Tracking in the ILD concept

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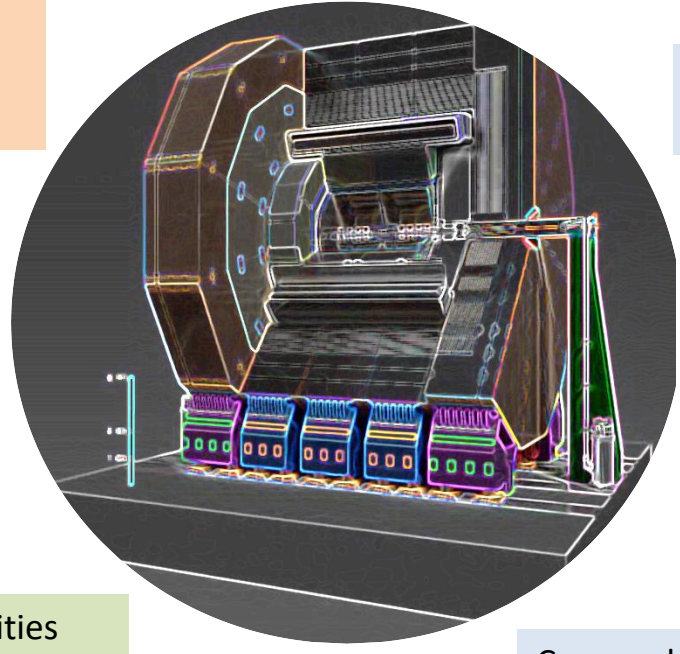
LCTPC collaboration meeting

ILD meeting at CERN, January 2024

ILD: where we are starting

ILD has been conceived about 10 years ago It is now time to re-visit many of the choices and “modernize” ILD. There is no need to fundamentally change ILD

Is particle flow still the right paradigm for a detector at a Z or Higgs factory?



Is a gaseous central detector still the right choice?

The conditions in particular for the inner part of the detector are very different for different collider concepts

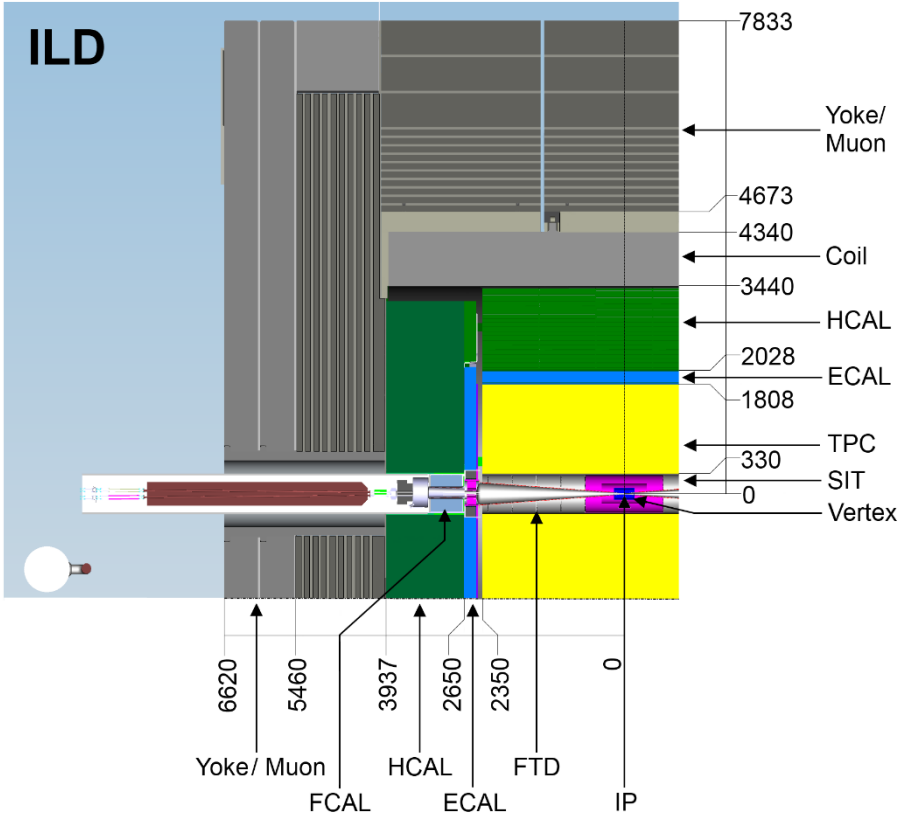
What is the right balance between VTX/ SIT/ TPC/SET?

