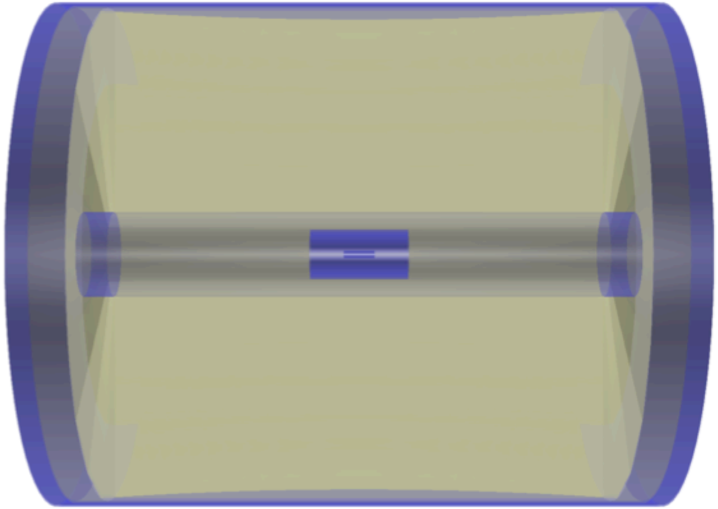
IDEA Drift Chamber and IDEA full tracking system



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Workshop on the Circular e^-e^+ collider, May 2018, Rome

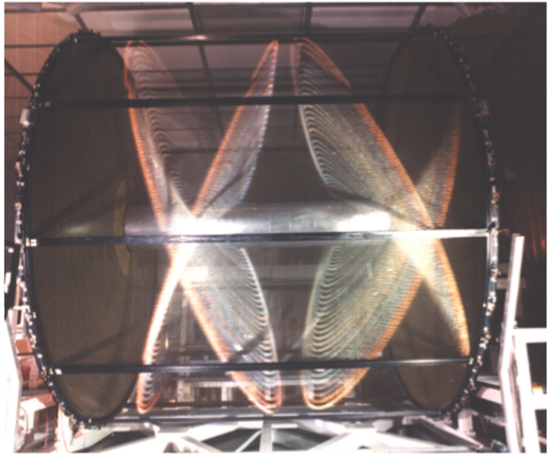
Outline

- IDEA Drift Chamber
  - Novel approach at construction technique of high granularity and high transparency Drift Chambers (From KLOE DCH to IDEA DCH)
  - Geometrical parameters
  - Cluster Counting/Timing and P.Id. expected performance
- IDEA tracking system (DCH+SVX+PSHW)
  - Possible layouts
  - Simulation
  - Expected IDEA tracking performance
  - DCH occupancy due to incoherent e^+e^- pairs
- Summary

Novel approach at construction technique of high granularity and high transparency Drift Chambers (From KLOE DCH to IDEA DCH)

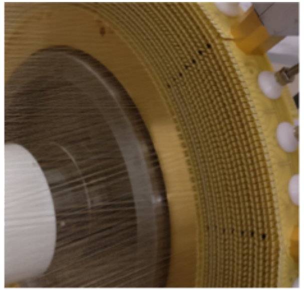
- Ancestor chamber: **KLOE** at INFN LNF Daφne ϕ factory (commissioned in 1998 and currently operating)
- **CluCou** Chamber proposed for the **4th-Concept** at ILC (2009)
- **I-tracker** chamber proposed for the **Mu2e experiment** at Fermilab (2012)
- **DCH** for the **MEG-II upgrade** at PSI (under commissioning)

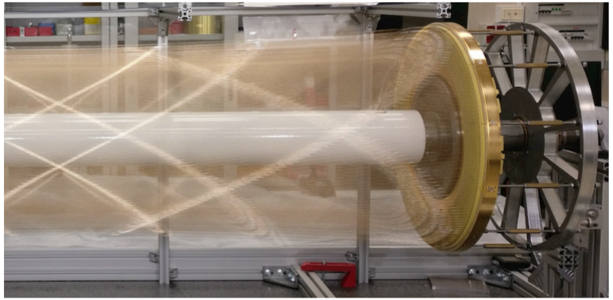
KLOE DCH



	KLOE	MEG-II
stereo	**Fully (~ 80 mrad)**	**Fully (~120 mrad)**
diameter	**4 m**	**0.6 m**
length	**3.3 m**	**2.0 m**
structure	**C-fiber**	**C-fiber**
Gas (He-iC_4H_{10})	**90% - 10%**	**85% - 15%**
Sense wires	**12000**	**2000**
Total wires	**52000**	**12000**
Weaker wire	**80 μm Al**	**40 μm Al**
cell size	**2x2 - 3x3 cm²**	**0.7x0.7 - 1x1 cm²**
Wire density	**~0.4 wires/cm²**	**~12 wires/cm²**

MEG-II DCH





High wire densities prevent the use of feed-through, needing novel approaches to the wiring procedures

Novel approach at construction technique of high granularity and high transparency Drift Chambers (From KLOE DCH to IDEA DCH)

Based on the MEG-II DCH new construction technique the IDEA DCH can meet these goals:

- Gas containment – wire support functions separation:

  allows to reduce material to $\approx 10^{-3}\,X_0$ for the inner cylinder and to a few x $10^{-2}\,X_0$ for the end-plates, including FEE, HV supply and signal cables (Mu2e proposal design: $1.5\times10^{-3}\,X_0$ and $8\times10^{-3}\,X_0$, respectively)

- Feed-through-less wiring:

  allows to increase chamber granularity and field/sense wire ratio to reduce multiple scattering and total tension on end plates due to wires by using thinner wires

- Cluster timing:

  allows to reach spatial resolution < 100 μm for 8 mm drift cells in He based gas mixtures (such a technique is going to be implemented in the MEG-II drift chamber under construction)

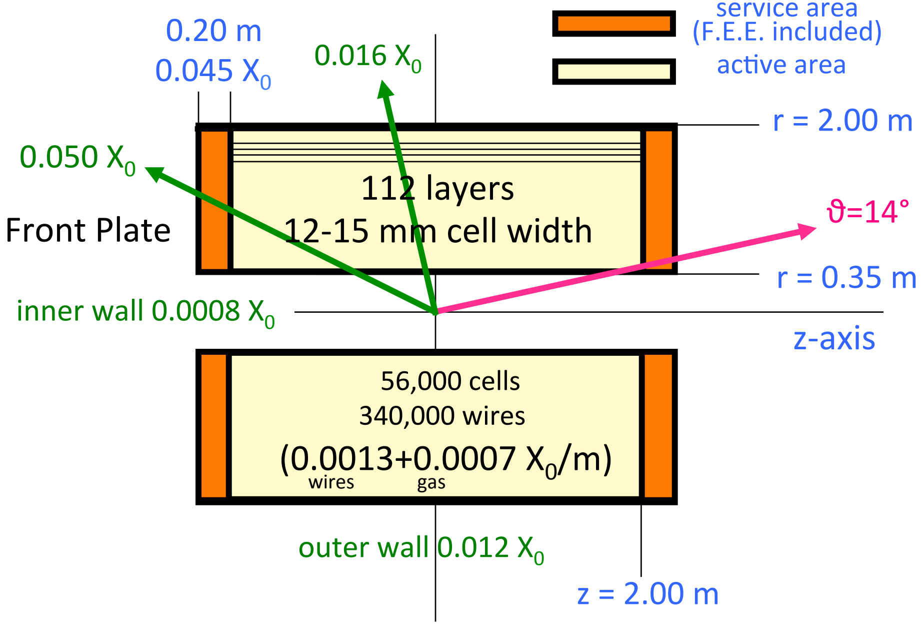
- Cluster counting:

