IDEA Drift Chamber simulation e TB

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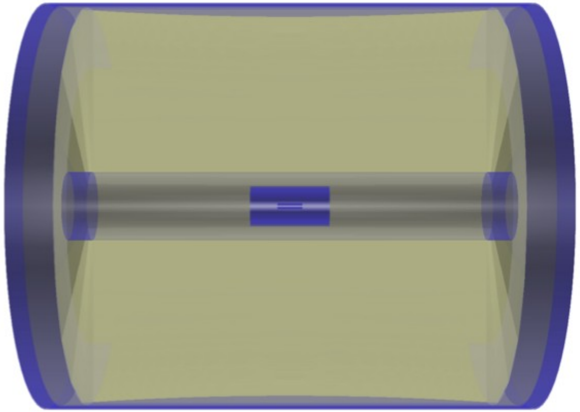
Outline

- IDEA tracking system (DCH + SVX + SOT + PSHW) simulation status
  - Implementation with a standalone Geant4 code
  - Implementation in FCC-sw
  - Results
  - To do
- DCH test beam
  - Detector status
  - To do
  - Needs for test beam
- Summary

Implementation with a standalone Geant4 code



- Study was performed with a standalone geant4 simulation:
  - Geant4 10.01 p03 (and 10.03)
  - Physics List: QGSP_BERT 4.0
  - 2T Constant Magnetic Field, G4ClassicalRK4 motion integrator
  - particles generator used: General Particle Source
  - Interfaced with HEPMC generator data format
- The DCH geometry description is detailed
- The DCH Hit simulation is approximated but a detailed version is available
- The SVX, SOT, PSHW geometry description is simplified
- The SVX, SOT, PSHW Hit simulation is just a geometrical segmentation
- 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.
- A “preliminary” pattern recognition code is interfaced

IDEA tracking system - Possible layouts (DCH)

	Current	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 SL	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

Geometry is not yet optimized:

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

All these numbers are under update to reach a well established Base line

IDEA tracking system - Possible layouts (SVX)

Barrel:

Base line

Lyg	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

All these numbers are under update to reach a well established Base line

Option 1 (larger DCH)

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:

Base line:

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):

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)

All these numbers are under update to reach a well established Base line

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)

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

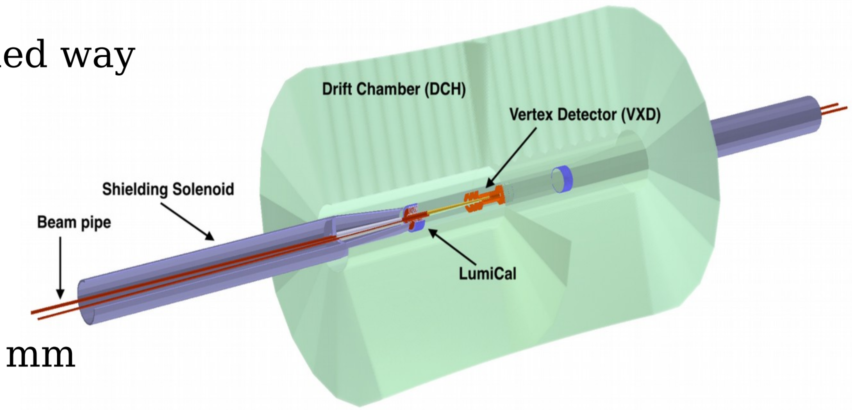
Ly	R_{in} [mm]	R_{out} [mm]	Zpos [mm]	Thick [X_0]	pitch [μm]
1	300	2150	2300	1%	70
2	300	2150	2325	1%	250
3	300	2150	2350	1%	250

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

Implementation in FCC-sw

The DCH is implemented in a good but not detailed way

- Some details as wires and support structures are missing
- The Hit simulation is made with the following assumption:
  - Stepping in the gas with a step length of 2 mm
  - Reject ionization acts with:
    - $E_{dep} < 10$ eV
    - G4Step length < 5μm
    - Total $E_{dep} < 100$ eV
  - Drift the E_{dep} to the nearest wire assuming constant drift velocity of 2 cm/μs
  - For each wire, merge the E_{dep} with a drift time smaller than the maximum drift time in the cell
- Beam-pipe, interaction region (IR), LumiCal and SVX taken from the CLD concept.



Standalone simulation:

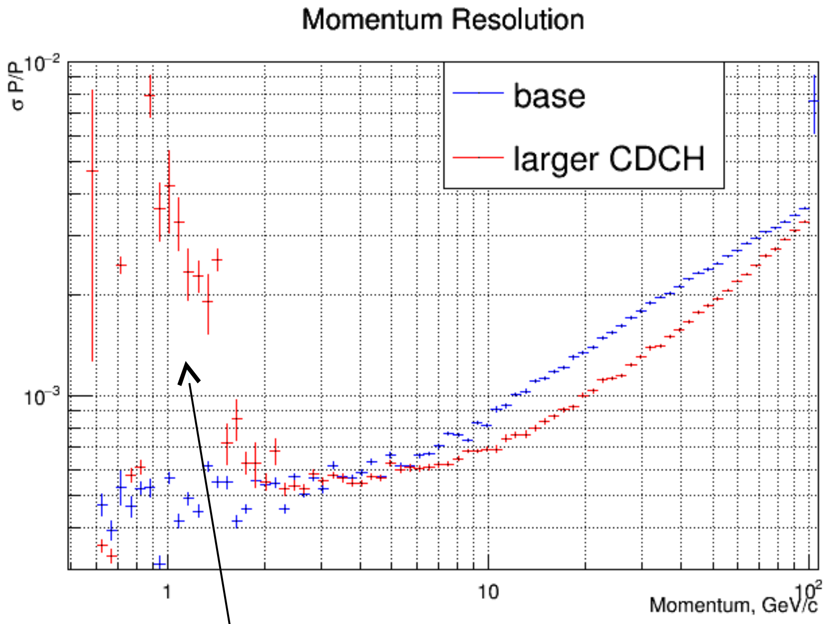
- Performed resolution performance studies on single tracks as function of the momentum (0.5-100 GeV/c).
- Performed a scan of the resolutions as a function of the theta angle for tracks of fixed momenta (1, 10, 30, 100 GeV/c).
- started some Pattern Recognition studies.