Is the ILD forwards tracking still good enough?

The connection to the R&D activities needs to be re-invented in the times of DRD’s

Can we do significantly better on the material budget?

The ILD detector

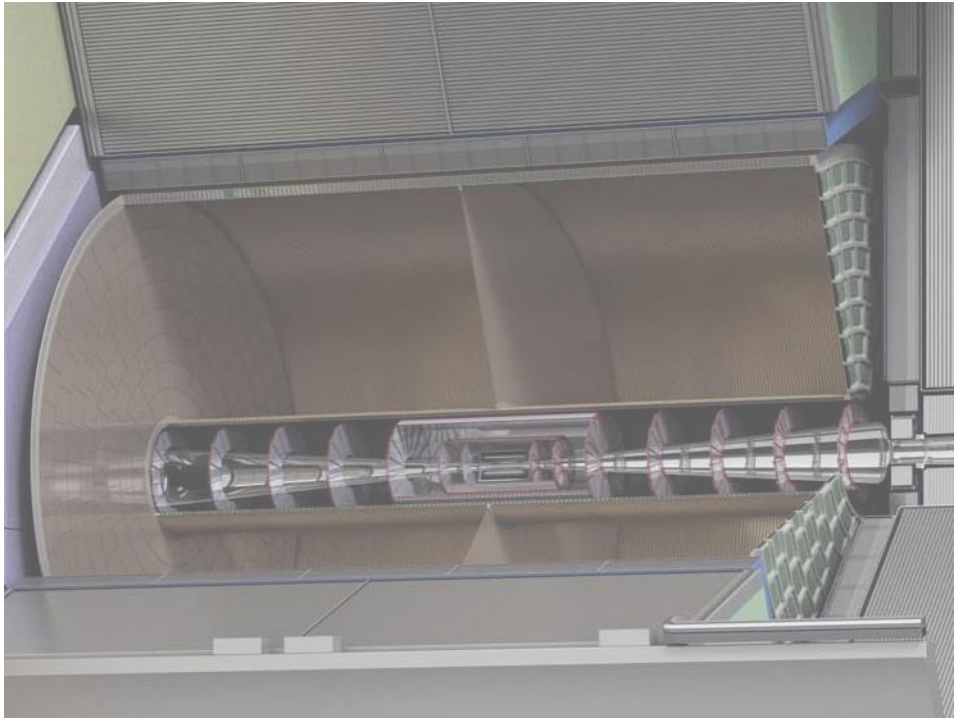


The tracking system:

- High precision low mass vertex
- Precision Silicon intermediate tracker
- Large volume low mass TPC
  - Low mass field cage
  - Low mass endplate
- Precision Silicon outer tracker
- Optimized for running at and above the Higgs threshold

The ILD inner tracking System

Parameter	
Geometrical parameters	r_{in} 329 mm; r_{out} 1808 mm; z $\pm$ 2350 mm
Solid angle coverage	up to $\cos\theta \simeq 0.98$ (10 pad rows)
TPC material budget	$\simeq 0.05\ X_0$ including outer fieldcage in r
	$< 0.25\ X_0$ for readout endcaps in z
Number of pads/timebuckets	$\simeq$ 1-2 $\times 10^6$/1000 per endcap
Pad pitch/ no.padrows	$\simeq 1\times$ 6 mm^2 for 220 padrows
σ_{point} in $r\phi$	$\simeq$ 60 μm for zero drift, $<$ 100 μm overall
σ_{point} in rz	$\simeq 0.4 - 1.4$ mm (for zero – full drift)
2-hit resolution in $r\phi$	$\simeq$ 2 mm
2-hit resolution in rz	$\simeq$ 6 mm
dE/dx resolution	$\simeq$ 5 %
Momentum resolution at B=3.5 T	$\delta(1/p_t) \simeq 10^{-4}$/GeV/c (TPC only)