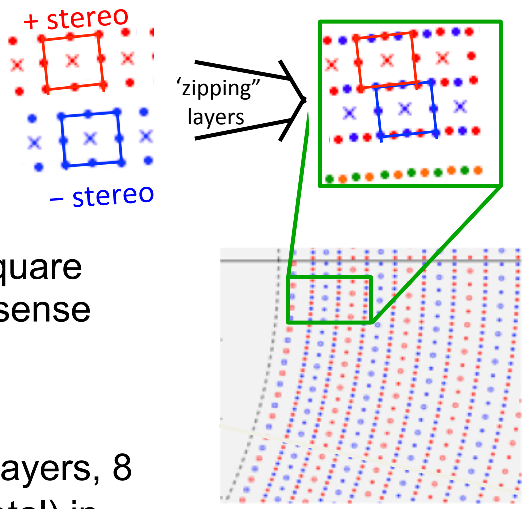
  allows to reach dN_{cl}/dx resolution < 3% for particle identification (a factor 2 better than dE/dx as measured in a beam test)

DCH Geometrical parameters

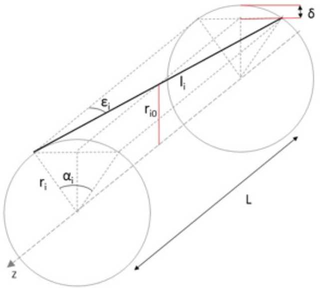
tracking efficiency $\varepsilon \approx 1$
for $\vartheta > 14°$ (260 mrad)
97% solid angle

0.016 X_0 to barrel calorimeter
0.050 X_0 to end-cap calorimeter



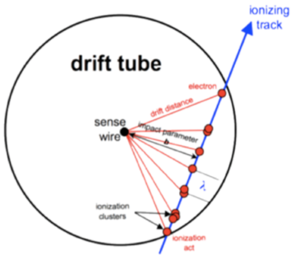


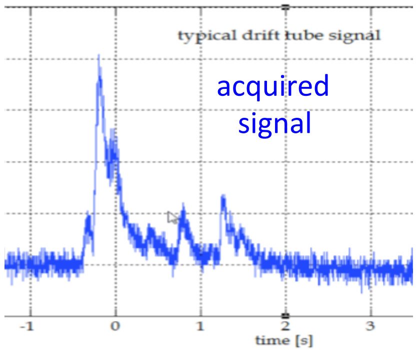
- 12÷15 mm wide square cells 5 : 1 field to sense wires ratio
- 56,448 cells
- 14 co-axial super-layers, 8 layers each (112 total) in 24 equal azimuthal (15°) sectors ($N_i = 192 + (i - 1) \times 48$)
- alternating sign stereo angles ranging from 50 to 250 mrad



Cluster Counting/Timing and P.Id. expected performance

From the ordered sequence of the electrons arrival times, considering the average time separation between clusters and their time spread due to diffusion, reconstruct the most probable sequence of clusters drift times: $\left\{t_i^{cl}\right\} \qquad i = 1, N_{cl}$





dE/dx

$$\frac{\sigma_{dE/dx}}{(dE/dx)} = 0.41 \cdot n^{-0.43} \cdot \left(L_{track}[m] \cdot P[atm]\right)^{-0.32}$$

from *Walenta parameterization (1980)*

truncated mean cut (70-80%) reduces the amount of collected information n = 112 and a 2m track at 1 atm give

$\sigma \approx$ **4.3%**

Increasing P to 2 atm improves resolution by 20% ($\sigma \approx$3.4%) but at a considerable cost of multiple scattering contribution to momentum and angular resolutions.

dN_{cl}/dx

$$\frac{\sigma_{dN_{cl}/dx}}{(dN_{cl}/dx)} = \left(\delta_{cl} \cdot L_{track}\right)^{-1/2}$$

