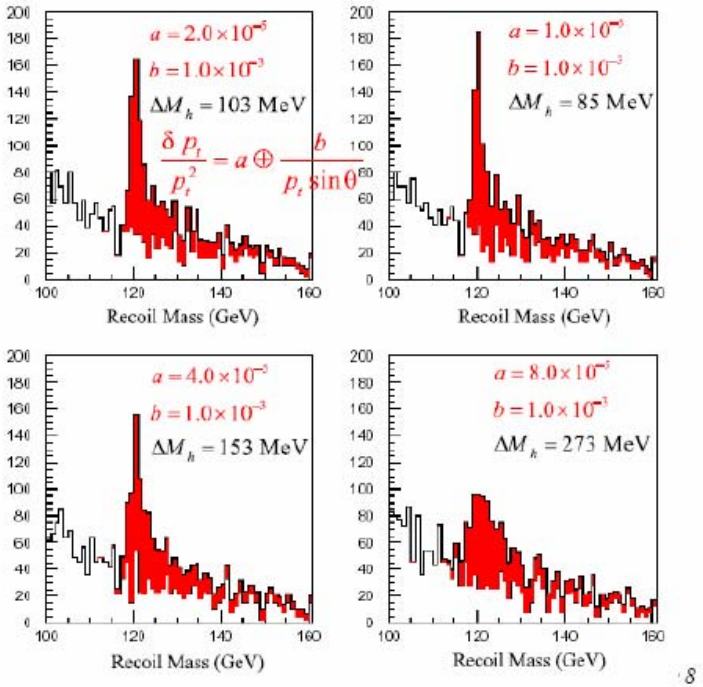
- Requirements for tracking at ILC
- CLUster COUnting
- 4thConcept CLUCOU Drift Chamber
- Preliminary studies
- Conclusions

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:
  - $\delta M_{ll} < 0.1x\ \Gamma_Z$
  - δM_H dominated by beamstrahlung



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

$$\frac{\delta p_\perp}{p_\perp{}^2} = 5.3\frac{\varepsilon_\perp}{\sqrt{N+4}} \oplus \frac{7.2\times10^{-3}}{p_\perp \sin\theta}\sqrt{\frac{L}{X_0}} \Rightarrow 2\times10^{-5} \oplus \frac{1\times10^{-3}}{p_\perp \sin\theta}$$

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

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

N = 150 , L ~ 2m
(1 cm² 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}

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

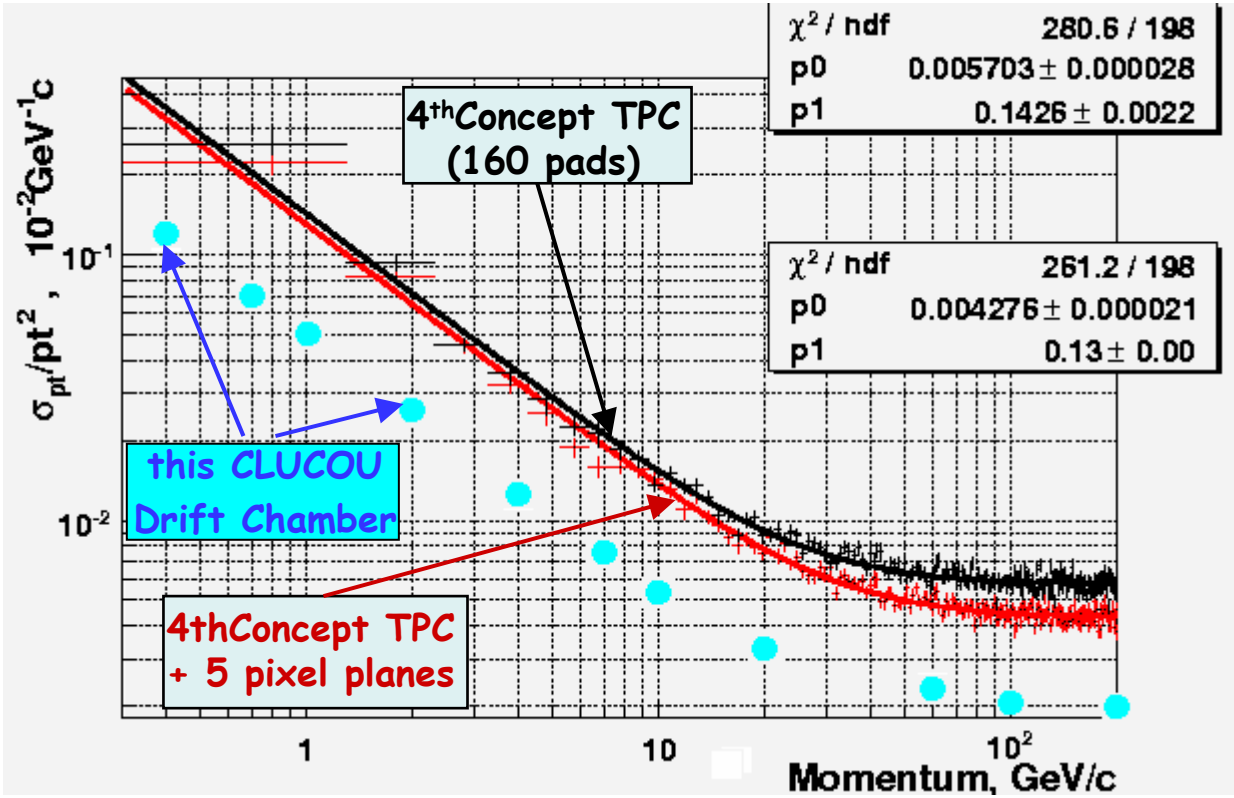
$$X_0 = 360m$$

Sagitta measurement contribution (in ⊥ plane):