The case for gaseous detectors

Low material budget and PID capabilities

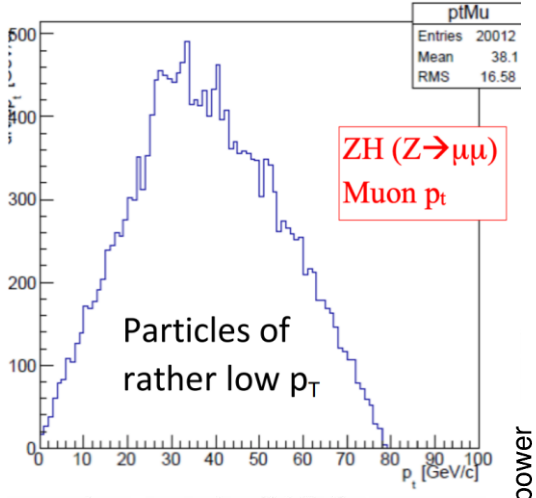
Tracking system should be as light as possible

- Momentum resolution dominated by multiple scattering at low momentum
- Particle Flow requires as little material as possible in front of ECAL

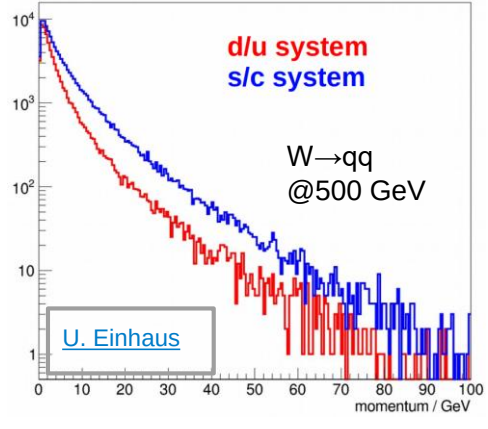
Flavor studies require PID over wide momentum range

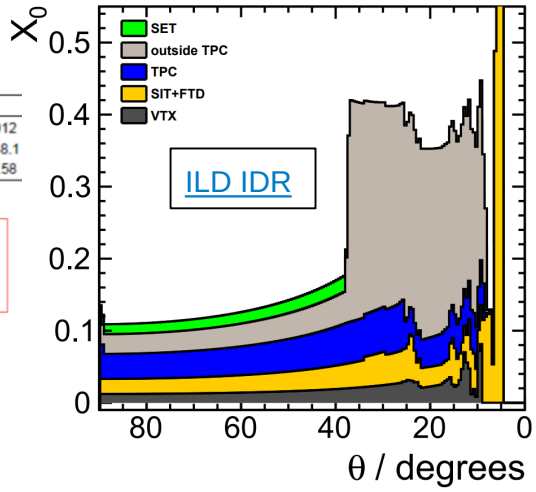
- Many studies require excellent charged hadron separation
- dE/dx or dN/dx possible up to 50 GeV
- Lower momentum ranges can be augmented with TOF based measurements

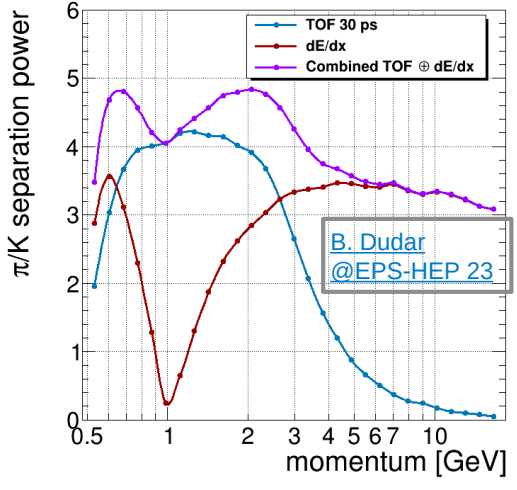
Detection of in-flight decays via continuous pattern recognition