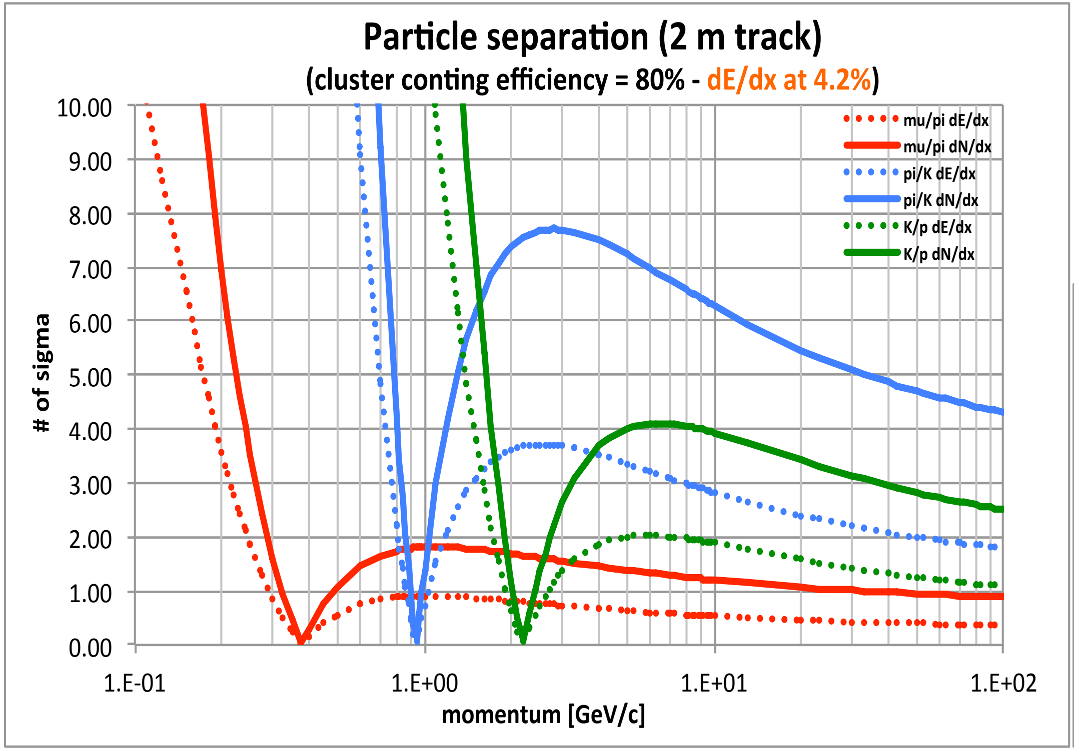
from *Poisson distribution*

δ_{cl} = 12.5/cm for He/iC_4H_{10}=90/10 and a 2m track give

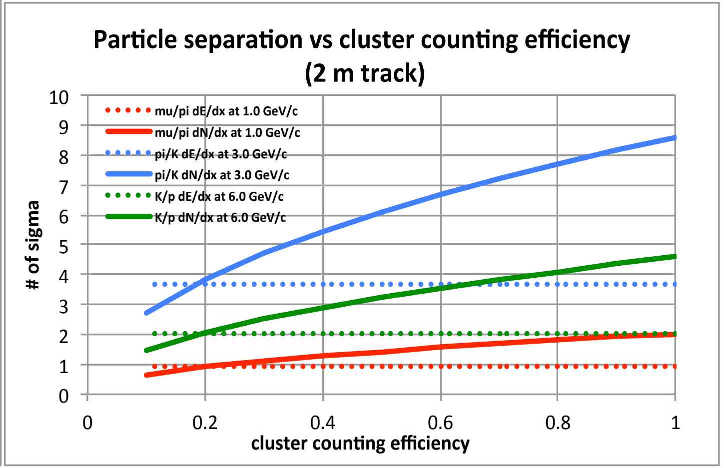
$\sigma \approx$ **2.0%**

A small increment of iC_4H_{10} from 10% to 20% (δ_{cl} = 20/cm) improves resolution by 20% ($\sigma \approx$1.6%) at only a reasonable cost of multiple scattering contribution to momentum and angular resolutions.

Cluster Counting/Timing and P.Id. expected performance



analytic evaluation,
to be checked with detailed simulations
and test beams



IDEA tracking system - Possible layouts (DCH)

Geometry is not yet optimized:

	Base Line	Option 1	Option 2	
	value	value	value	dim.
R_{in}	345	200*	250	mm
R_{out}	2000	2150	2000	mm
active area length	4000	4000	4000	mm
total length	4500	4500	4500	mm
total cells	56448	34560	52704	n.
layers	112	96	112	n.
Superlayers	14	12	14	n.
Layers per Superlay.	8	8	8	n.
phi sector	12	12	12	n.
smaller cell	11.85	14.2	11.65	mm
larger cell	14.7	22.5	15.25	mm
min. stereo angle	48	25	35	mrad
max. stereo angle	250	240	245	mrad

* not over the entire length, to avoid overlap with beam pipe etc.
A possible construction strategy is available.

IDEA tracking system - Possible layouts (SVX)

Base line

Barrel:

Ly	R_{in} [mm]	length [mm]	Thick [µm]	pixel [µm]
1	17	200	300	20
2	23	200	300	20
3	31	200	300	20
4	180	600	300	20
5	200	600	300	20
6	330	1000	950	20
7	340	1000	950	20

Forward:

Ly	R_{in} [mm]	R_{out} [mm]	Zpos [mm]	Thick [µm]	pixel [µm]	Double
1	30	170	230	300	20	yes
2	60	170	400	300	20	yes
3	100	320	650	300	20	yes
4	165	340	1100	950	20	
5	225	340	1500	950	20	

Option 1 (larger DCH)

Barrel:

Ly	R_{in} [mm]	length [mm]	Thick [µm]	pixel [µm]
1	17	200	300	20
2	23	200	300	20
3	31	200	300	20
4	180	600	300	20
5	190	600	300	20

Forward:

Ly	R_{in} [mm]	R_{out} [mm]	Zpos [mm]	Thick [µm]	pixel [µm]	Double
1	30	170	230	300	20	yes
2	60	170	400	300	20	yes
3	100	190	650	300	20	yes
4	120	190	800	300	20	yes

IDEA tracking system - Possible layouts (Outer Si Layer + PSHW)

Base line

Barrel:

Ly	R_{in} [mm]	length [mm]	Thick [X_0]	pitch [µm]
1	2005	2400	1%	70
2	2025	2400	1%	250
3	2045	2400	1%	250

Forward:

Ly	R_{in} [mm]	R_{out} [mm]	Zpos [mm]	Thick [X_0]	pitch [µm]
1	300	2000	2300	1%	70
2	300	2000	2325	1%	250
3	300	2000	2350	1%	250

Option 1 (larger DCH)

Barrel:

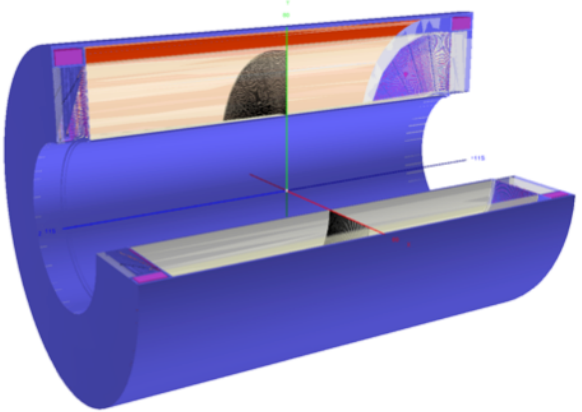
Ly	R_{in} [mm]	length [mm]	Thick [X_0]	pitch [µm]
1	2155	2400	1%	70
2	2175	2400	1%	250
3	2195	2400	1%	250

Forward:

Ly	R_{in} [mm]	R_{out} [mm]	Zpos [mm]	Thick [X_0]	pitch [µm]
1	300	2150	2300	1%	70
2	300	2150	2325	1%	250
3	300	2150	2350	1%	250

between two measurement layers there is an absorber shell equivalent to 1 X_0 (used 6mm of Lead)

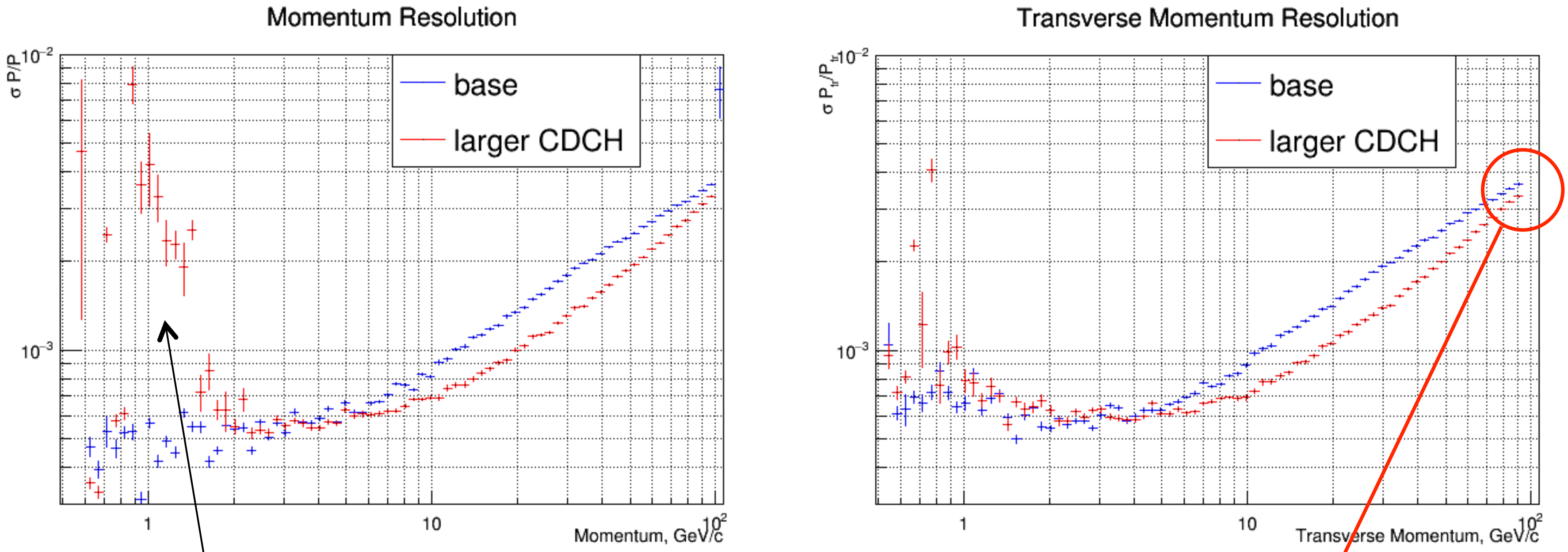
IDEA tracking system – Simulation details