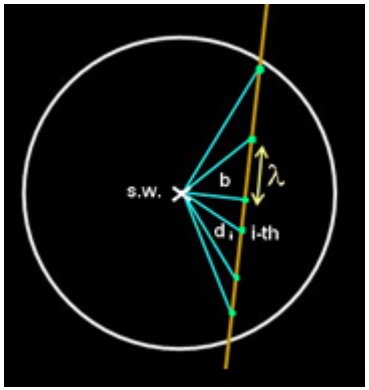
$$\sigma_{xy} = 50\mu m$$

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

dominated by mult. scatt. for $p_\perp \sin\theta \leq 25\,GeV/c$



CLUster COUnting

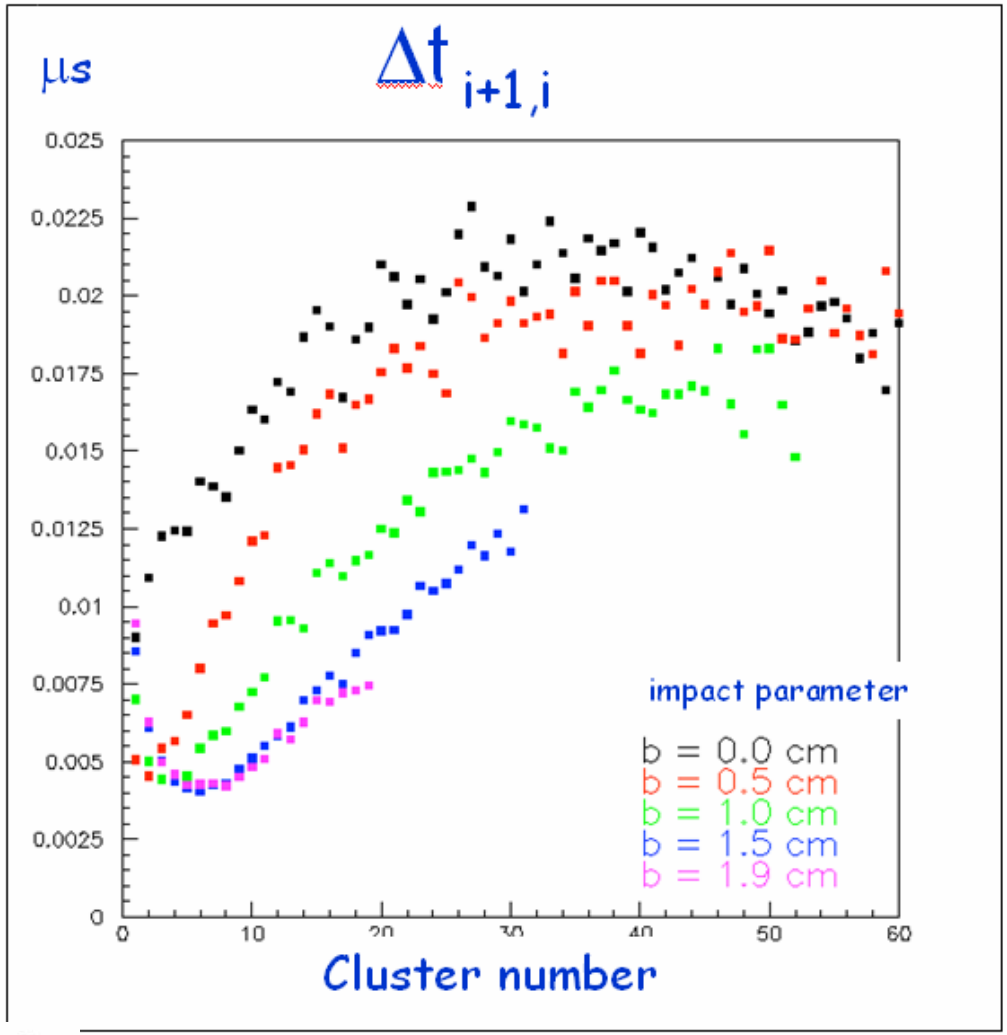


2 cm drift tube

90%He-10%iC_4H_{10}

few x 10^5 gain

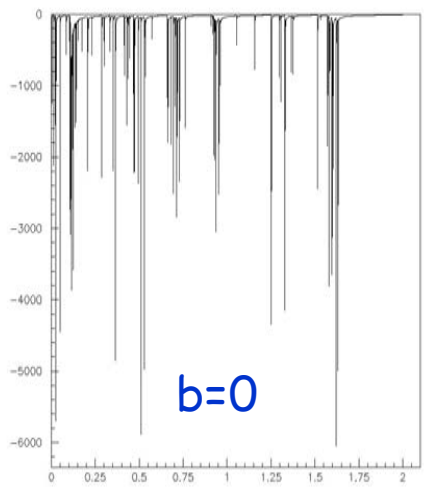
$\Delta t_{i+1,i}$: time separation between consecutive ionization clusters, as a function of their ordered arrival time, for different impact parameters. (caveat: electrons!)

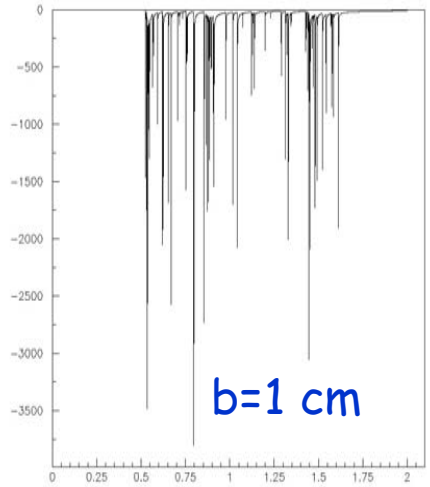


In this He mixture , **provided that:**
sampling frequency of signals > 2 Gsa/s and rise (and fall) time of single electron signals < 1ns
single electron counting is possible.

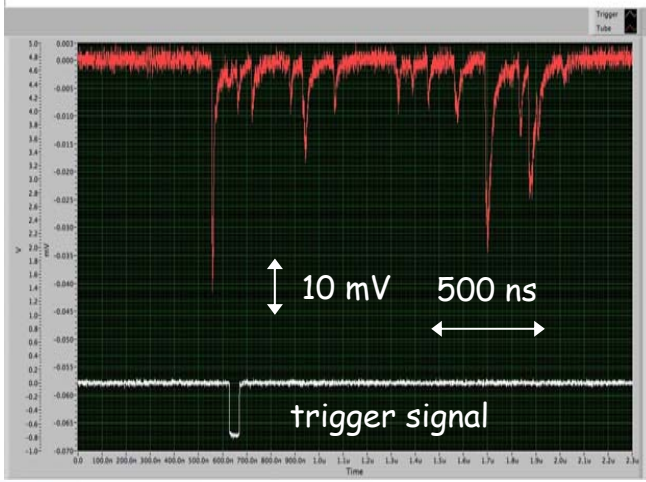
CLUster COUnting

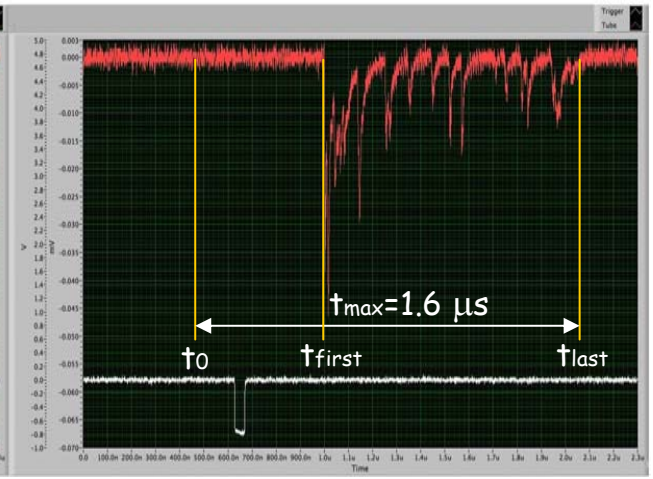
MC generated events:
2cm diam. drift tube
gain = few x 10
gas: 90%He–10%iC_4H_{10}
no electronics simulated
vertical arbitrary units





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

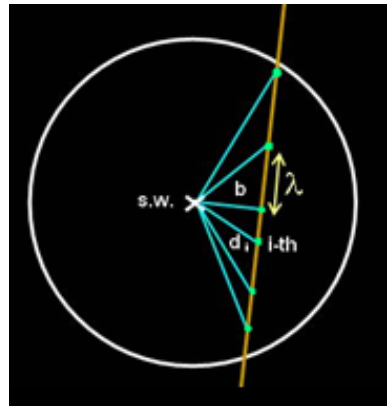
$N_{ele} = 1.6 \times N_{cl}$ expected number of electrons (to be compared with counted one)

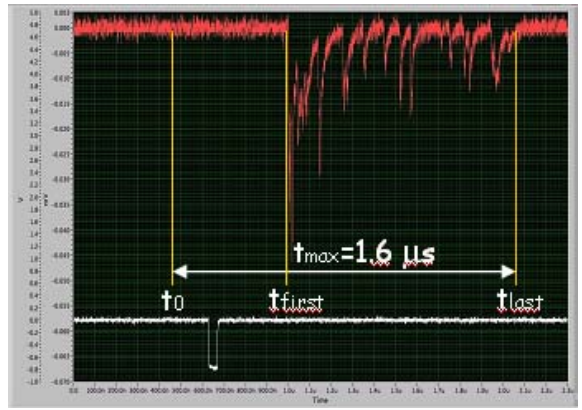
$\{t_i\}$ and $\{A_i\}$, $i=1,N_{ele}$ ordered sequence of ele.drift times and their amplitudes

$P(i,j)$, $i=1,N_{ele}$, $j=1,N_{cl}$ 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



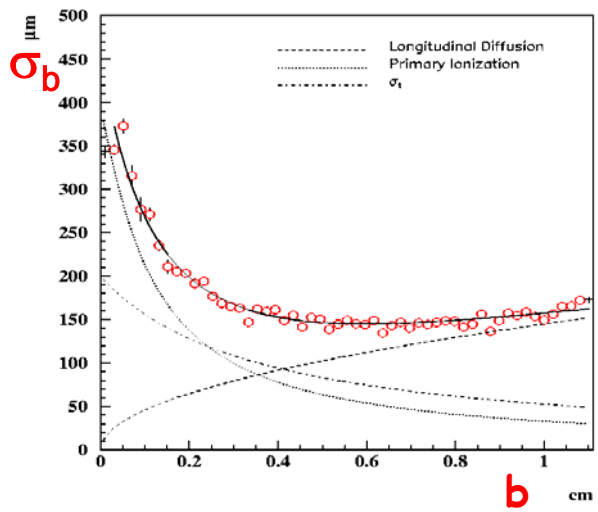


Each cluster contributes to the measurement of the impact parameter with an independent estimate weighted according to the Poisson nature of the process and the electron diffusion along the drift path.

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)

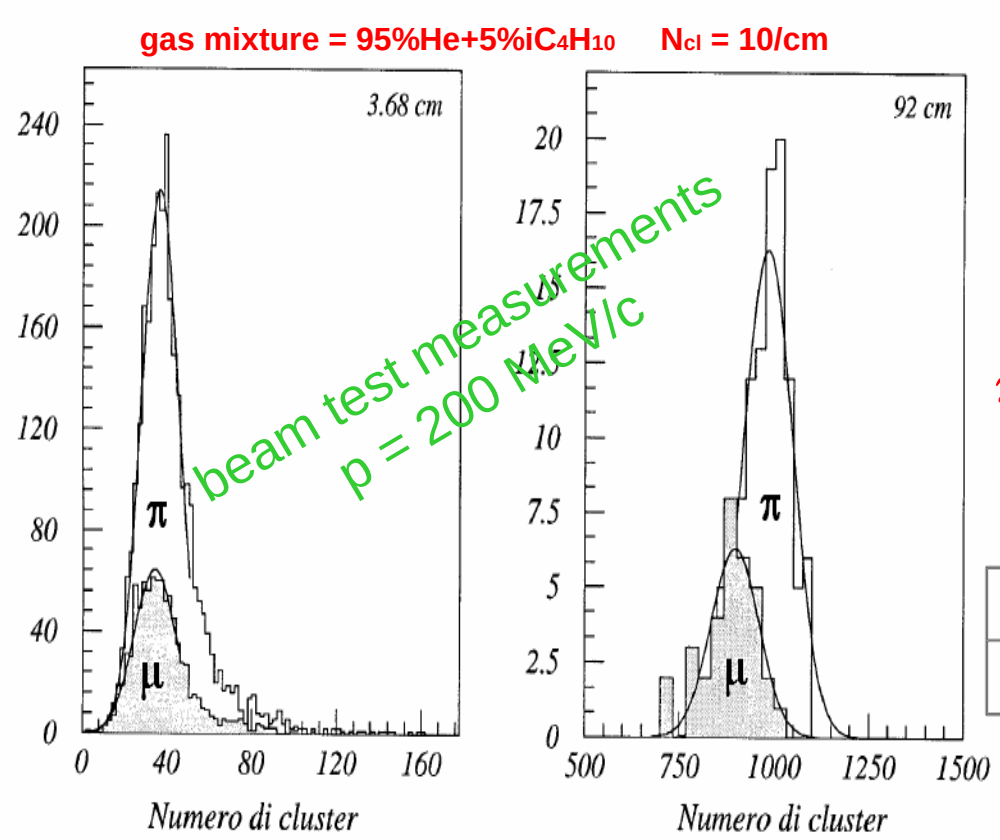


Fit to resolution function:
(from KLOE data)