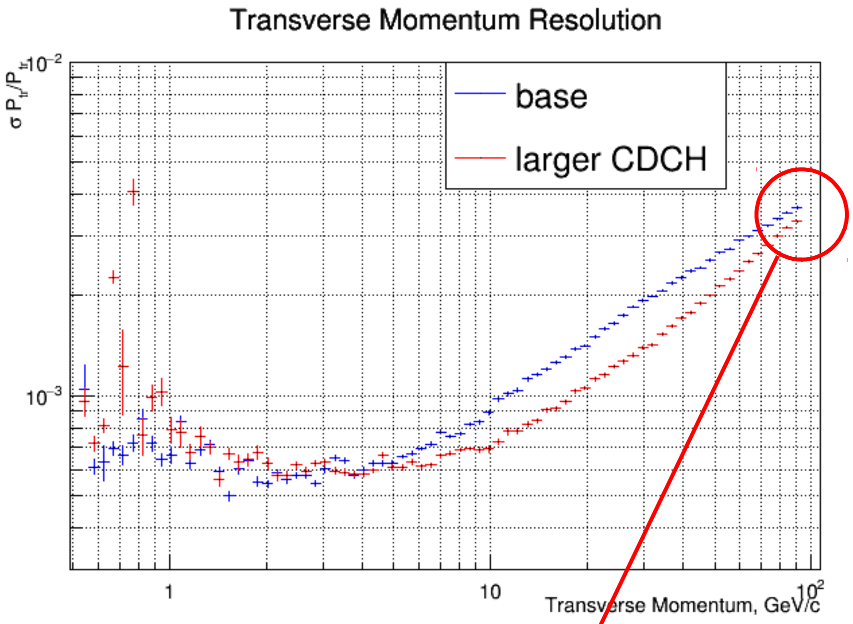
FCC-sw simulation:

- Performed occupancy studies induced by background sources:
  - incoherent e^+e^- pairs on the interaction region (IR) at 365 GeV and at Z energy
  - SR

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

Red curve has half of the statistic of blue one





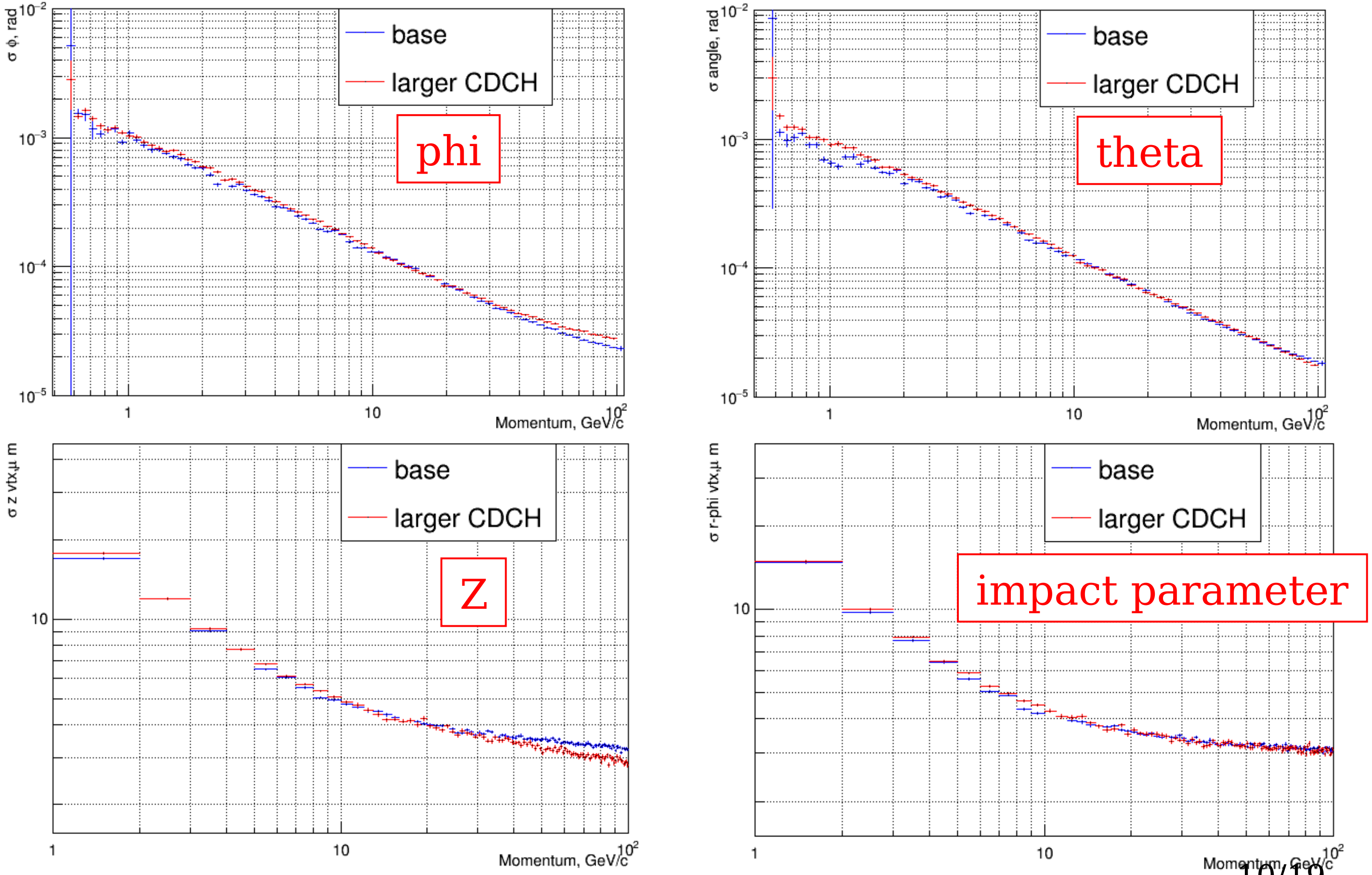
Due to not enough statistics and to less points in the SVX could be recovered by using SVX with double layers