kaon momentum distribution

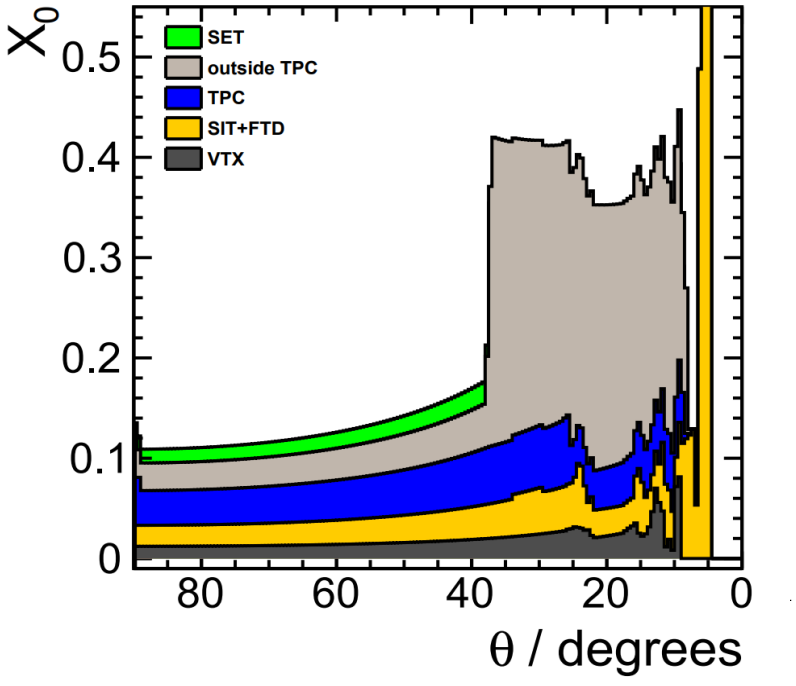


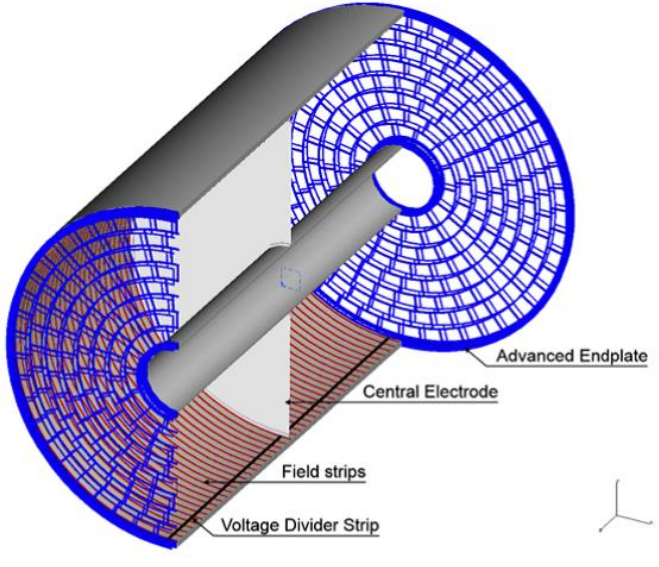




Slide takenfrom Thomas Madlener, DESY, talk at the ILD meeting 2024

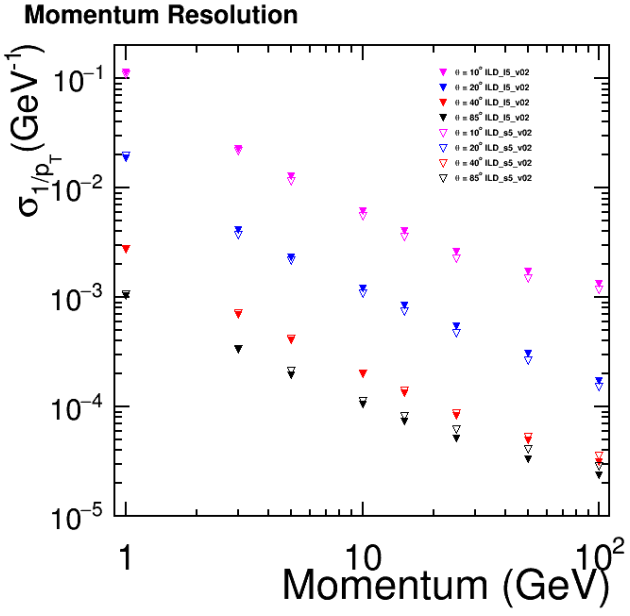
The ILD tracker: Material

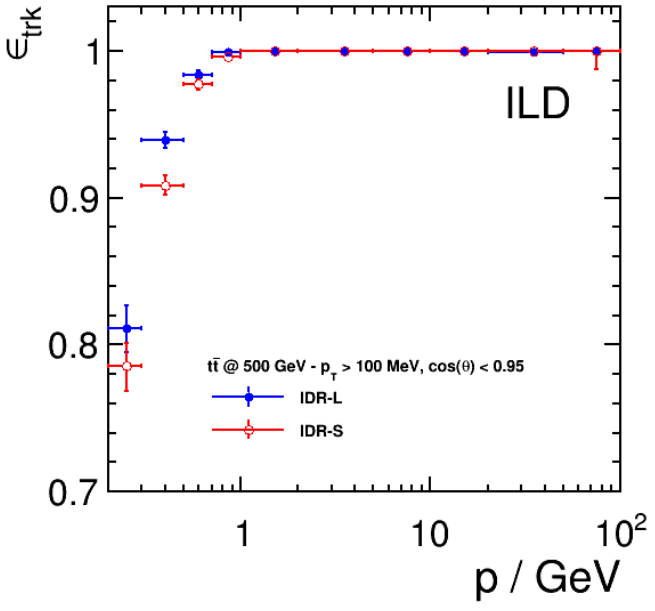




Light weight composite material inner and outer field cage

Tracking performance





Excellent momentum resolution and high efficiency demonstrated in detailed simulation
