ILD Vertex Detector;
adapting the design to a multi-TeV environment

Vertex Detector WG for CLIC,

CLIC-WG4

CERN, Geneva,

April 22, 2010

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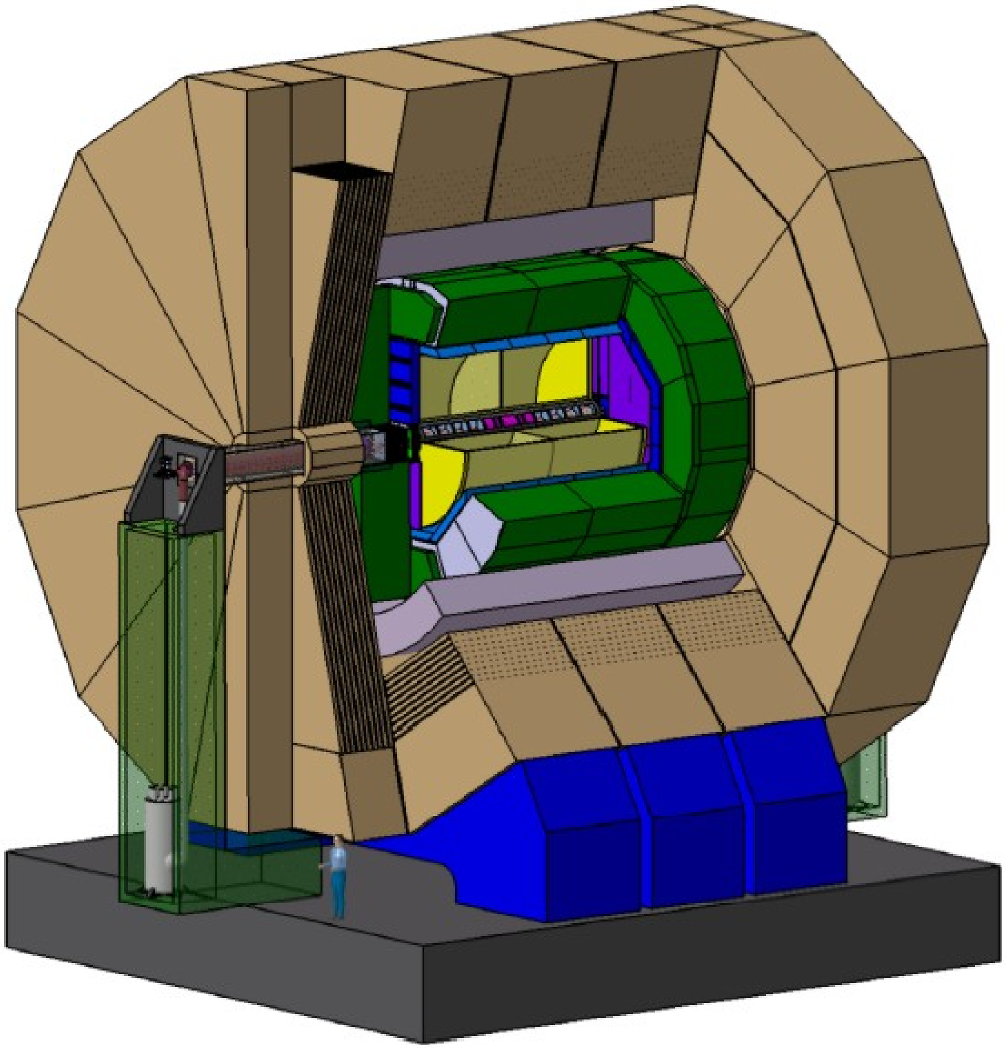
The ILD detector concept



http://www.ilcild.org/

A more or less global
“proto-collaboration”
650 LOI signatories
from 170 institutes

VXD

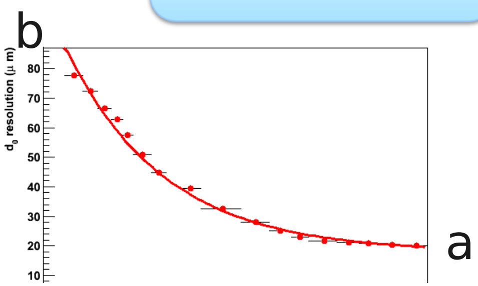
VXD: impact parameter resolution 5 – 10 μm.