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

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

angular vertex resolution:

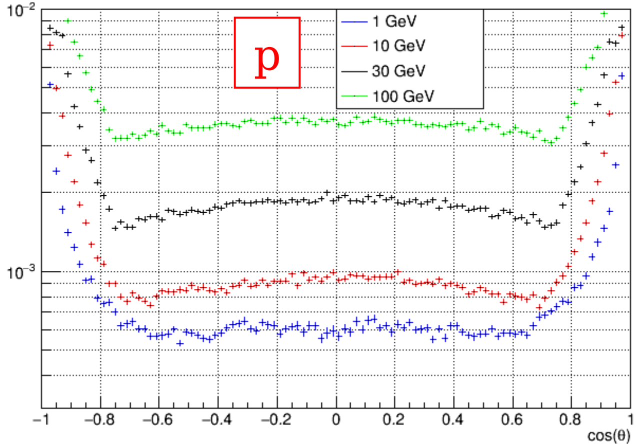
spatial vertex resolution:

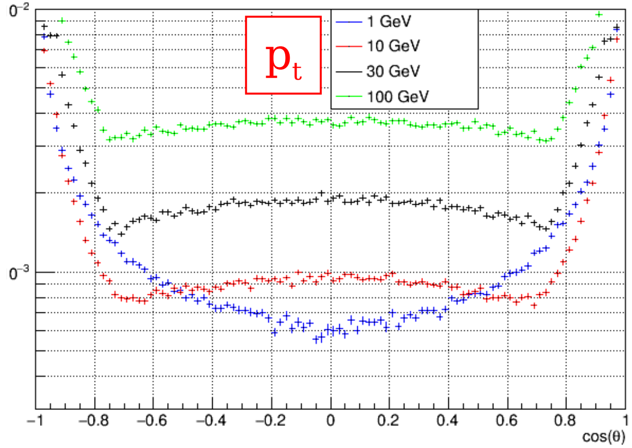


IDEA tracking system – Expected tracking performance (single muon as function of ϑ)

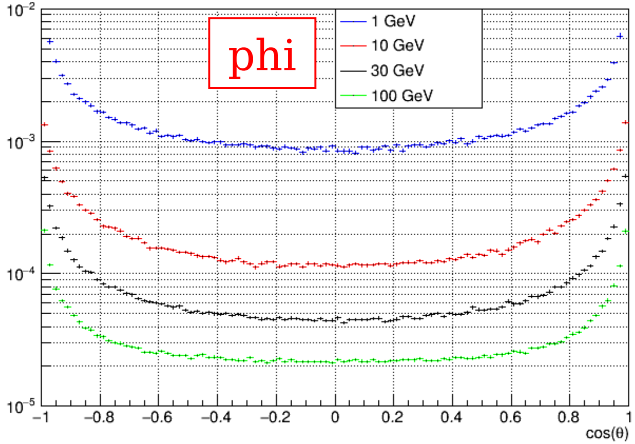
base line option

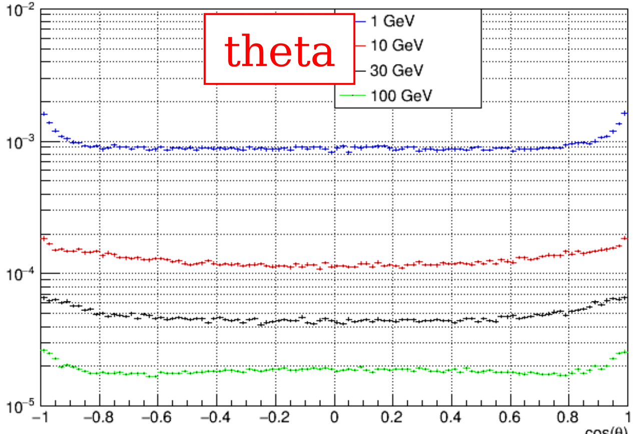
momentum resolution:





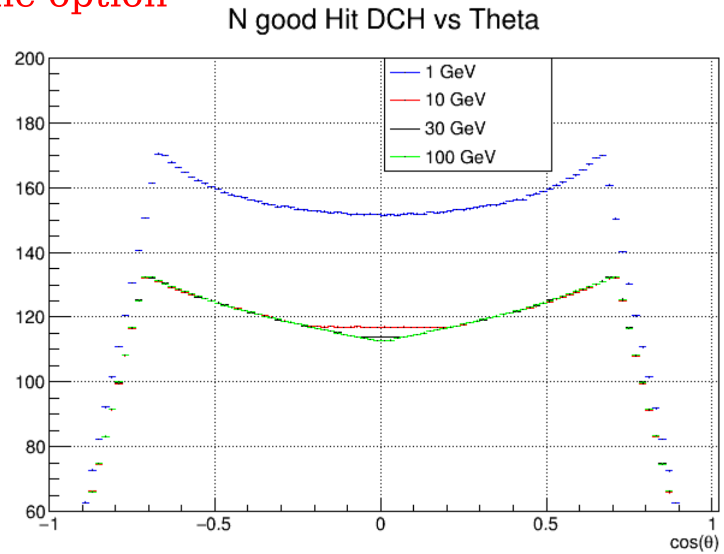
angular vertex resolution:



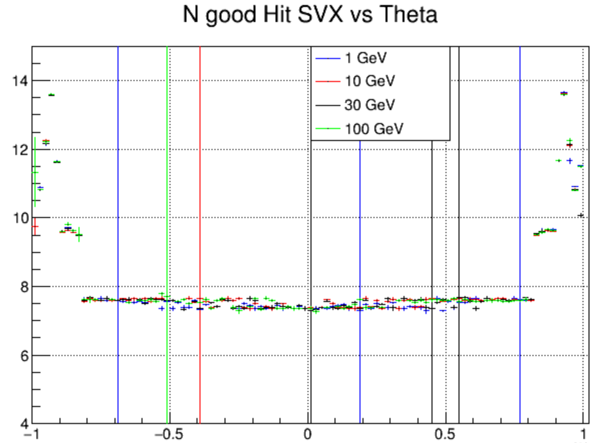


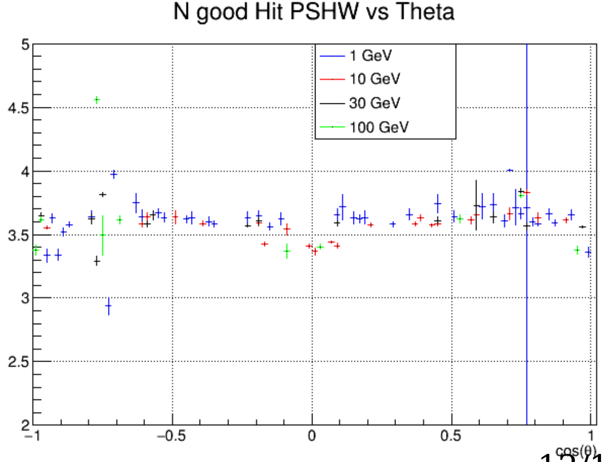
IDEA tracking system – Expected tracking performance (single muon as function of ϑ)

base line option



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



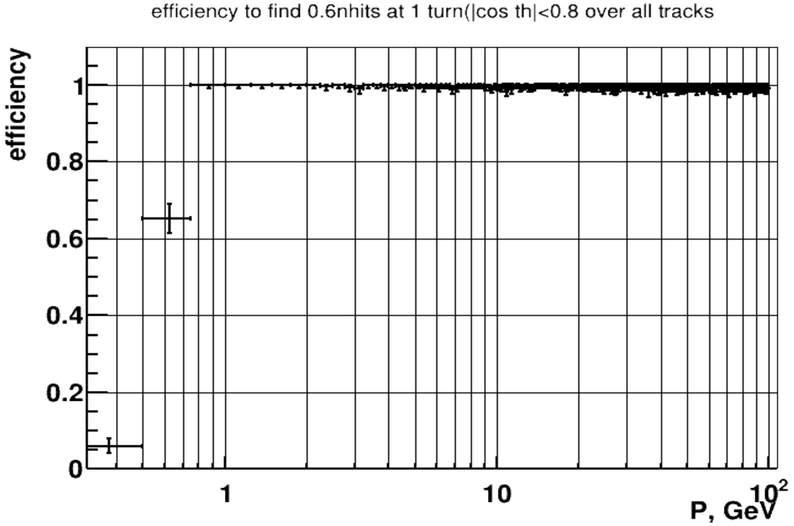


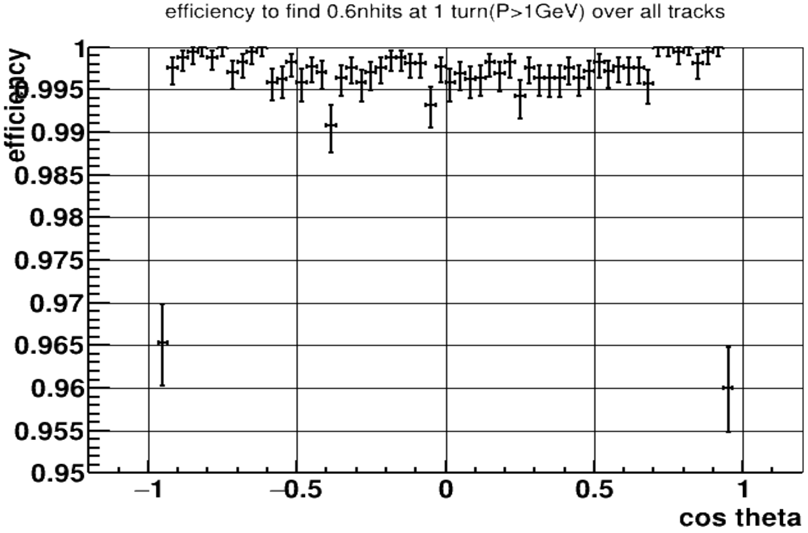
IDEA tracking system – Expected tracking performance PR