Combined Silicon – TPC tracking performance

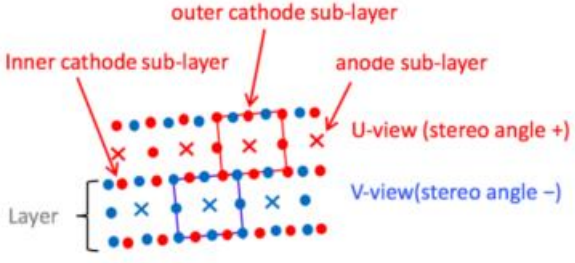
Options considered for ILD

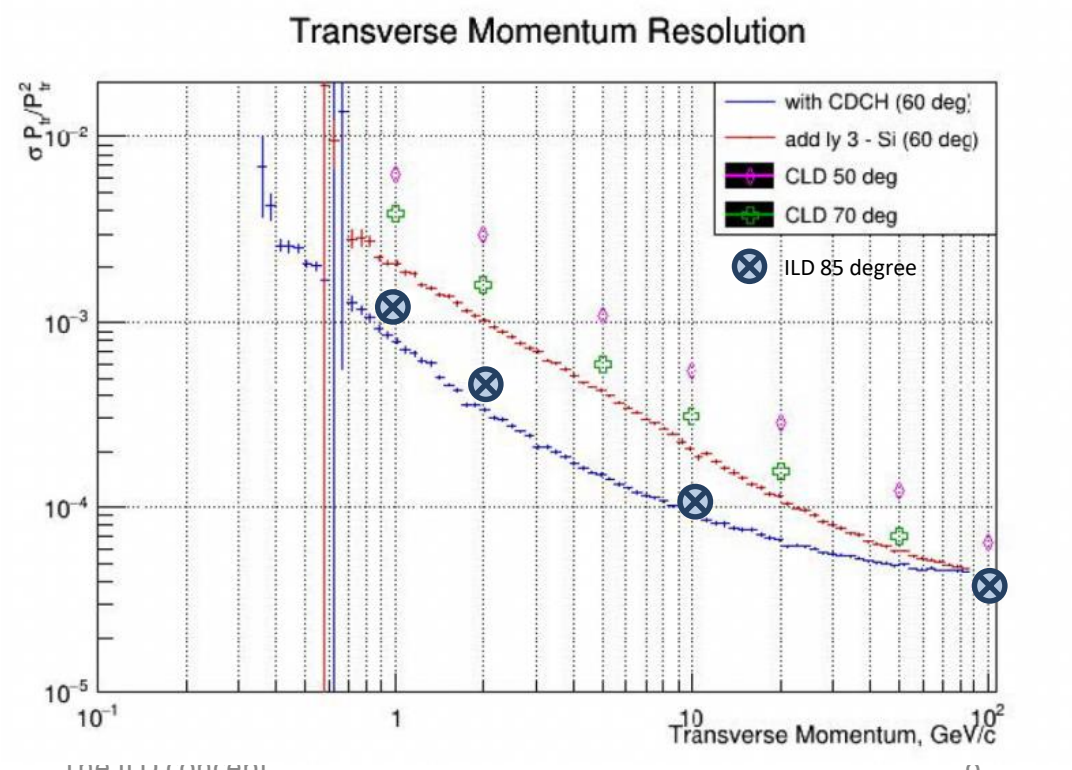
- GEM based TPC
  - Based on the DESY/ KEK developments
  - Reasonably well established design and mechanics
  - Prototyped
- MM based TPC
  - Based on Saclay developments
  - Reasonably well established design/ mechanics
  - Prototyped
- Grid-based TPC readout
  - Based on NIKHEF/ Bonn developments
  - Prototyped
  - Design of mechanics under development