This precision is required to achieve excellent heavy flavour tagging,
Based on charm ($c\tau$ ~150 μm) and bottom ($c\tau$ ~ 450 μm) life-time

RHIC: a=13, b=19

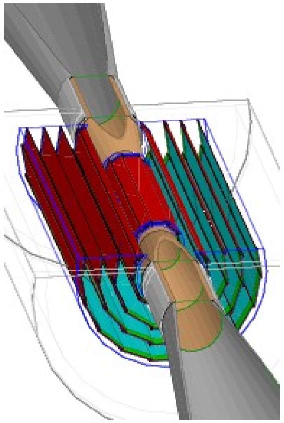
	a (μm)	b (μm GeV)
LEP	25	70
SLD	8	33
LHC	12	70
ILC	5	10

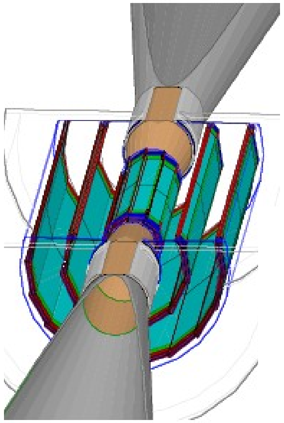
$$\sigma_{IP} = a \oplus \frac{b}{p\sin^{3/2}\theta}$$



Unprecedented precision
(small pixels, 20x20 μm^2)

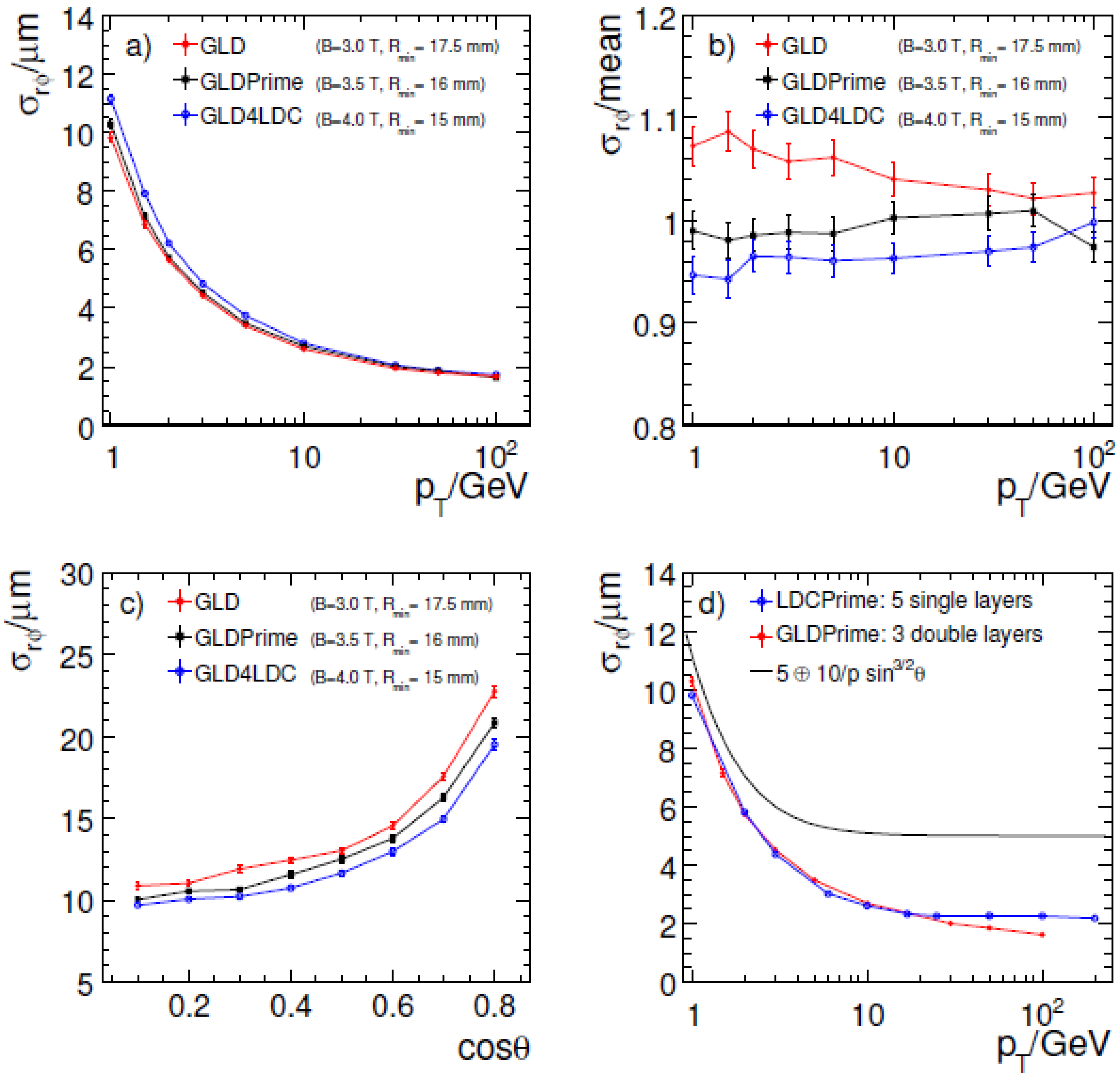
Strongly reduce the multiple Coulomb scattering term
(material: 0.1 % X_0 / layer ~ 100 μm Si)