- Study was performed with a standalone geant4 simulation:
  - Geant4 10.01 p03
  - Physics List: QGSP_BERT 4.0
  - 2T Constant Magnetic Field, G4ClassicalRK4 particle motion integrator
  - particles generator used: General Particle Source
- The code is organized in a modular way, the geometry description is "quite" plug and play, it is possible to import in a framework with minor changes.
- We used the ROME (developed for MEG experiment https://midas.psi.ch/rome/) framework to manage the output data and run the track fitting and reconstruction.
- The GenFit2 is interfaced to perform this preliminary study on the expected tracking system performances on track fitting.
- we simulated single muon at fixed theta 65 deg (only a quality cut on $Chi^2/nDof < 25$ was applied).
- we performed a scan of the resolutions as a function of the theta angle for tracks of fixed momenta (1, 10, 30, 100 GeV/c).
- We started to perform Pattern Recognition studies

IDEA tracking system – Expected tracking performance (single muon at 65 deg)

Red curve has half of the statistic of blue one



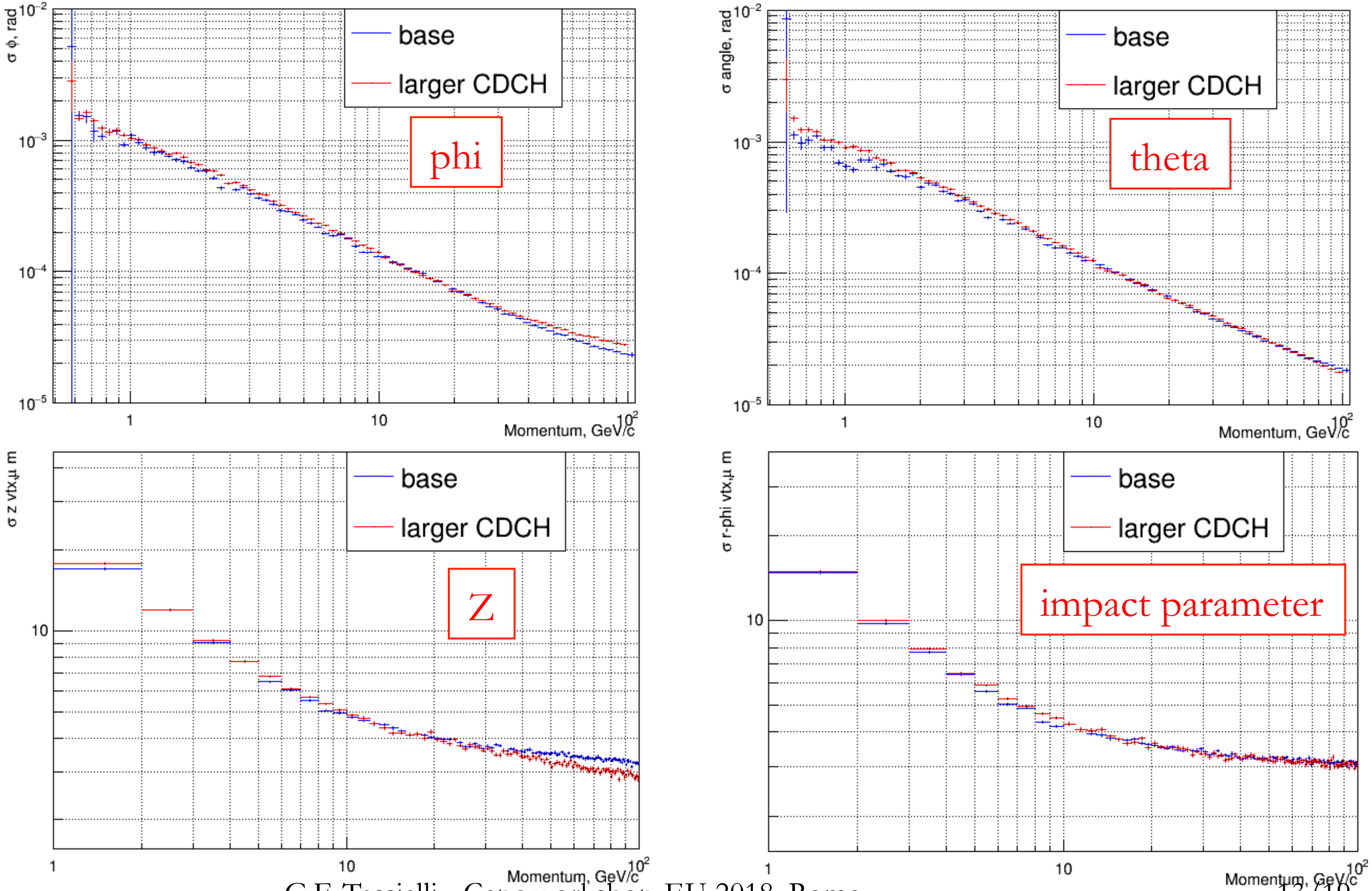
Due to not enough statistics and to less points in the SVX could be recovered by using SVX with double layers

$$\frac{\sigma_{p_t}}{p_t^2} = 3-4 \bullet 10^{-5}$$

IDEA tracking system – Expected tracking performance (single muon at 65 deg)

angular vertex resolution:

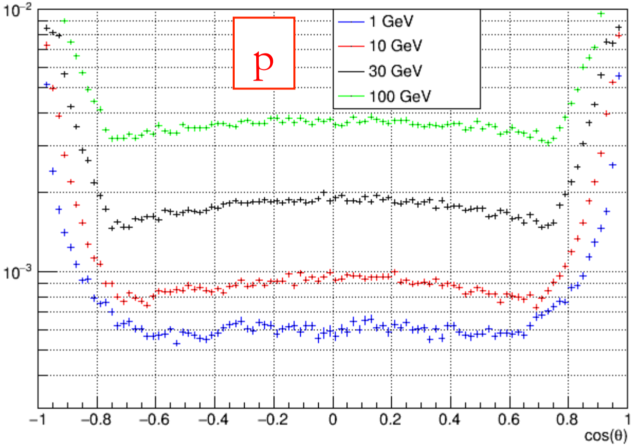
spatial vertex resolution:

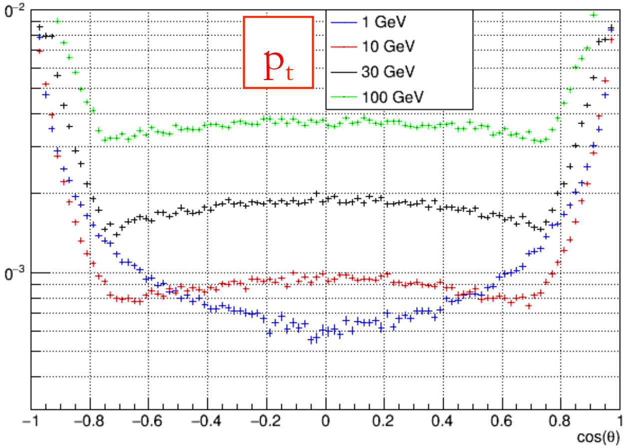


IDEA tracking system – Expected tracking performance (single muon as function of ϑ)

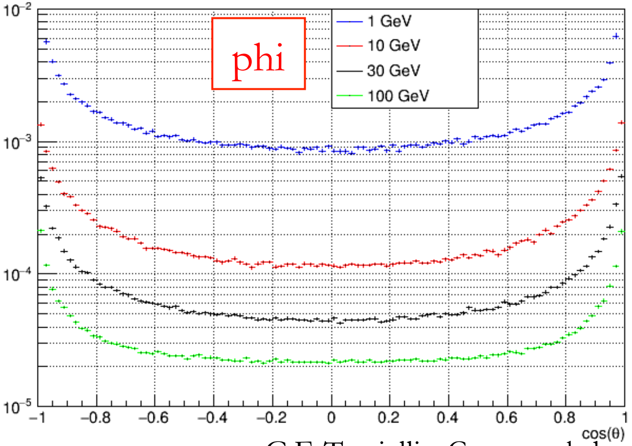
base line option

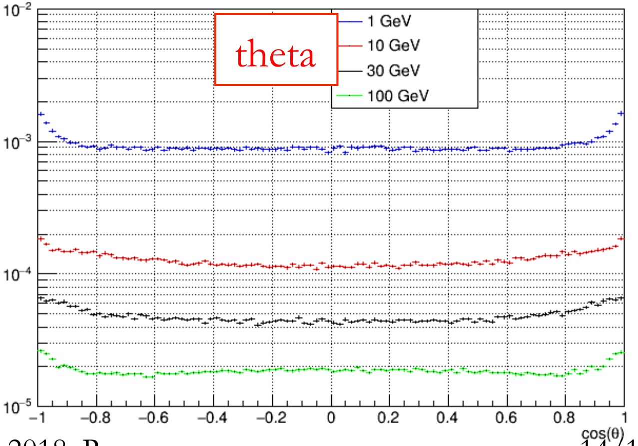
momentum resolution:





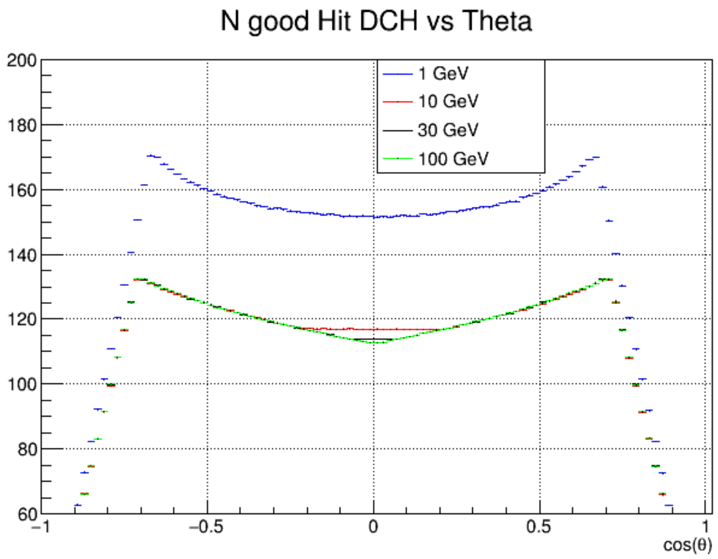
angular vertex resolution:

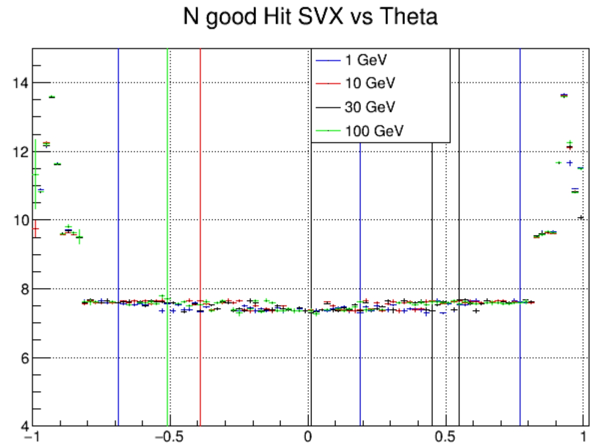


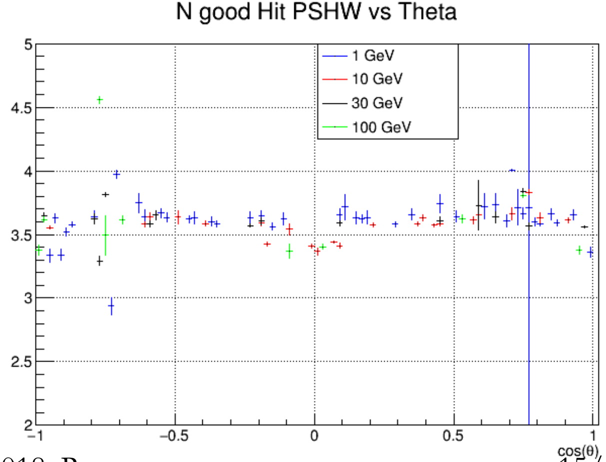


IDEA tracking system – Expected tracking performance (single muon as function of ϑ)

base line option







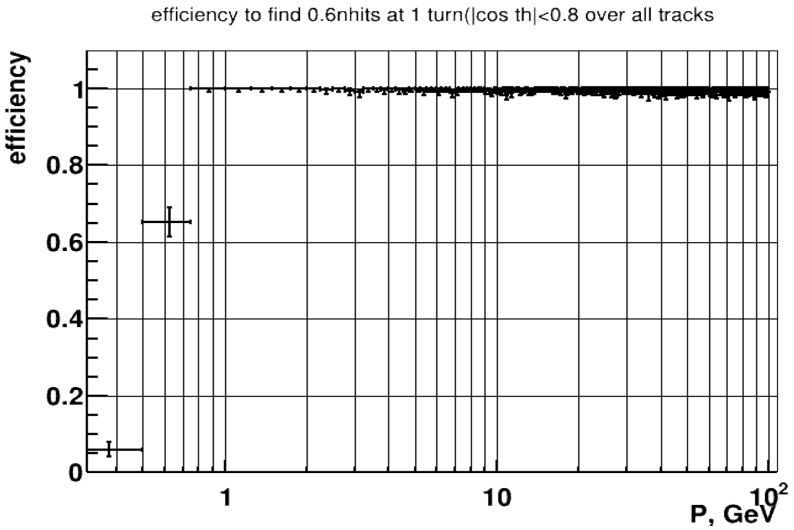
More than 100 Hits per tracks -45°<ϑ<45°
More than 60 Hits per tracks -25°<ϑ<25°