Are there alternatives to a TPC

Small cell drift chamber

- O(20000) wires
- Stereo layers
- Relatively fast readout
- See talk later today





Towards an “new” ILD tracker

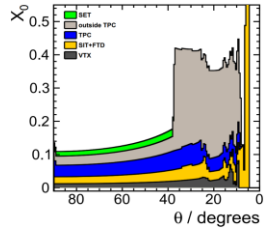
Case of E(cms)>91 GeV

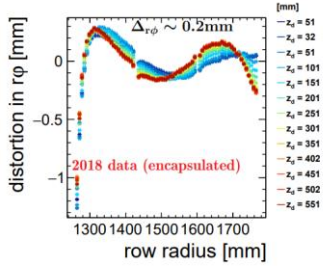
- Further reduce the material budget, in particular, in the endcap
  - Need a program on the field cage and the end-plate mechanics
  - Choice of gas?
  - What would be the goal?

- Do a real design of the cathode plane

- Do a real design of the electrostatics of the endplate
  - Field distortions at the module edges
  - Field distortions in between modules

- Do a real design of a gating system and integrate this into the pad-plane/ readout module

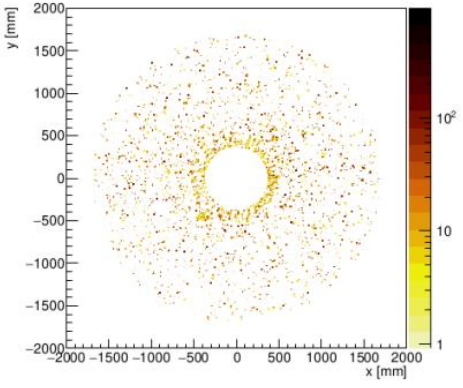


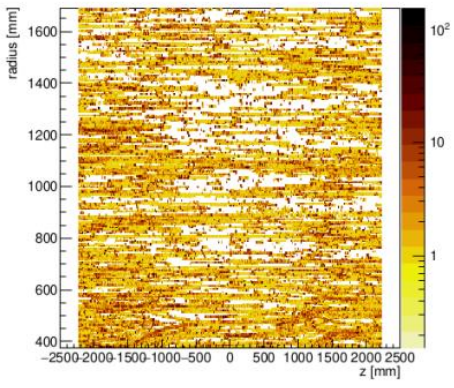


ILD @ low energies

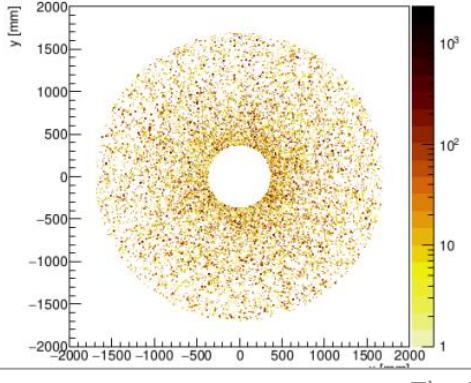
TPC hits
superimpose
100 bunch crossings