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

eff ~ 99.5%
particle separation $\Delta\varphi_0$ ~ 0.005 rad

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

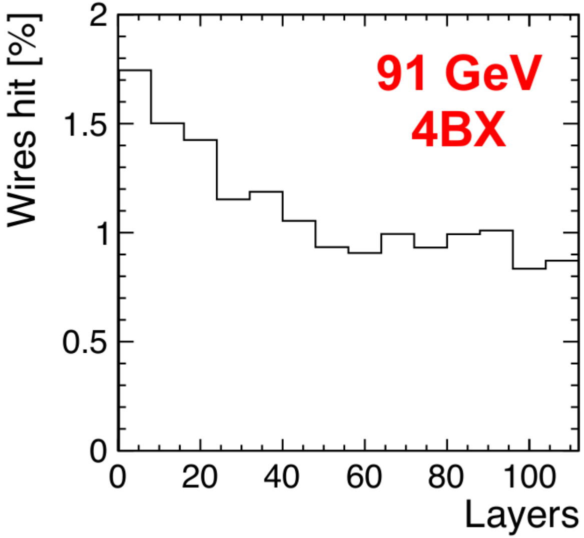




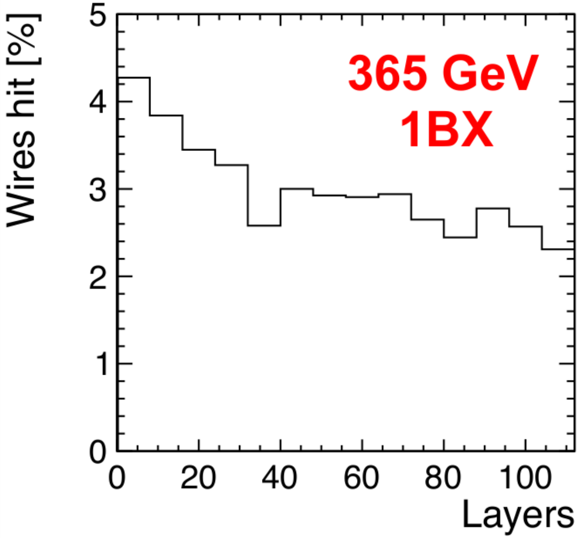
DCH occupancy due to incoherent e+e- pairs

(thanks to Niloufar Alipour Tehrani)

average DCH occupancy (400ns integration time) over 4 Bunch crossing ~ 1.2% (neglecting Hit from single G4 step)

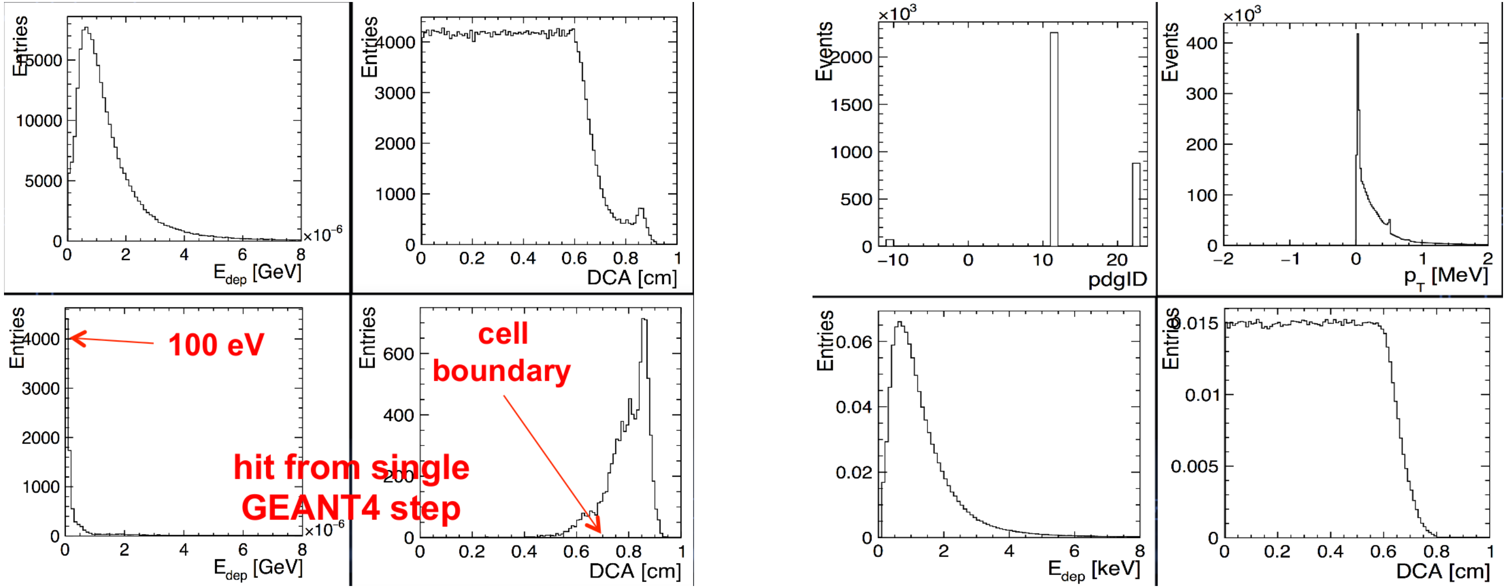


average DCH occupancy (400ns integration time) over 100 events ~ 2.8%



DCH occupancy due to incoherent e+e- pairs (single G4step problem)

Hit created by a single G4 step create strangeness in the single cell distribution and a large occupancy at Z energy.
Removing them the distribution become normal and the occupancy at Z energy decrease at a reasonable level.
We have to check if is too optimistic or at which level the can be removed.

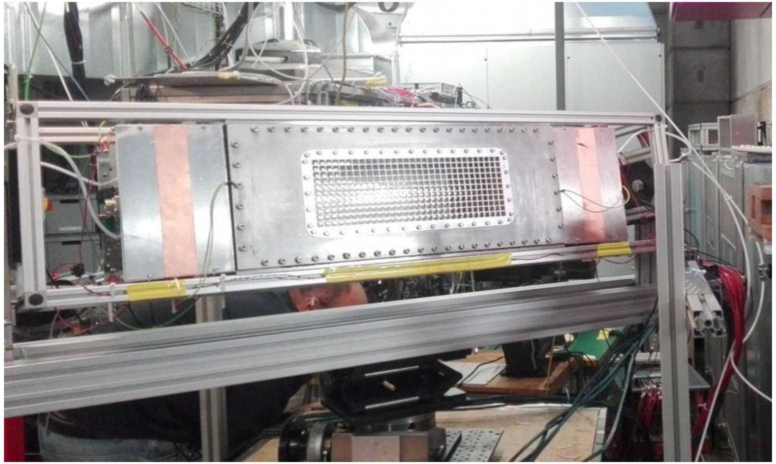


(thanks to Niloufar Alipour Tehrani)