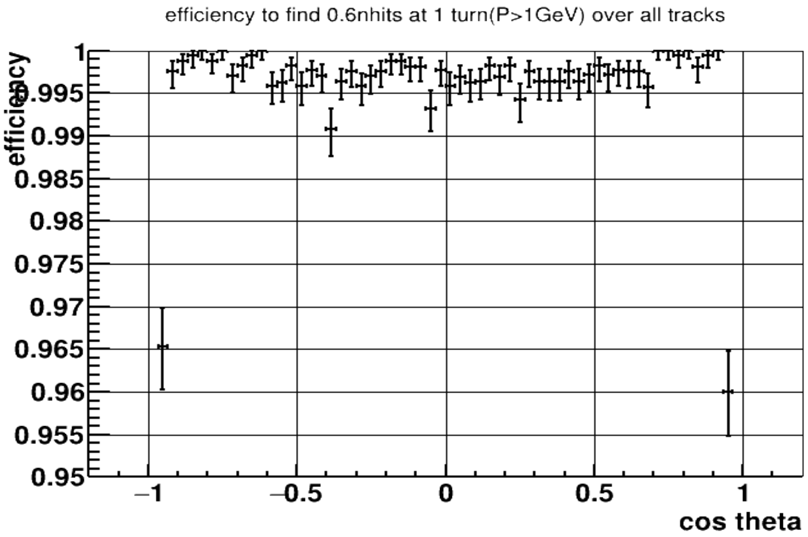
IDEA tracking system – Expected tracking performance PR

10 μ's (0-100 GeV), DCH only (no longitudinal info used) with Z vtx preselection of seeds

eff ~ 99.5%
particle separation $\Delta\phi_0$ ~ 0.005 rad

to be tested for secondary particles
with vertex out of the SVX

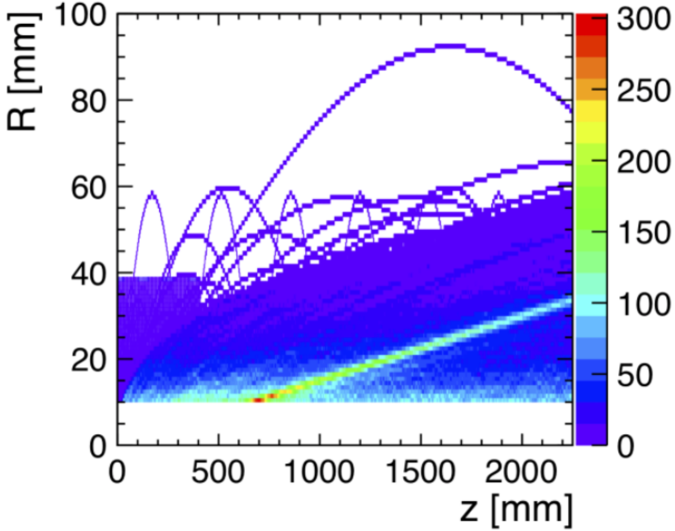




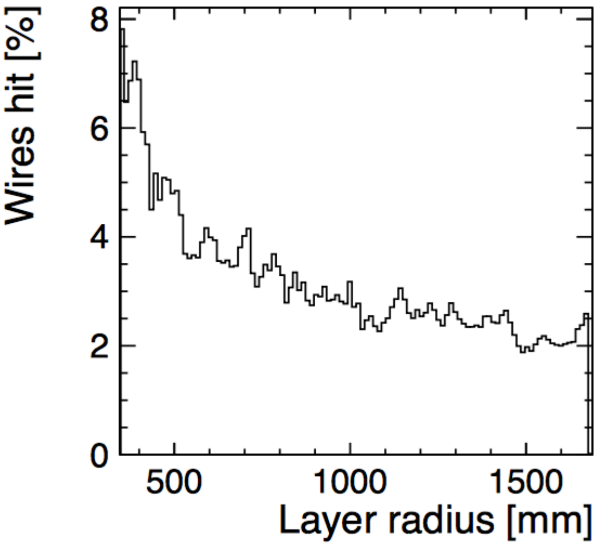
DCH occupancy due to incoherent e+e- pairs

using FCCsw with a preliminary DCH implementation and GUINEA-PIG to generate the incoherent e^+e^- background particles at a √s of 365 GeV (thanks to Niloufar Alipour Tehrani)

expected background tracks trajectories



average DCH occupancy (400ns integration time) over 100 events ~ 2.8%

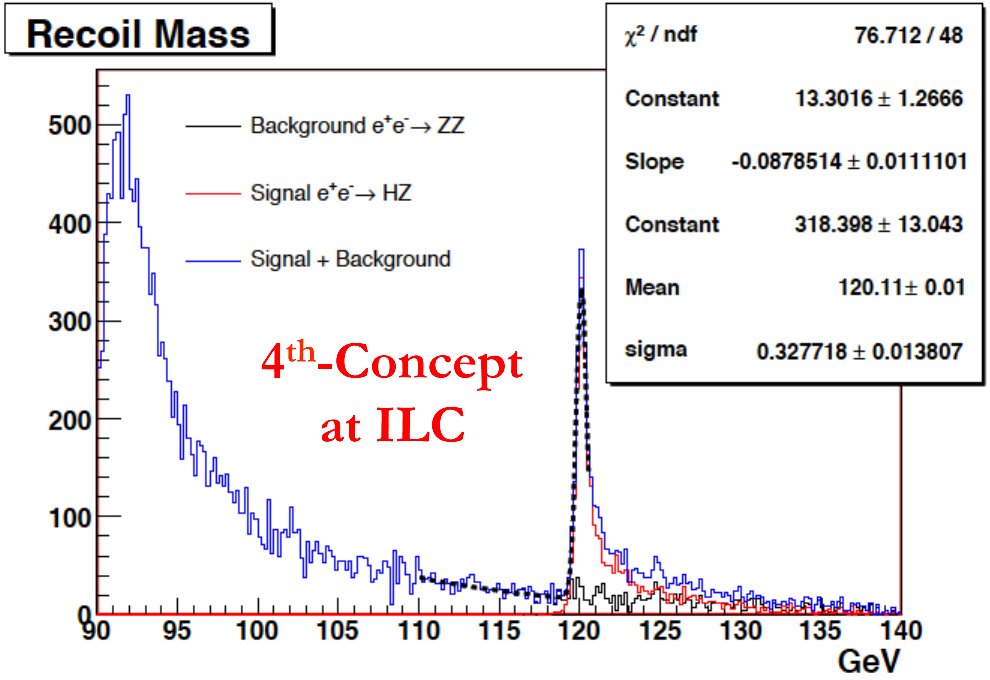


IDEA expected Higgs resolution

the ILC 4th concept detector had a central tracking system based on a similar Drift Chamber system.
The tracking performance was a little bit worst than the IDEA detector