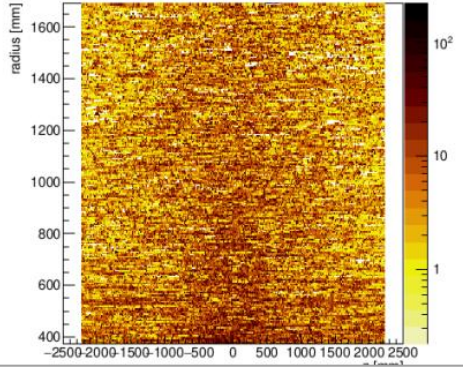
ILD_l5_v11y @ FCCee-91





ILD_l5_v03 @ ILC-250



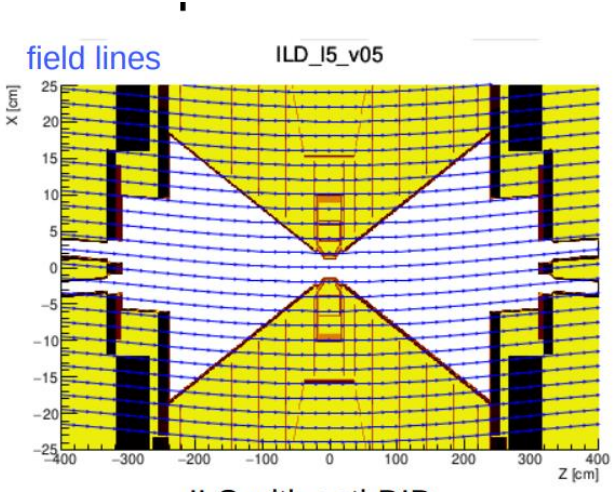


Intrinsic background

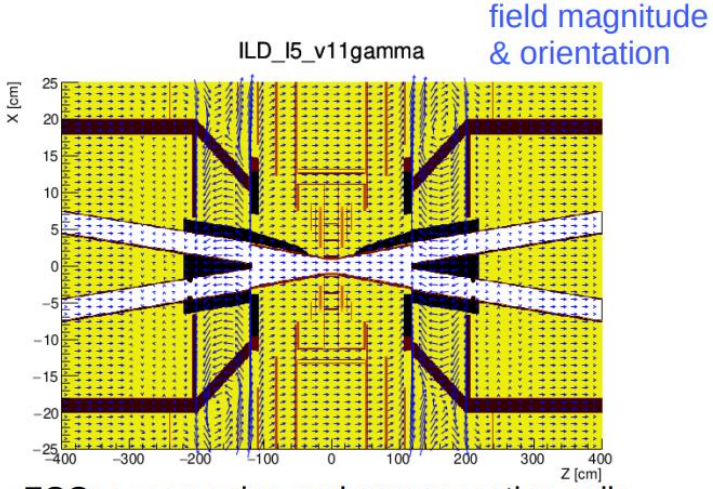
- Less at circular collider

From talk by D. Jeans at ILD meeting

ILD @ circular collider



ILC with anti-DID



FCCee: screening and compensating coils

Intrinsic background

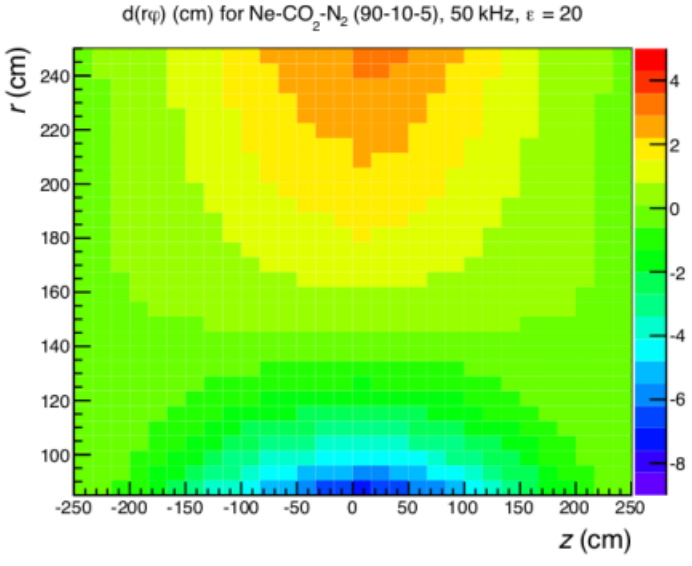
- Less at circular collider
- But much larger contribution from "MDI"

Primary "Charge" in a TPC:
(much simplified picture, see talk by D.Jeans for full discussion)