$\lambda = 770 \pm 14$ 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 $\sigma_b = 50$ 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

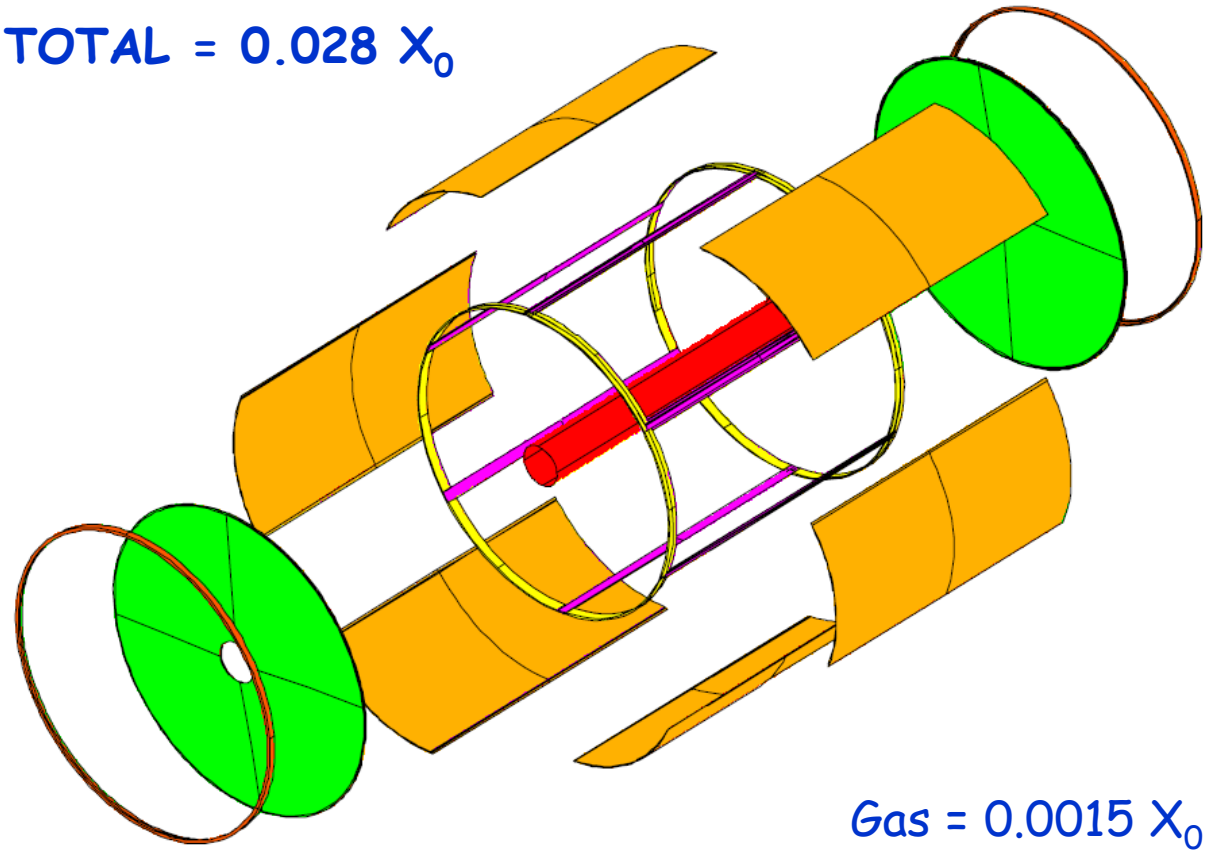
CLUCOU chamber expected dN_{cl}/dx resolution for a 2 m m.i.p. at 13 cluster/cm:

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

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)

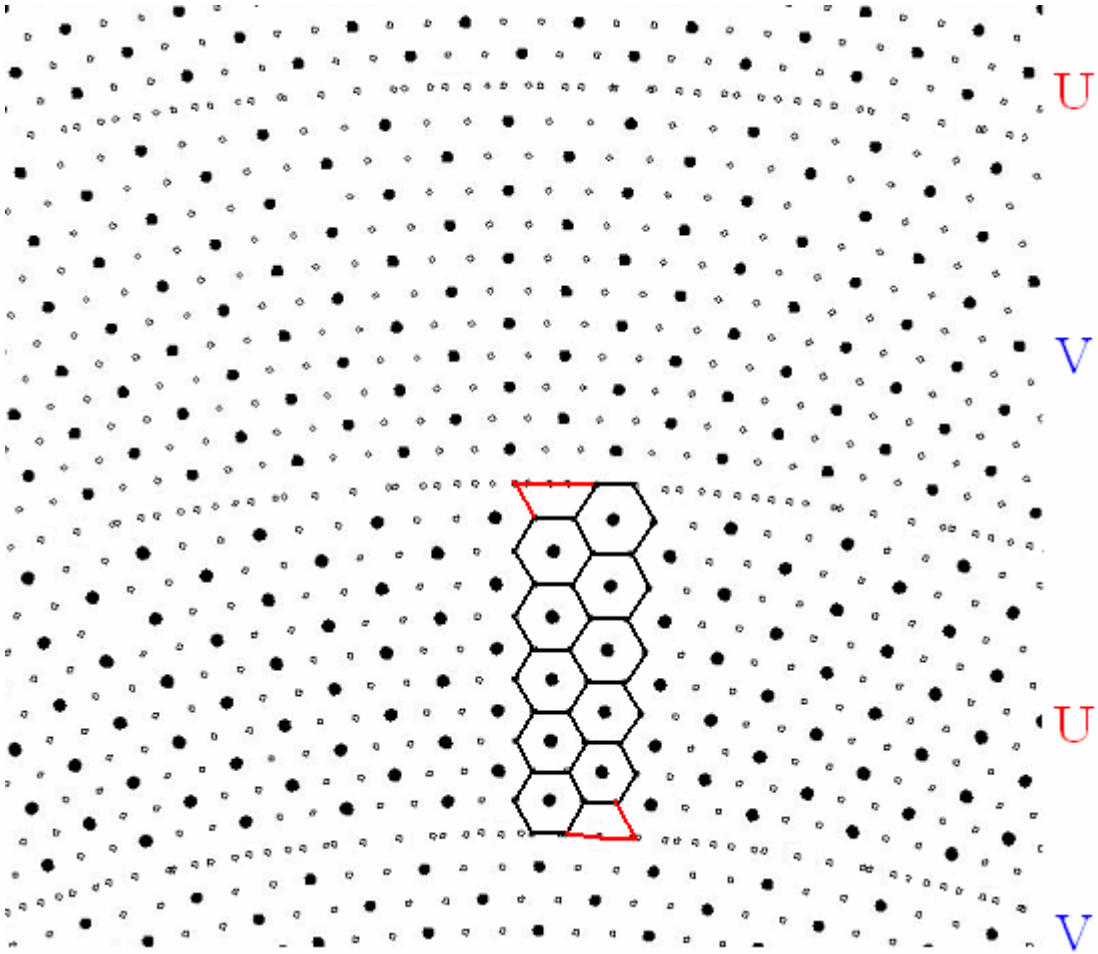
Outer cylindrical wall:
C-f./hex.cell. sandwich
held by 6 unidir. struts
0.020 X_0)

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 radius: 6.00 ÷ 7.00 mm

(max. drift time < 300 ns !)