Higgs Strahlung events:
$ZH \rightarrow \mu^+\mu^- + X$

we should expect a measure of Higgs width ~< 300 MeV/c^2



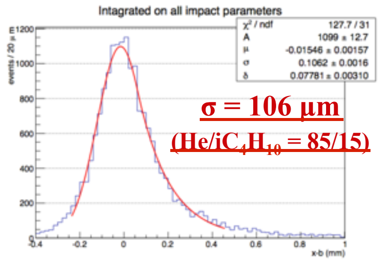
Summary

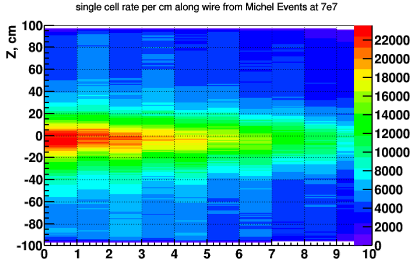
- We designed a ultra light Drift Chamber for the IDEA central tracking systems;
- We have a full simulation of the full IDEA tracking system (SVX+DCH+PSHW)
- The IDEA tracking system shows good performance and meet the CepC tracking requirements
- The CC technique can add a plus in particle identification (we will have a test beam on September to prove it at the momentum range of interest)
- To do:
  - work on the Pattern Recognition and test its performance;
  - optimization of the IDEA geometry configuration (SVX: n. layers and radii; DCH dimensions and cell layout);
  - perform some analysis on physics channels (like Higgs recoil mass in the Higgs Strahlung channel)
  - improve the hit makers to handle correctly the tracks pile up;
  - Simulate the dN/dx and the PID;
  - improve porting the DCH geometry etc. into the FCC framework (see Niloufar Alipour Tehrani);
  - integrate the Dual Readout calorimeter in the simulation
  - … etc …