	91 GeV	250 GeV
ILC	6.5+-19	960+-150
FCC-ee	390+-120	11000+-2400

From talk by D. Jeans at ILD meeting

Distortions



Charge in TPC volume creates large distortions

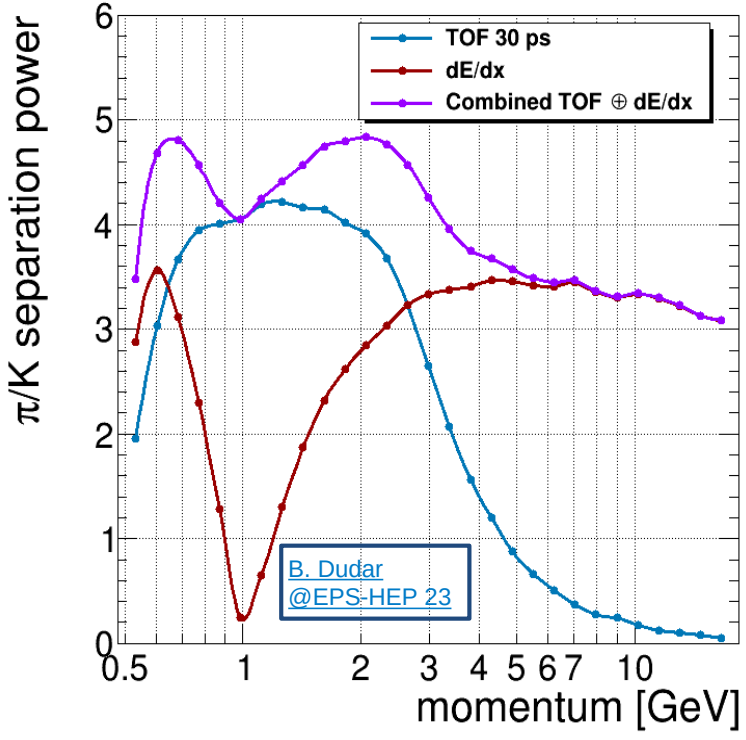
- O(cm) when running on the Z with FCC-ee conditions
- Significantly less in ILC conditions

Need to develop a strategy to deal with the distortions due to charge in the TPC volume

Overall running conditions on the Z:

- P. Kluit: probably ok, even with the long integration times

Particle ID



Pi-K separation much better in gaseous detectors for p>2 GeV
Combined with TOF: good system performance for broad momentum range up to 10's of GeV

- Gridpix based TPC offers some improvement
  - Final system performance needs to be demonstrated

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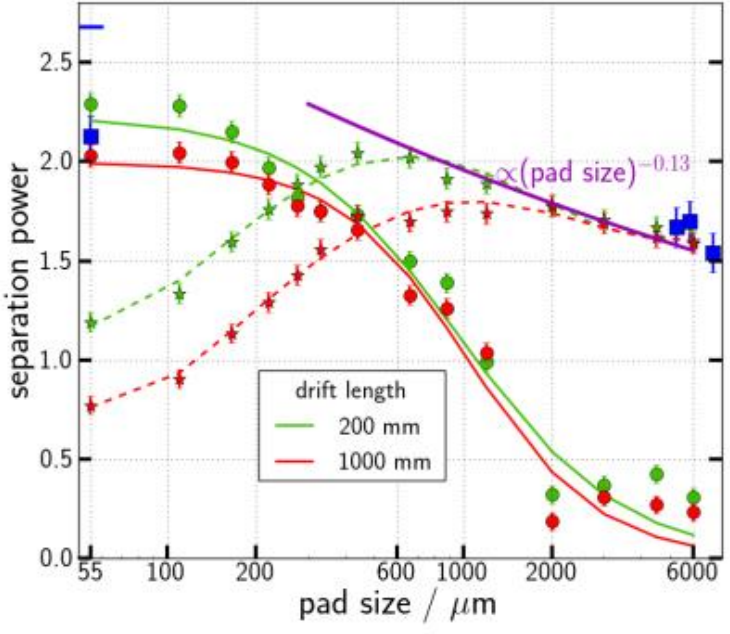

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- "hybrid" Pad-Pixel TPC (U. Einhaus, studies at CEPC) might offer similar performance

Discussion

Main areas for improvement:

- Material budget
- Electrostatic behavior
- Gating
- Distortion control
- De/dx method

If we can control the distortions,
a TPC remains an attractive option
also for other collider concepts than ILC ,
and also for lower energies