20 superlayers, in 200 rings
10 cells each (7.5 in average)
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

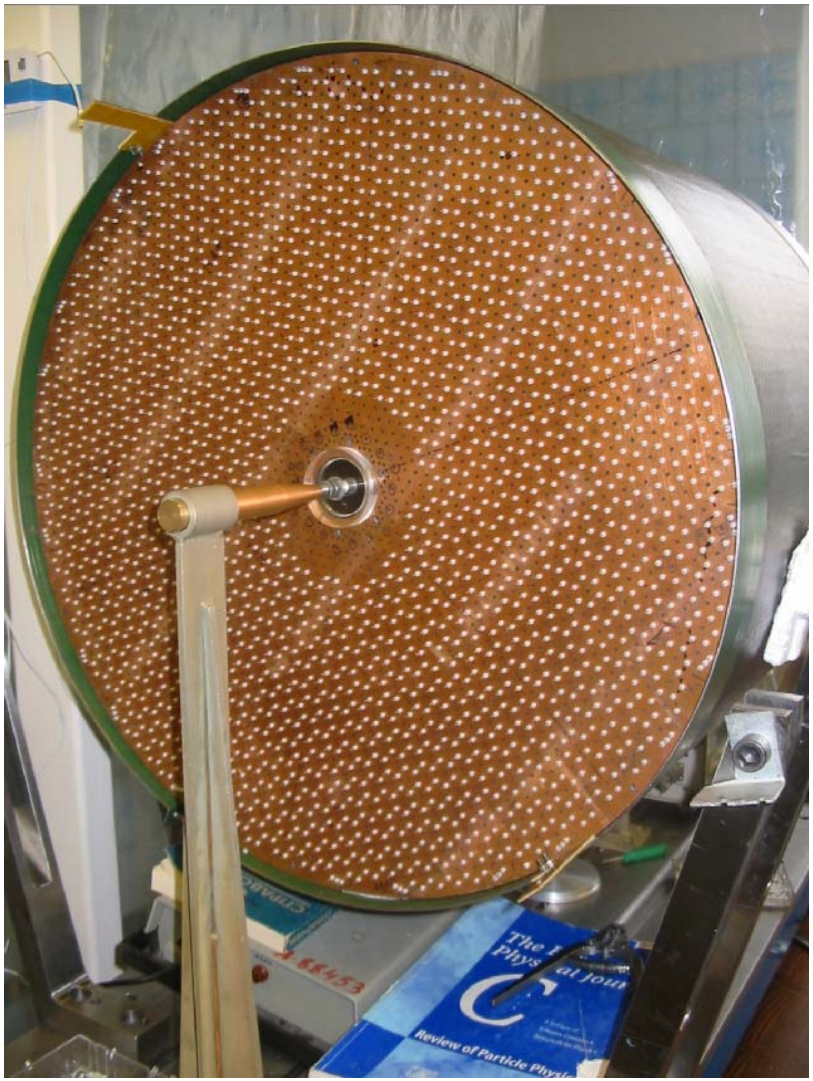
A drift chamber à la KLOE with cluster counting (≥ 1GHz, ≥ 2Gsa/s, 8bit)

- uniform sampling throughout >90% of the active volume
- 60000 hexagonal drift cells in 20 stereo superlayers (72 to 180 mrad)
- cell radius 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 cell impact par. σ_b = 50 μm (σ_z = 300 ÷ 700 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)
- poweful 3D reconstruction algorithm
- 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

Drift Chamber for CMD-3 Detector @ VEPP-2000, Novosibirsk

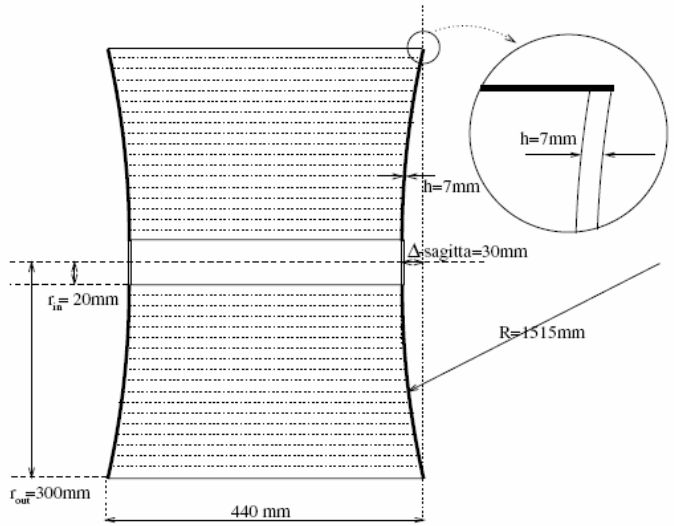


The number of cells for chosen geometry is 1218. The sensitive wires of 15 μm diameter are made with gold-plated W-Re alloy. The field wires of 80 μm diameter are made with gold-plated titanium. The ratio between numbers of sensitive and field wires is 1:2.

The gas mixture is Ar:iC_4H_{10} (80:20), and the gas gain coefficient is about 10^5 at 2 kV applied voltage. The electric field strength on the surface of the field wires is less than 20 kV/cm which is safe from the point of view of aging. Maximum drift time is 600 ns.

The frame of the chamber is made from carbon fibers. To minimize the amount of passive matter in front of the endcap calorimeter the flanges are spherical in shape with a radius of curvature of 1515 cm (Figure 3). The flanges thickness is 7 mm, and the outer wall thickness 2 mm. The inner wall is made from 0.2 mm kapton. The chamber thickness for 90 degrees tracks is 0.01 X_0. The thickness of passive matter in front of the endcap calorimeter is 0.04 X_0.

The average spatial resolution in the cell is about 140 μm taking into account the cluster effect and diffusion. The cell has a hexagonal shape with a diagonal distance of 17 mm.



G.V. Fedotovich and the CMD-3 Collaboration
Nuclear Physics B - Proceedings Supplements Volume 162, December 2006, Pages 332-338
The Proceedings of the II International Workshop on e+e- Collisions from phi to psi

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]

[1]*Department of Innovation Engineering – University of Salento, Italy*
[2]INFN *Sezione di Lecce, Italy*
[3]*Department of Physics – University of Salento, Italy*

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

CLUCOU Proposal presented @ Tracking R&D Review during

9th ACFA ILC Physics and Detector Workshop & ILC GDE Meeting
Feb. 4-7, 2007, IHEP, Beijing
http://bilcw07.ihep.ac.cn/

23 March 2007

ILC Tracking R&D
Report of Review Committee

Review dates: 5-8 February 2007
ILC Workshop, Beijing

1. COMMITTEE MEMBERS

Members of ILC Detector R&D Panel

Chris Damerell RAL, UK (chair)
Dean Karlen U Victoria, Canada
Wolfgang Lohmann DESY, Germany
Hwanbae Park Kyungpook U, Korea
Harry Weerts ANL, USA

External Consultants

Peter Braun-Munzinger GSI, Germany
Ioanis Giomataris DAPNIA-CEA, France
Hideki Hamagaki Tokyo U, Japan
Hartmut Sadrozinski UCSC, USA
Fabio Sauli CERN, Switzerland
Helmuth Spieler LBNL, USA
Mike Tyndel RAL, UK
Yoshinobu Unno KEK, Japan

Chair of ILC Research and Development Board

Bill Willis Columbia U, USA

Regional Representatives

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Asia: Junji Haba KEK, Japan
America: Bing Zhou U Michigan, USA

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Ouyang Qun IHEP, Beijing, China

Admin Support

Naomi Nagahashi SLAC, USA
Maura Barone Fermilab, USA
Maxine Hronek Fermilab, USA
Xu Tongzhou IHEP, Beijing, China

The Tracking Review Committee studied the programmes of the three large R&D collaborations (LCTPC, SiLC and SiD tracking) plus one new idea (from the CLUCOU group). These cover the two main alternatives for ILC tracking, namely gaseous (central) plus silicon (forward), as opposed to an all-silicon system.

evaluating the performance of a large tracking prototype with respect to all relevant criteria, in sufficient detail to determine the performance of a full-scale detector constructed with this technology.

2. EXECUTIVE SUMMARY

A one-sentence summary of our recommendations: *Form a Tracking Coordination Group to coordinate the completion of the R&D programme, so that the community will be able to finalise the choice of tracking technologies for ILC detectors on the basis of these results.* we suggest the composition of this group could be:

representatives from the ILC Detector R&D Panel, for each of the main tracking collaborations (Dean Karlen, Hwanbae Park and Harry Weerts for the LCTPC, SiLC and SiD respectively)