To do (simulation):

- Produce a documentation and put in a common place the standalone simulation
- Investigate the background occupancy:
  - Use a full signal simulation or a (better parameterization)
  - Check the FCC-sw results with the standalone code
- Improve the FCC-sw DCH geometry description
- Approach the reconstruction task in FCC-sw
- Integration with the DR-calorimeter
  - In the standalone code the 4pi geometry is ready, needs help for the proper hit creation
  - In FCC-sw we have to start to implement the geometry first
- Implement a fast simulation (extract the right information form the full simulation) to perform physics studies

DCH test beam



- The prototype is built
- We are performing a working check and maintenance
- The DCH prototype is an array of 12X12 1cm drift cells
- The active area is reduced to 10x10 cells
- Only a set of central cell (at least 8, depends on the available digitizer channels) are digitized
- The other cells will be discriminated and read with a TDC.

DCH test beam (to do and needs)

To do:

- Build a mechanical support to install the prototype to the test beam area (1-2 working days)
- procure / build HV cables of the needed length
- Gas procurement and bureaucracy (we need info)
- Work on the DAQ to speed up the acquisition rate (1-2 weeks)

Needs:

- 1-2 weeks rent of a van + travel (3 k€)
- Gas + services (2 k€)
- Eventual Connectors, adapters etc. at CERN (1 k€)
- Support for 3-4 people (1.5 k€/person)

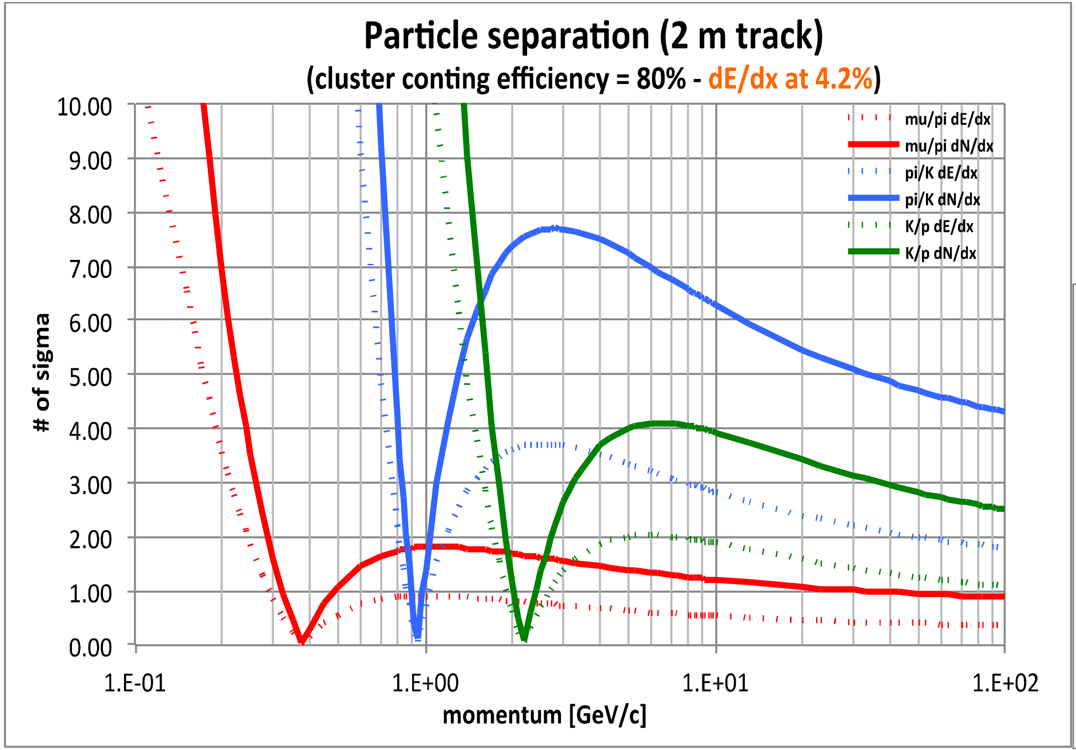
Tot. 12 k€

Summary

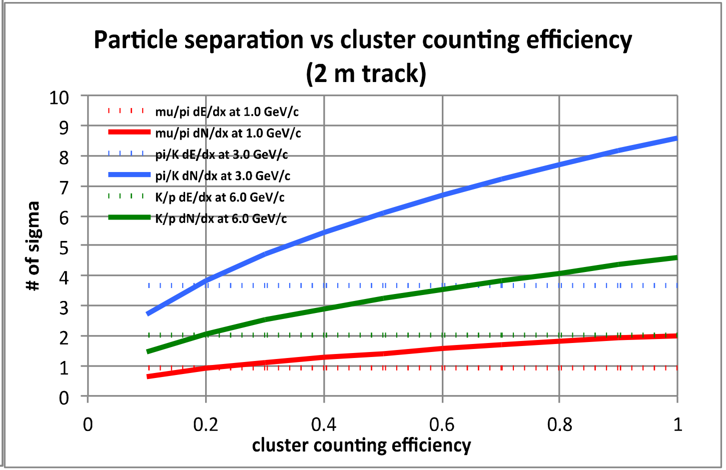
- A full simulation for the IDEA tracking system (DCH + SVX + SOT + PSHW) is ready at a good level of details
- The implementation in the FCC-sw is started and produce the first results on the DCH.
- Still more work to do:
  - work on the Pattern Recognition and test its performance;
  - optimization 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;
  - Finalize the integration of the Dual Readout calorimeter in the full simulation
  - … etc …
- Work on the test beam!