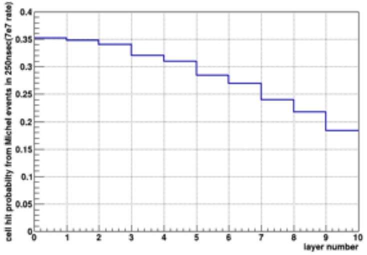
Thanks for your attention

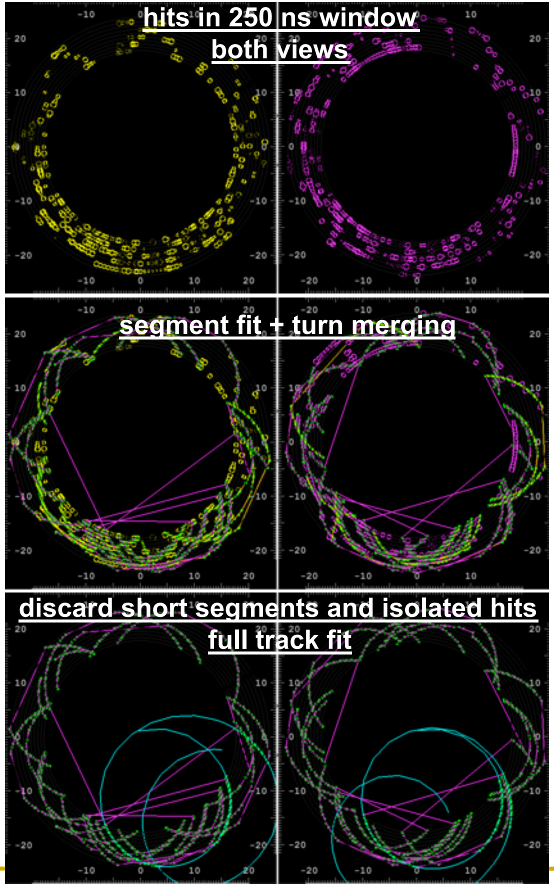
Backup

The MEG2 Drift Chamber Performance

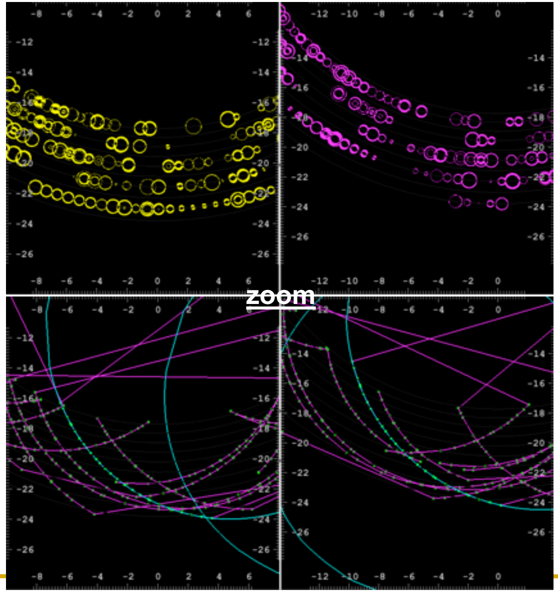








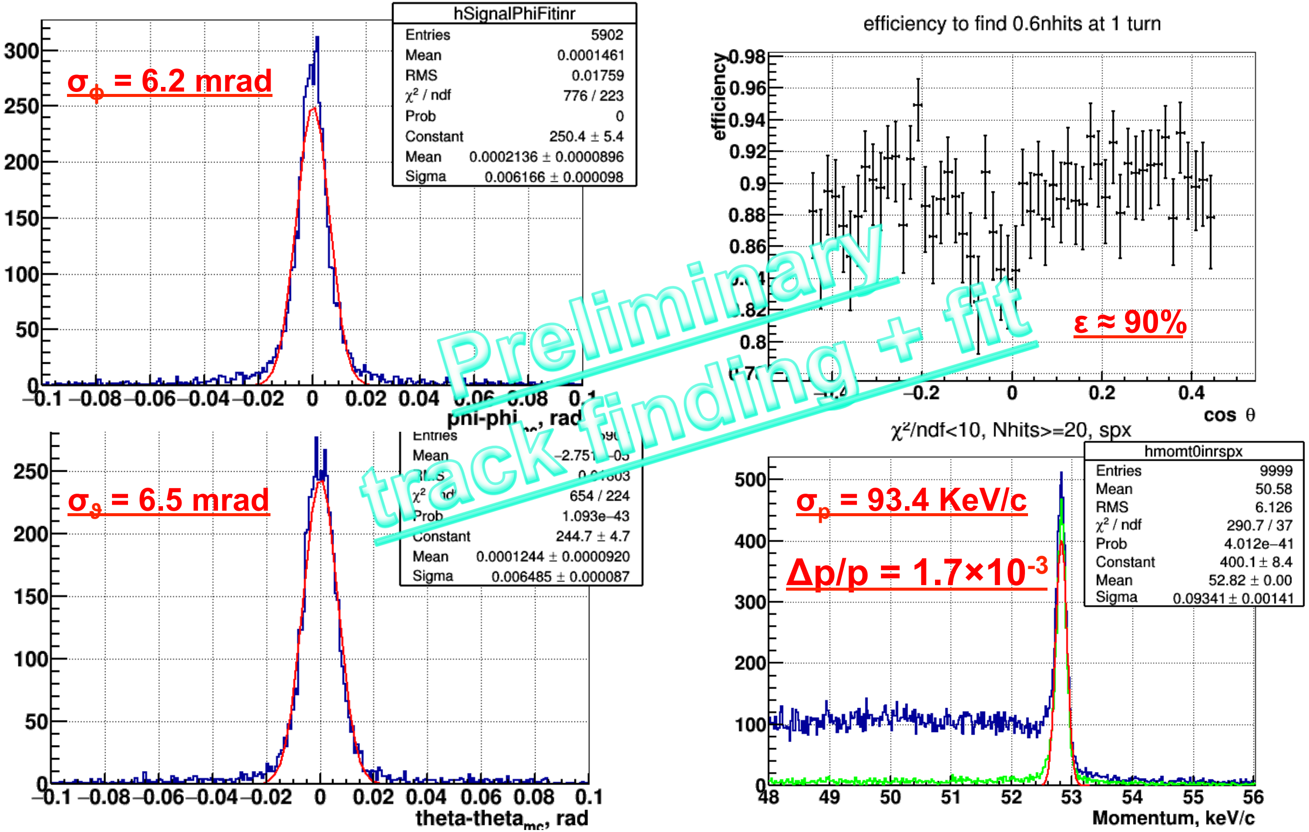
3D track finding and fit



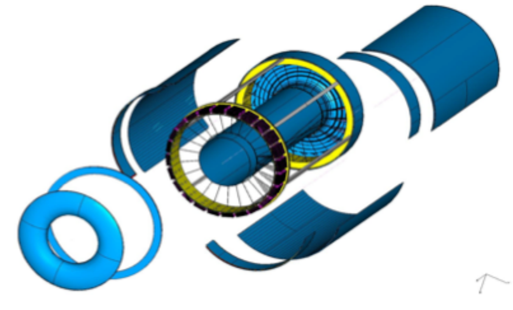
signal track

michel tracks

The MEG2 Drift Chamber Performance

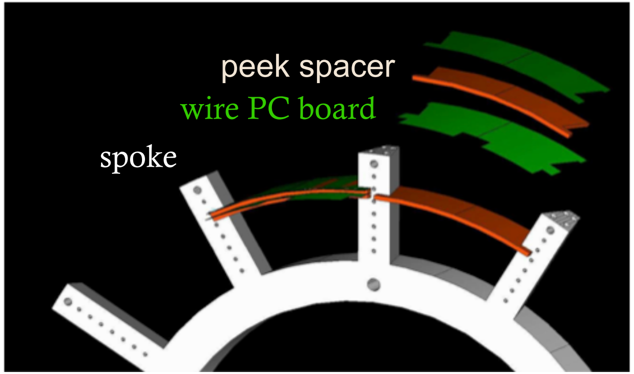


Novel approach at construction technique of high granularity and high transparency Drift Chambers (From KLOE DCH to IDEA DCH)



- Separate the end-plate function: mechanical support for the wires and gas sealer;
- Find a feed-trough-less wiring procedure.
  - end-plates numerically machined from solid Aluminum (mechanical support only);
  - Field, Sense and Guard wires placed azimuthally by Wiring Robot with better than one wire diameter accuracy;
  - wire PC board layers (green) radially spaced by numerically machined peek spacers (red) (*accuracy* $< 20\ \mu m$);
  - wire tension defined by homogeneous winding and wire elongation ($\Delta L = 100\ \mu m$ *corresponds to* $\approx 0.5\ g$);
  - Drift Chamber assembly done on a 3D digital measuring table;
  - build up of layers continuously checked and corrected during assembly;
  - End-plate gas sealing will be done with glue.

The solution adopted for MEG II:

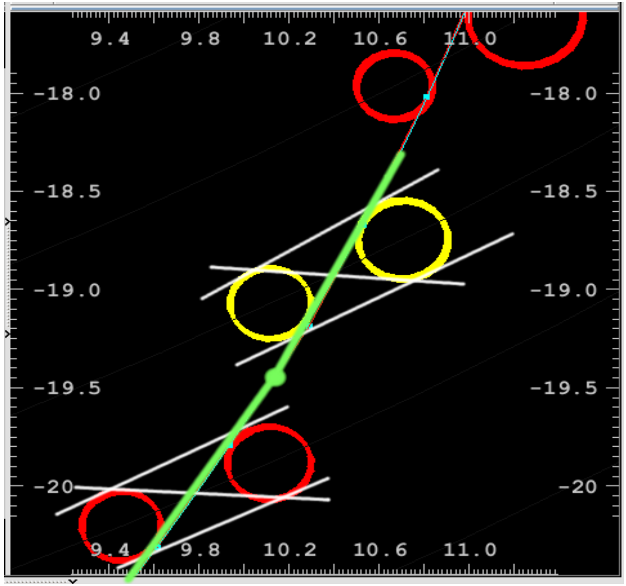


2 pairs seed construction (DCH only)

Seeding from 2 pairs of hits (each pair on same layer) pointing at the origin

- 2 consecutive hits in same layer
  → 4=2x2(Left-Right) pairs with direction
- 2 pairs from nearest layers compatible:
  $|\Delta\cos(\phi\,(\text{direction})-\phi\,(\text{position}))|<0.2$,
  crossing Z inside DCH
- 1 pair with origin → Pt estimate
  (averaged over 2 pairs)
- Cross Point of 2 opposite stereo pairs give Z-coordinate
  (with $\Delta\phi$ correction from Pt)
- Pz = 0 at beginning

Z measurement give additional compatibility check between 2 hits and between 2 pairs



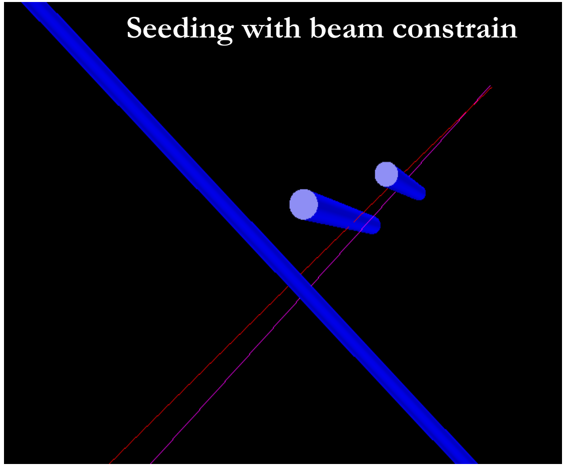
Red hits **projection at z=0 plane**
Yellow **rotated according to ϕ**

Combinatory low: 2 local compatibilities + 1 from opposite stereo view, but with direction angle check

additional seed construction (DCH only)

Seeding from 3 hits in different layers with origin constraint

- Take any 2 free hits from different stereo layers with a gap (4 or 6 layers)
- Cross Point of 2 wires give Z-coordinate (must be inside DCH volume)
- Select nearest free hits at middle (+-1) layer
- 2 hits from same stereo layer give initial angle in Rphi
- origin added with sigma Rphi~ 4cm Z ~ 100 cm (Mu2e case)
- Seeds constructed for all 2x2x2=8 combination of Left-Right possibilities
- Checked that at -4 (+-1) layer are available free hits with $\chi^2 < 16$
- Extrapolate and assign any compatible hits (by χ^2) from last to first hits
- Refit segment to reduce beam constraint
- Check quality of track segment:
  - $\chi^2/NDF < 4$
  - number of hits found (>=7)
  - number of shared hits (<0.4Nfound)



Combinatory high:
local compatibility over different layers,
+ 1 from different stereo view