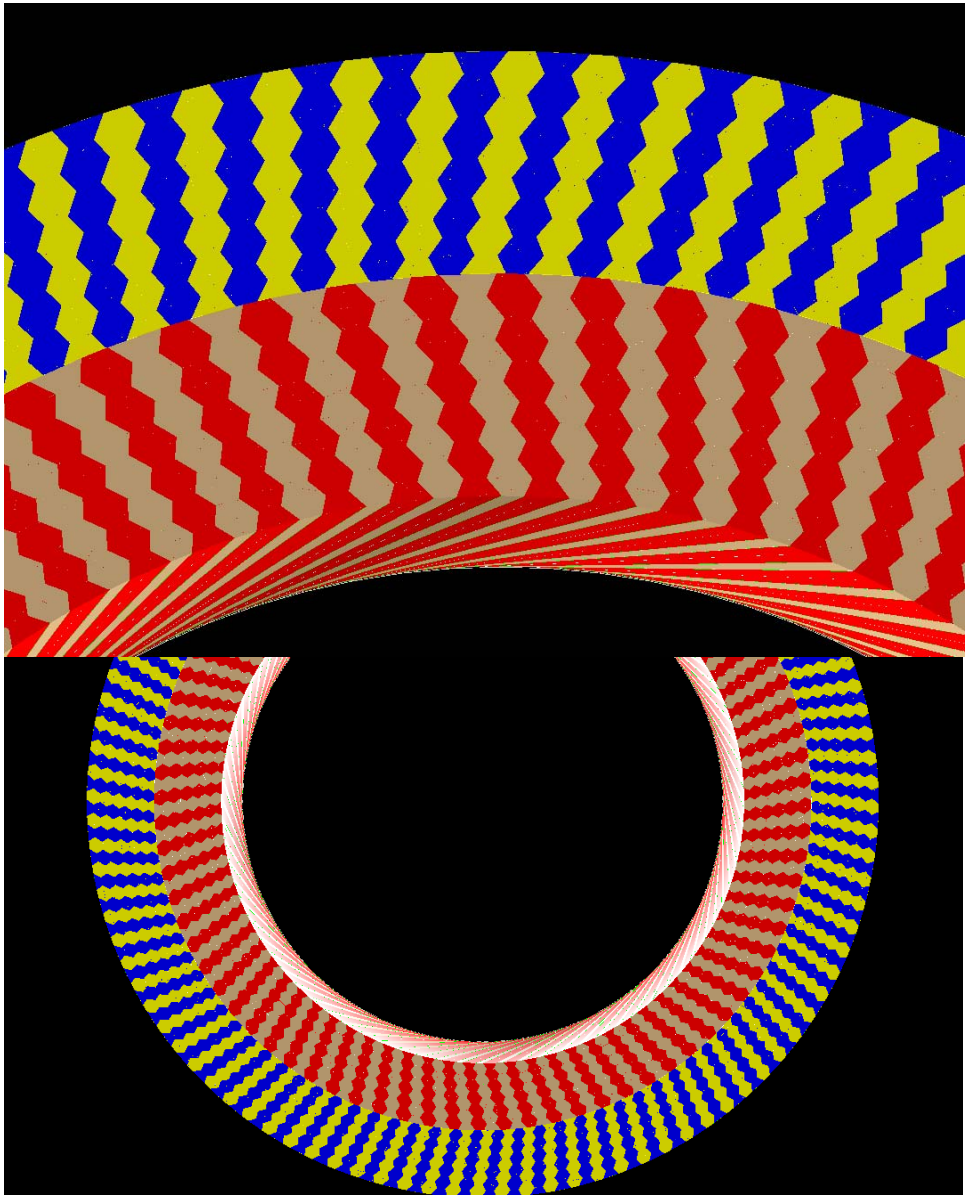
two further representatives from each of these collaborations, plus one from CLUCOU

6. RECOMMENDATIONS (SPECIFIC)

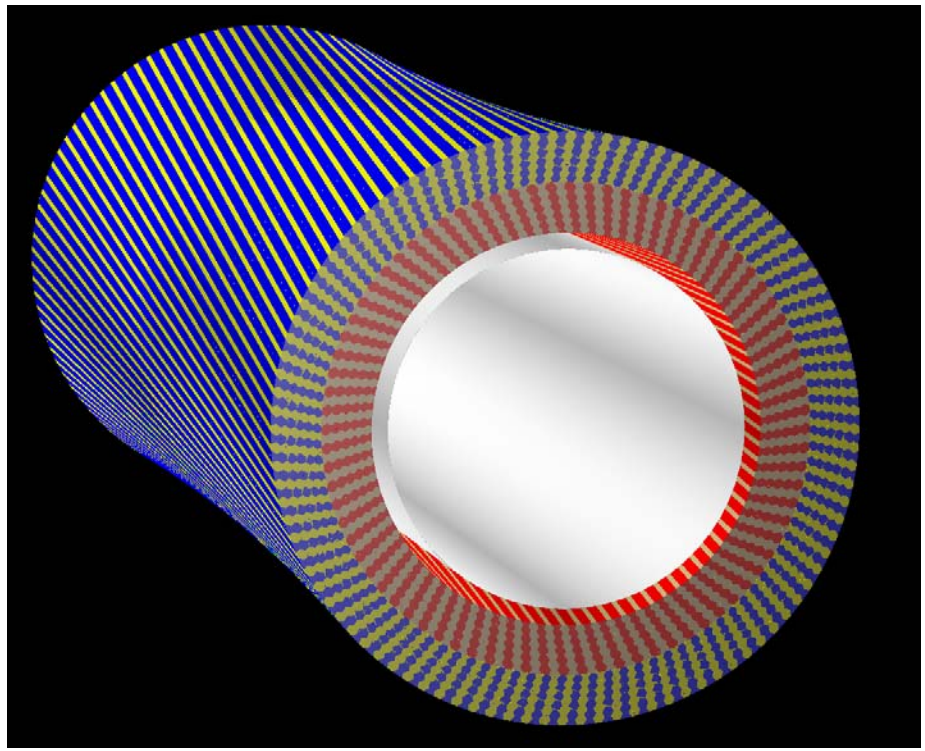
6.2. CLUCOU

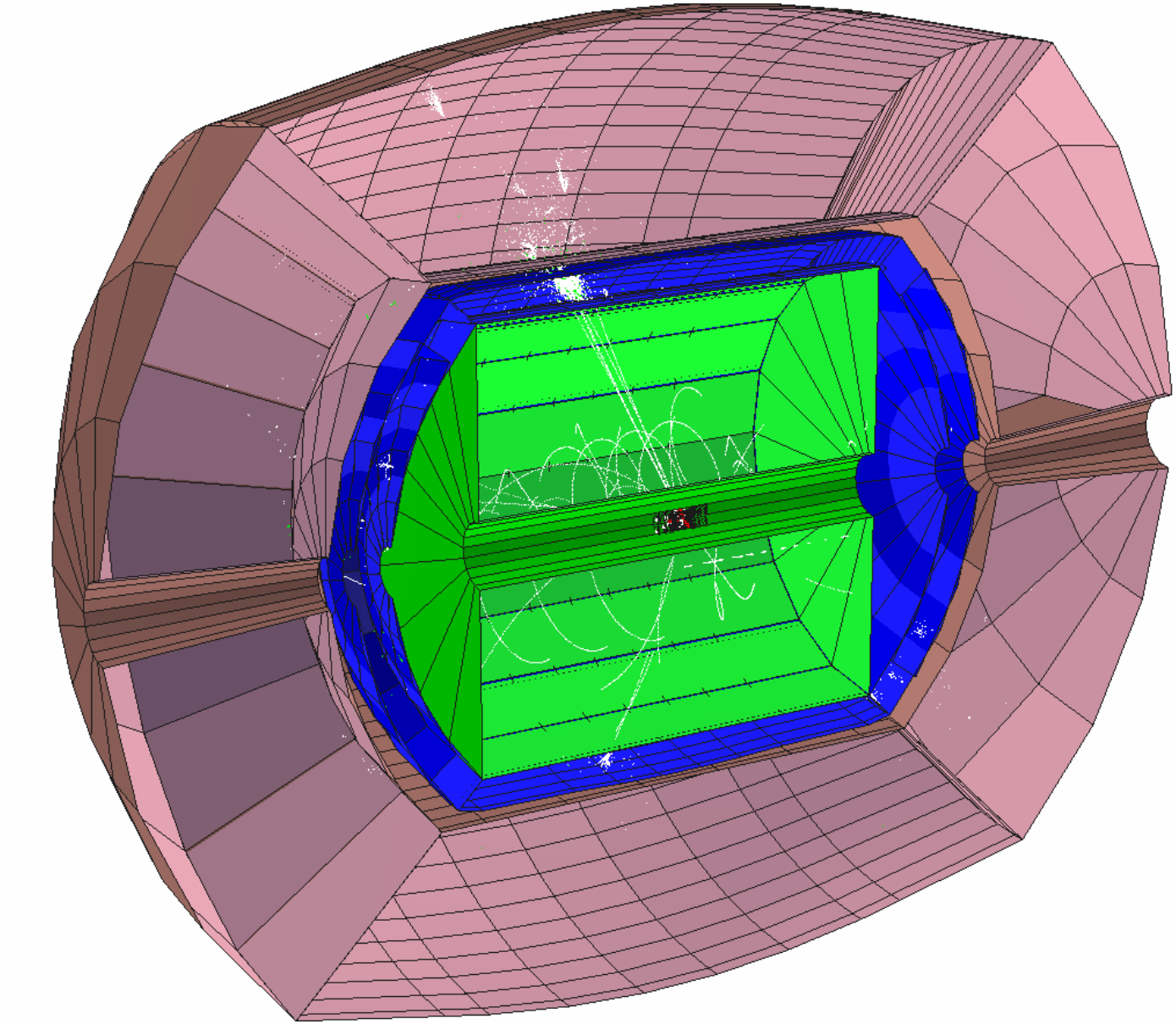
However, simulations are needed to see how bad the situation may be in the core of high energy jets, where some tracks could be unresolvable over the inner region. Even so, as with the TPC, it is the overall performance in conjunction with the vertex detector which really matters, so simple calculations tend to give misleading results. It will be very interesting to see what emerges from detailed simulations within the next year or so.