Backup

Cluster Counting/Timing and P.Id. expected performance

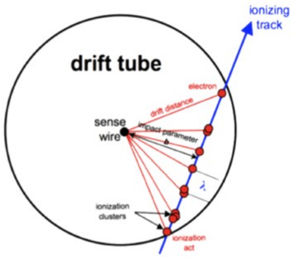


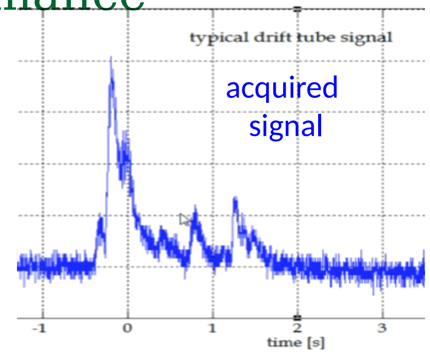
analytic evaluation,
to be checked with detailed simulations and test beams



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: $\{t_i^{cl}\} \qquad i = 1, N_{cl}$





dE/dx

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

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

σ ≈ 4.3%

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

dN_{cl}/dx

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

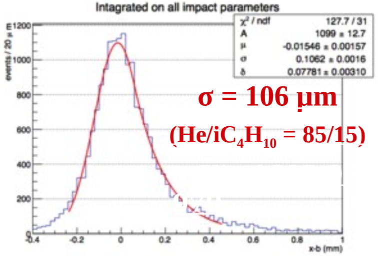
from *Poisson distribution*

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

σ ≈ 2.0%

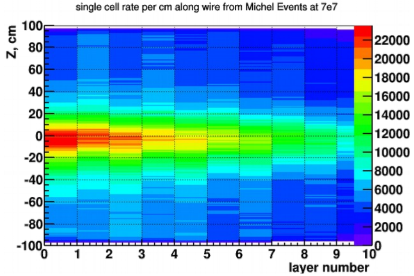
A small increment of iC_4H_{10} from 10% to 20% (δ_{cl} = 20/cm) improves resolution by 20% (σ ≈1.6%) at only a reasonable cost of multiple scattering contribution to momentum and angular resolutions.

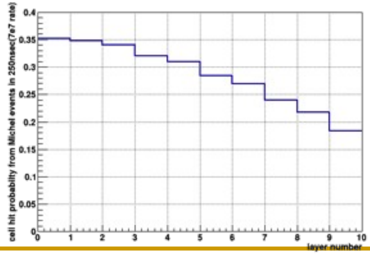
The MEG2 Drift Chamber Performance

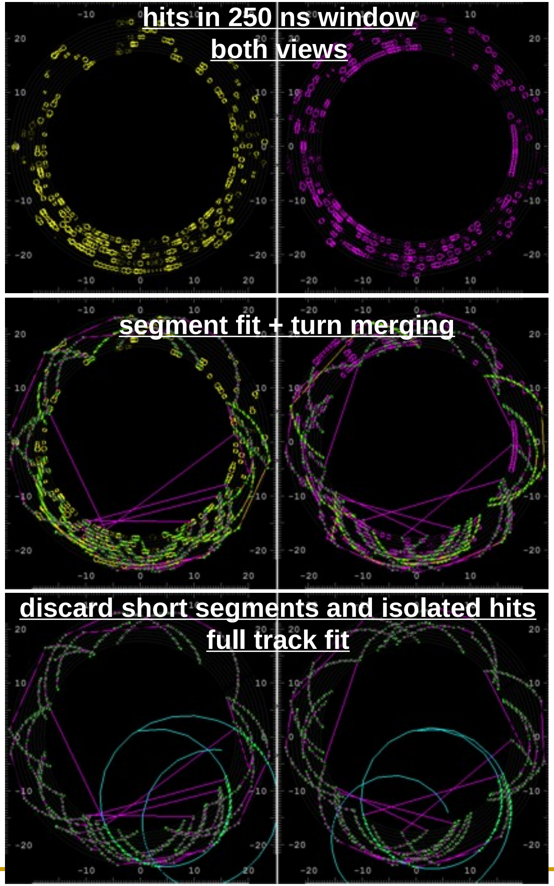


σ = 106 μm

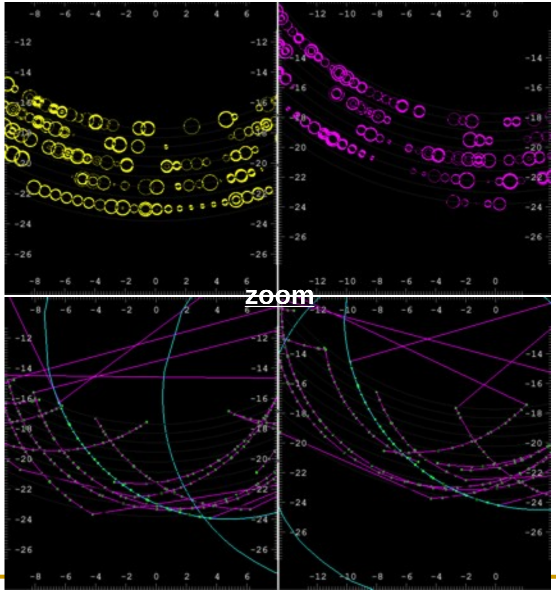
(He/iC_4H_{10} = 85/15)