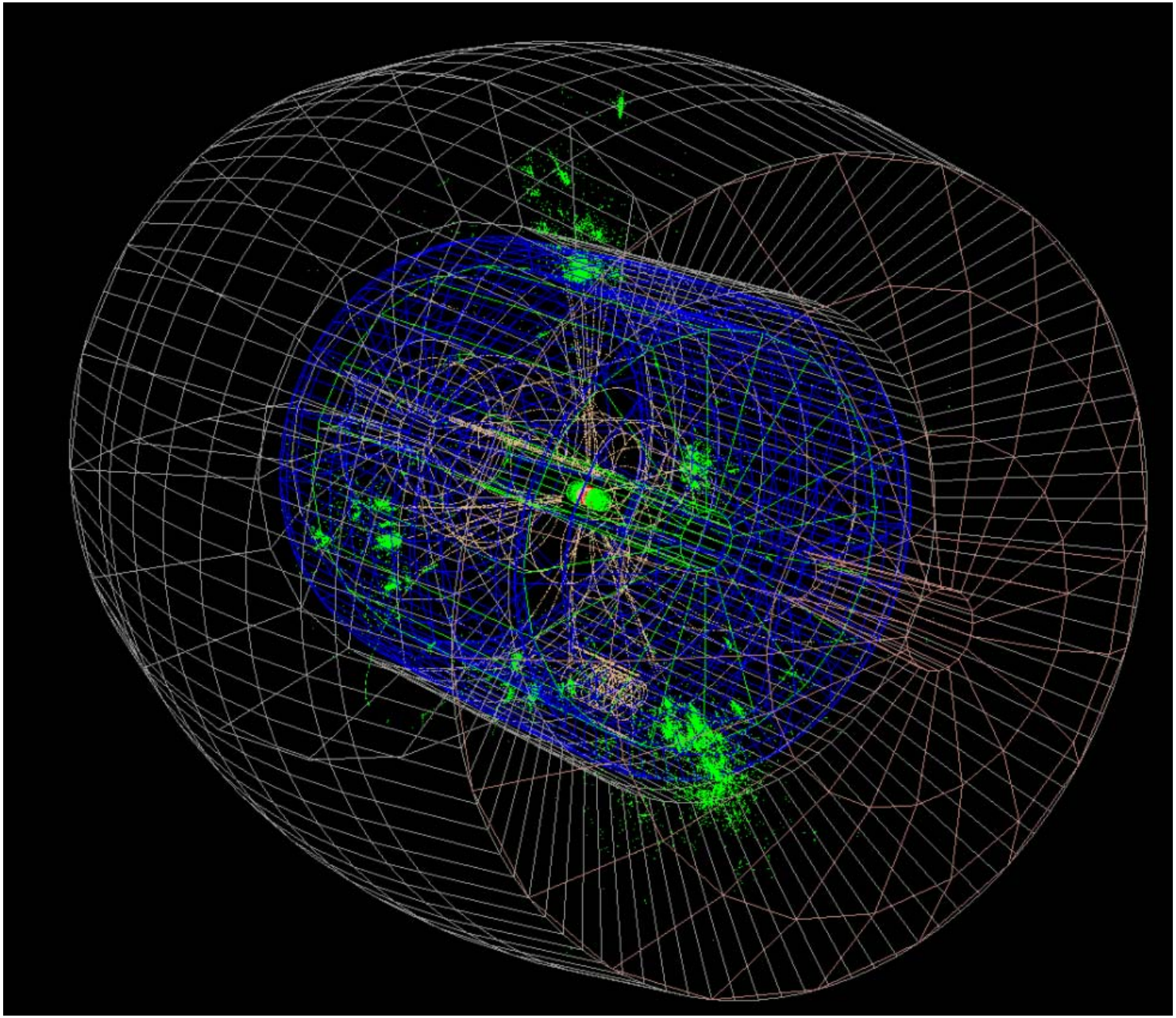
In summary, the CLUCOU group has only recently started to explore this approach to ILC tracking, in the light of a potential requirement which could prove to be serious. This review was obviously too early for an in-depth study of this approach, but the committee supports the scientific case, and looks forward with interest to the future evolution of this R&D programme.

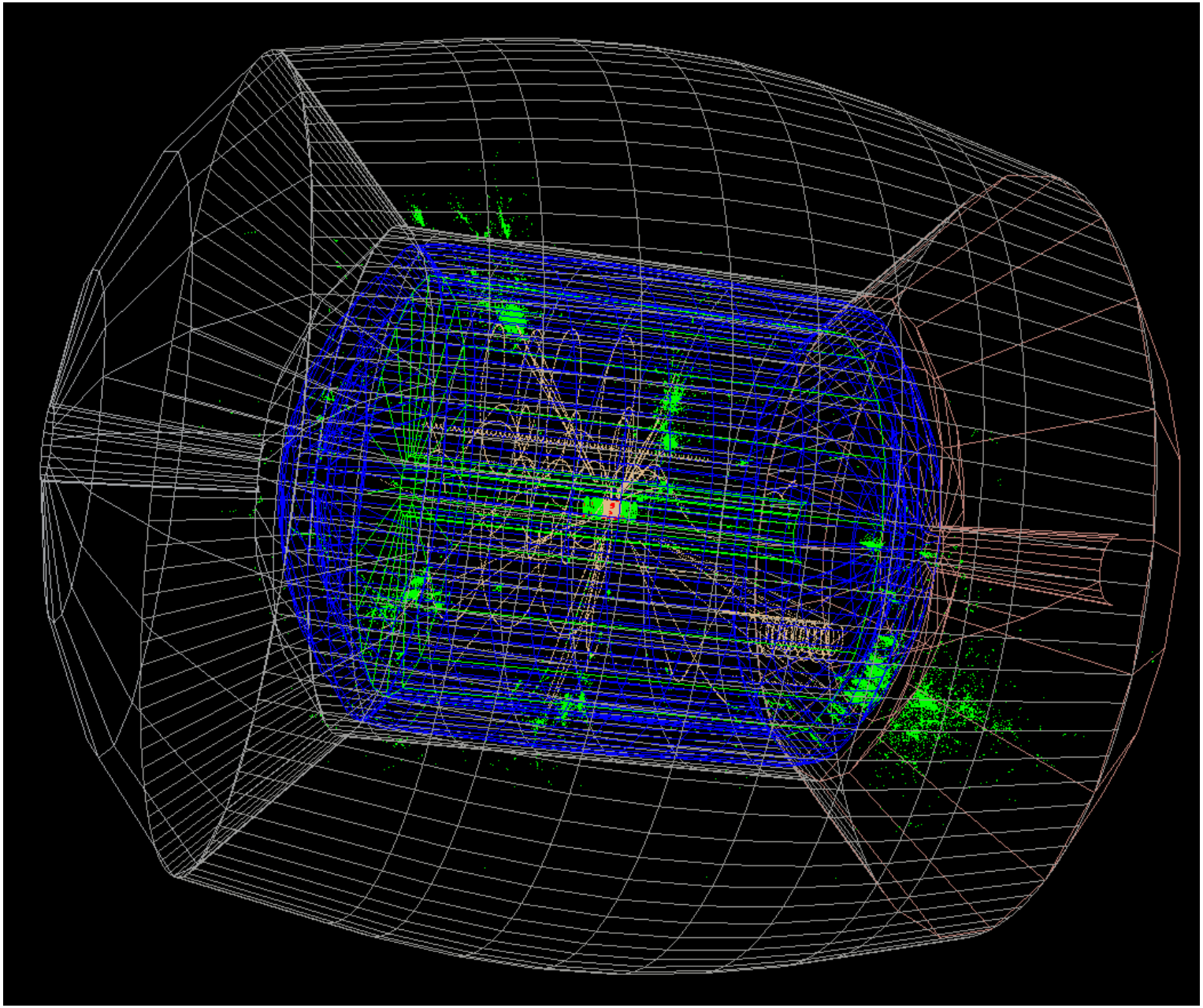


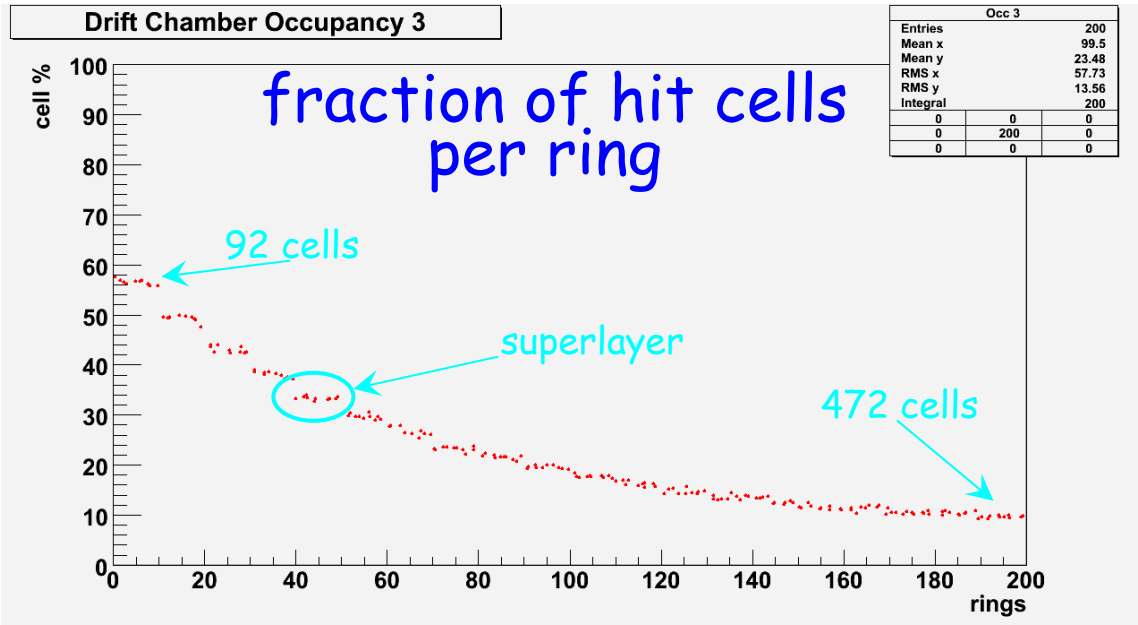
rendering of first two superlayer stereo