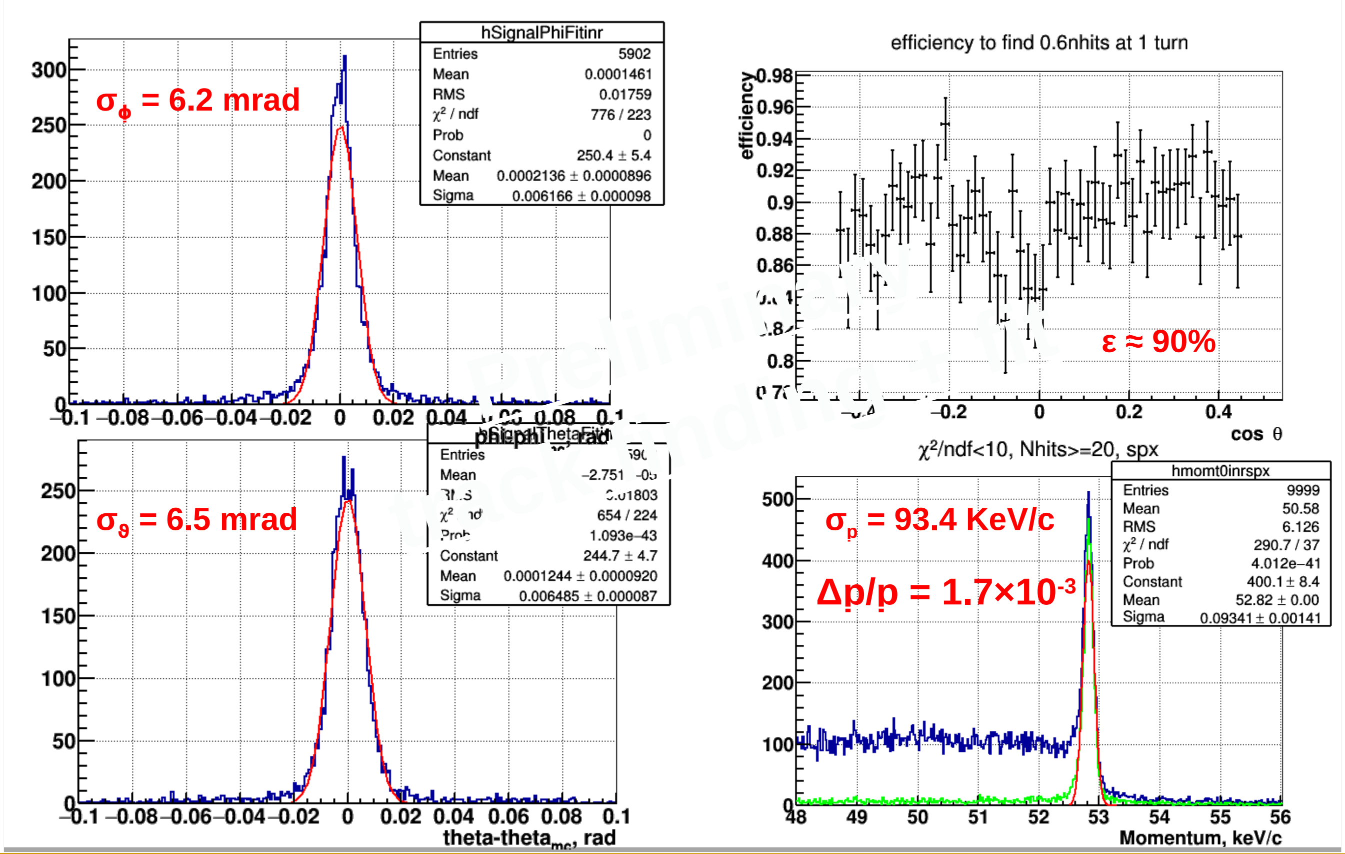
3D
track finding
and fit



signal track

michel tracks

The MEG2 Drift Chamber Performance



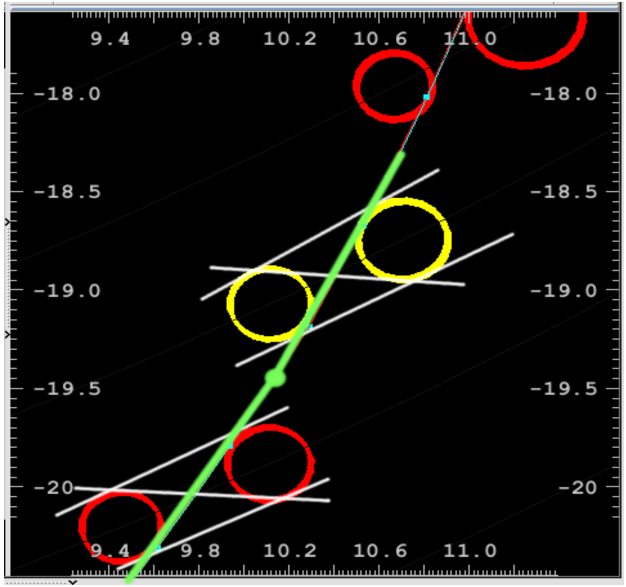
2 pairs seed construction (DCH only)

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:
- |Δcos(φ(direction)-φ(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 Δφ correction from Pt)
- Pz = 0 at beginning

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



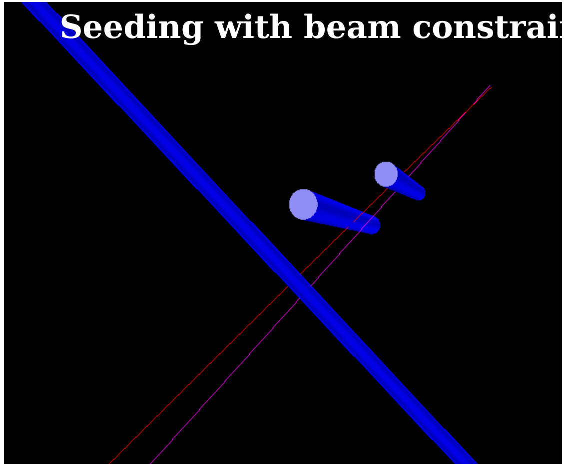
Red hits **projection at z=0 plane**
Yellow **rotated according to φ**

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

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