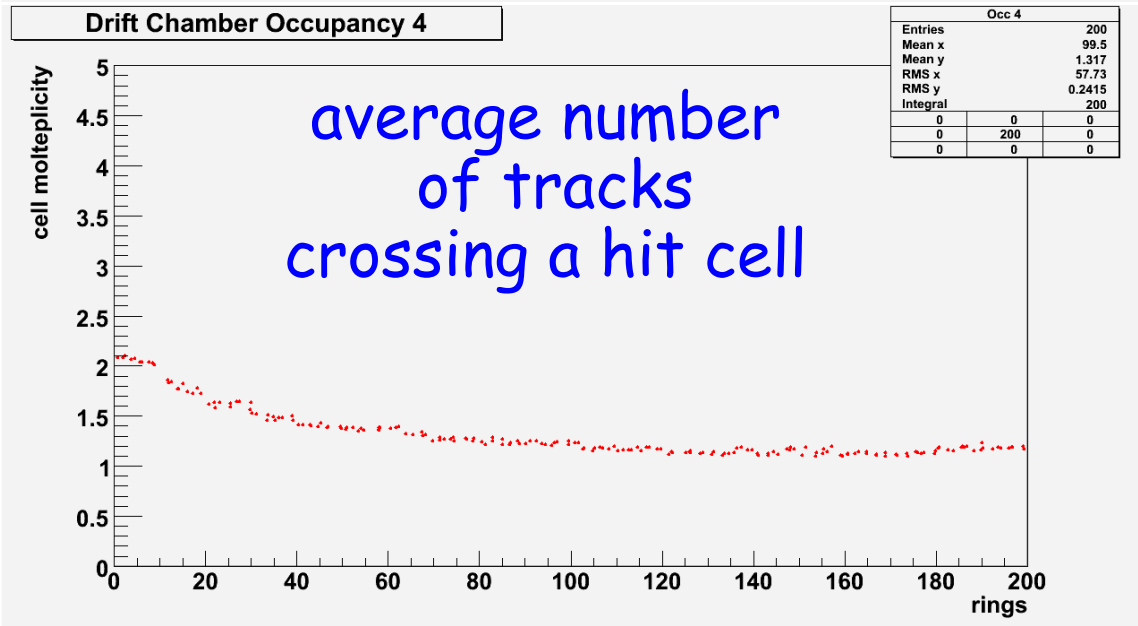








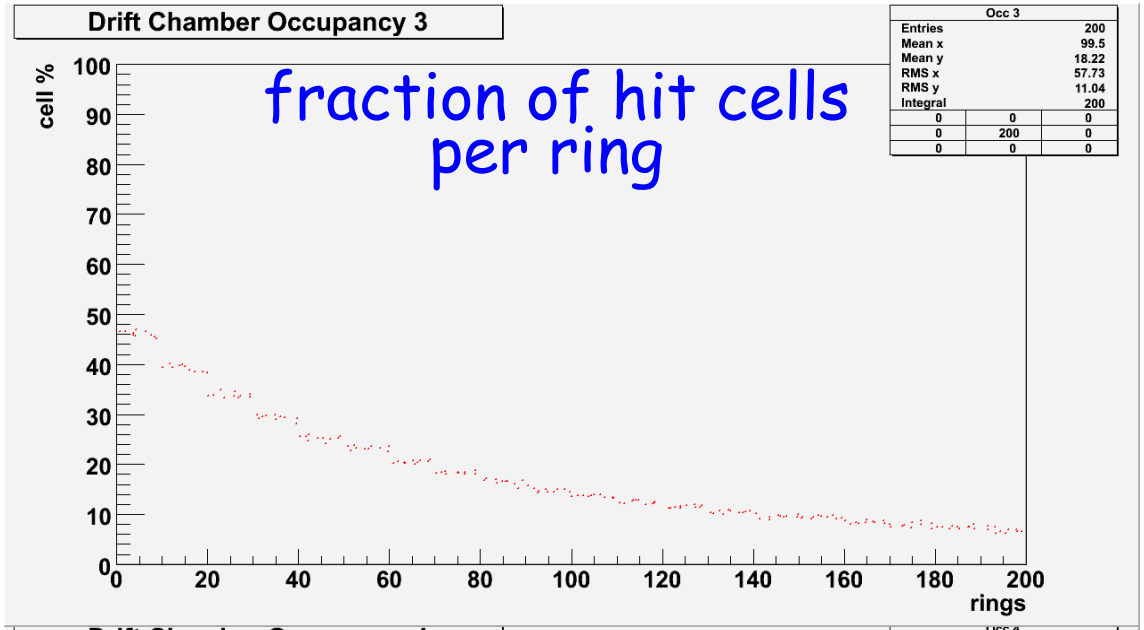


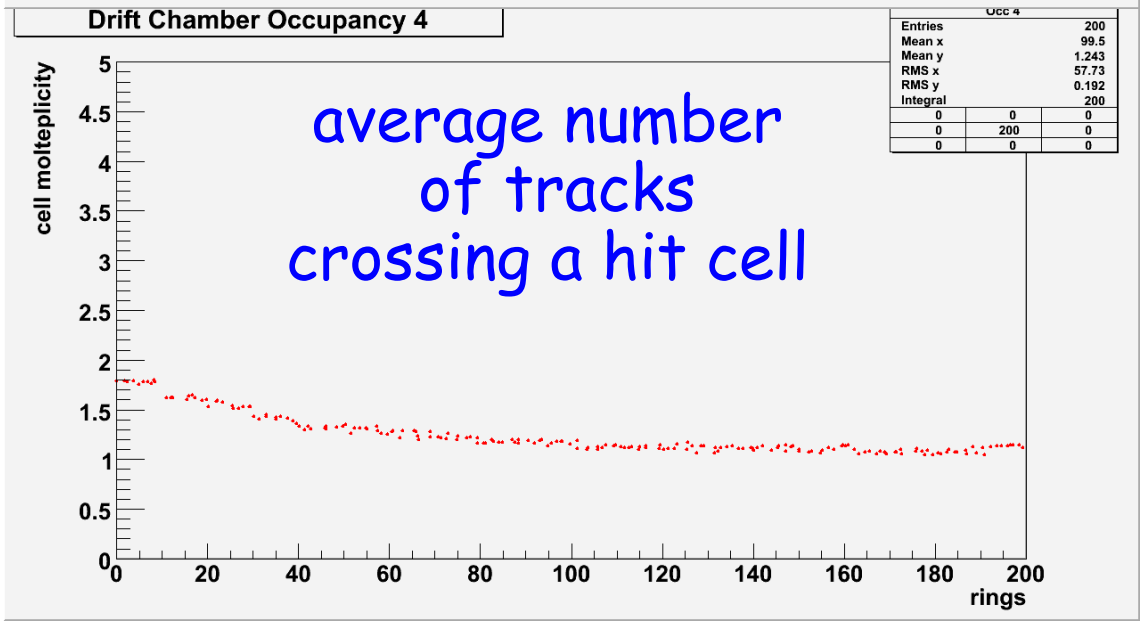


highest multiplicity events:

$$e^+e^- \rightarrow t\bar{t}$$

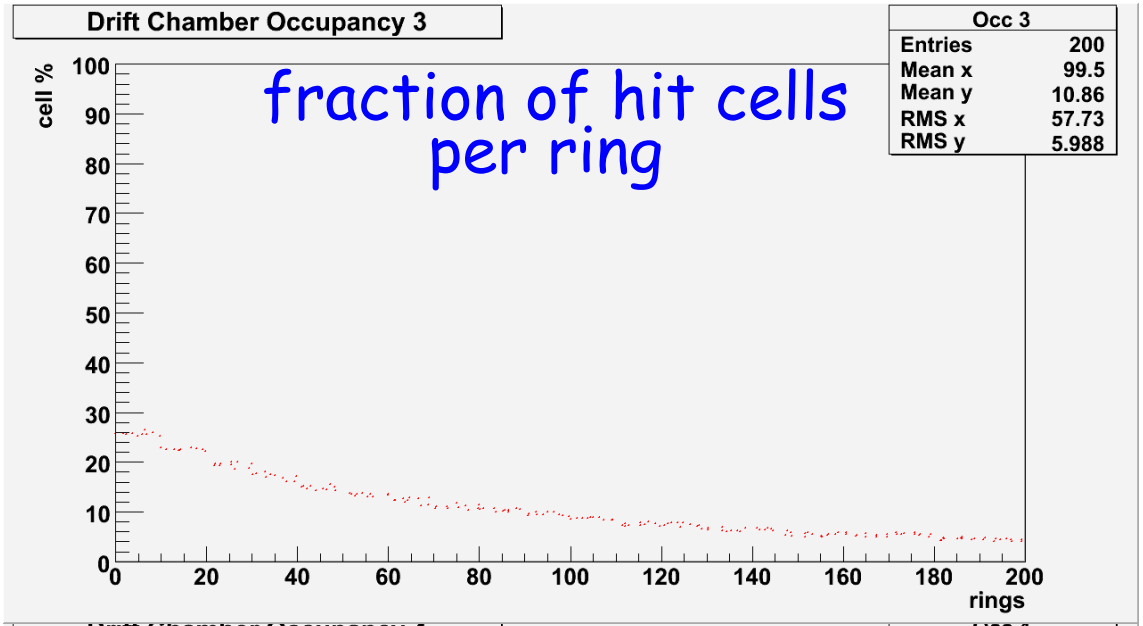
$$\rightarrow 6\ jets$$

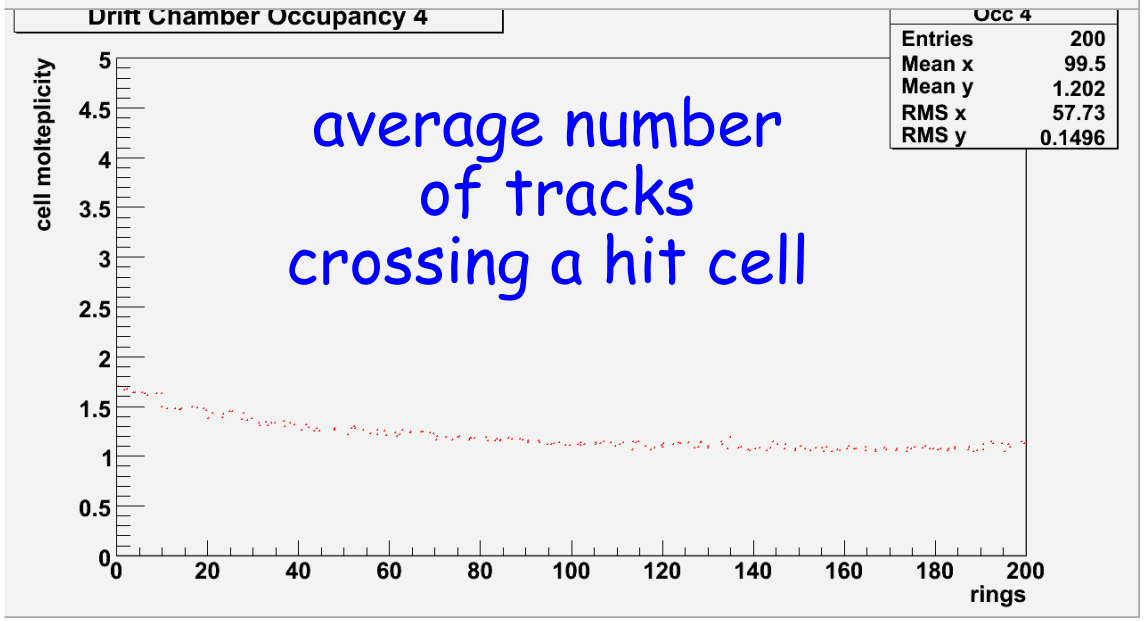




$$e^+e^- \rightarrow HHZ$$

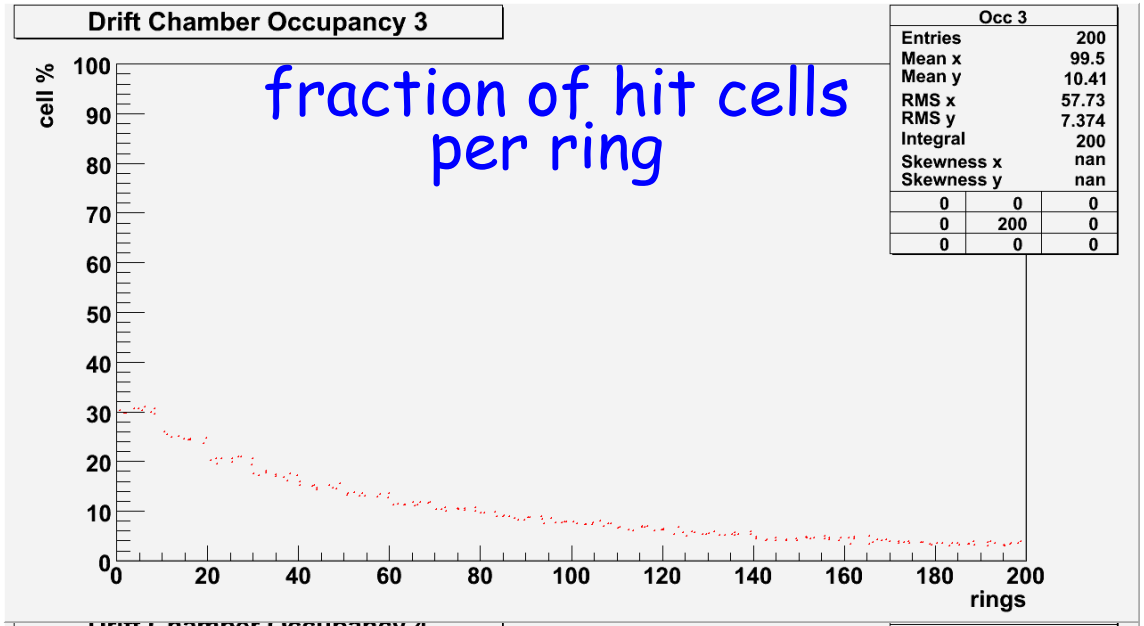
$$\rightarrow 4\,jets + 2\mu$$

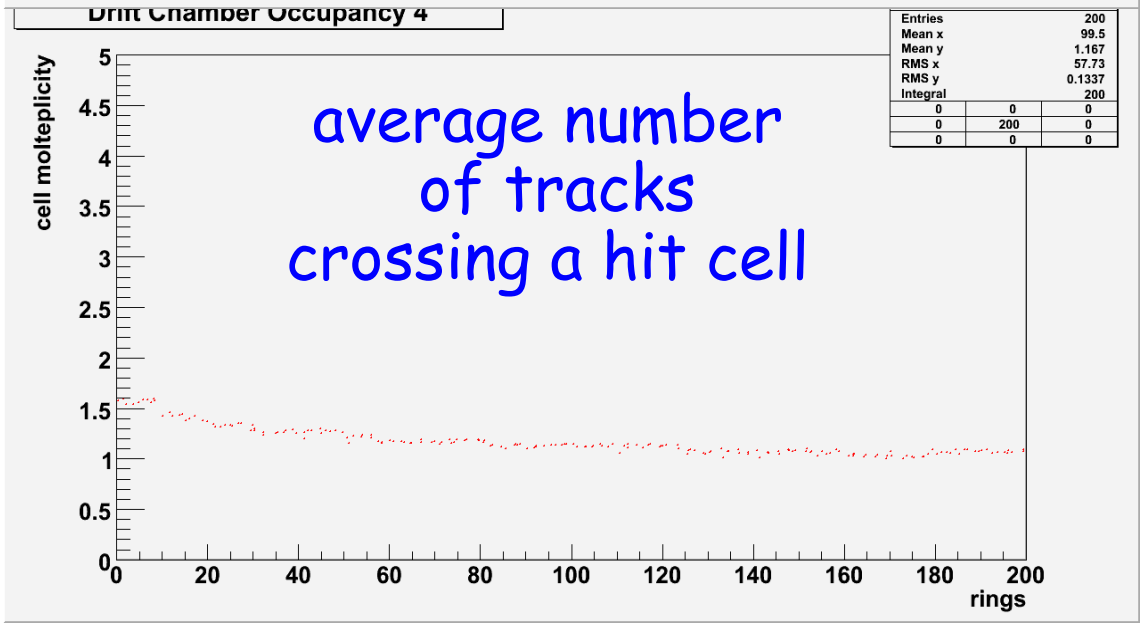




$$e^+e^- \rightarrow W^+W^-$$

$$\rightarrow 4\ jets$$





$$e^+e^- \rightarrow HZ$$

$$\rightarrow 2\,jets + 2\mu$$