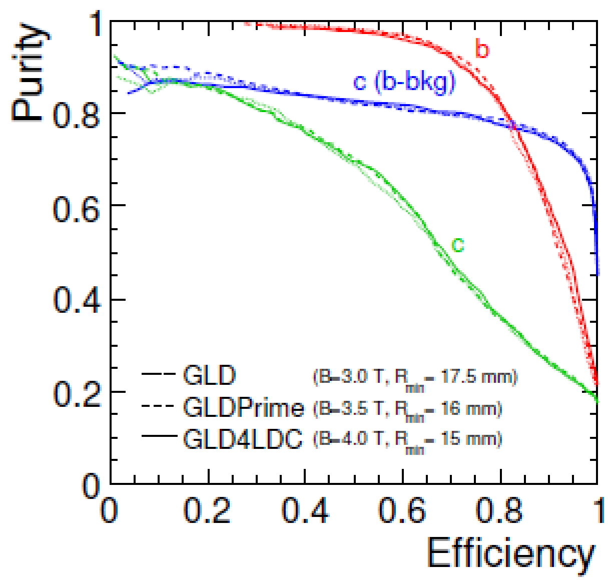
	radius [mm]		ladder length [mm]		read-out time [μs]	
geometry	VTX-SL	VTX-DL	VTX-SL	VTX-DL	VTX-SL	VTX-DL
layer 1	15.0	16.0/18.0	125.0	125.0	25–50	25–50
layer 2	26.0	37.0/39.0	250.0	250.0	50–100	100-200
layer 3	37.0	58.0/60.0	250.0	250.0	100-200	100-200
layer 4	48.0		250.0		100-200	
layer 5	60.0		250.0		100-200	

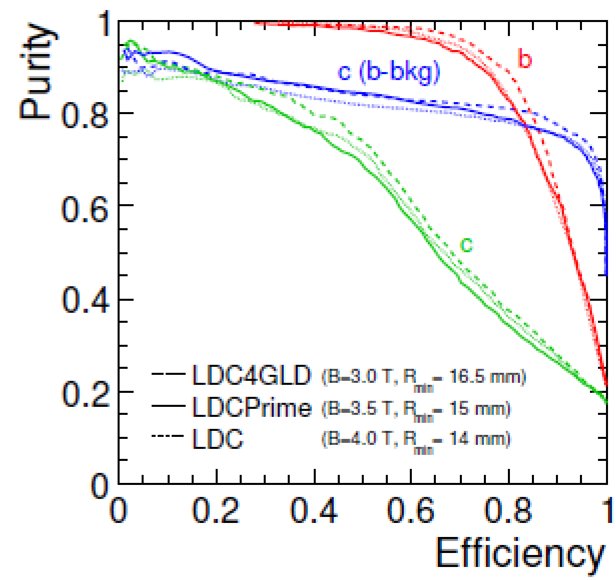
Performance



Differences GEANT4 interfaces (Mokka/Jupiter) yield compatible results. Small changes in performance as expected

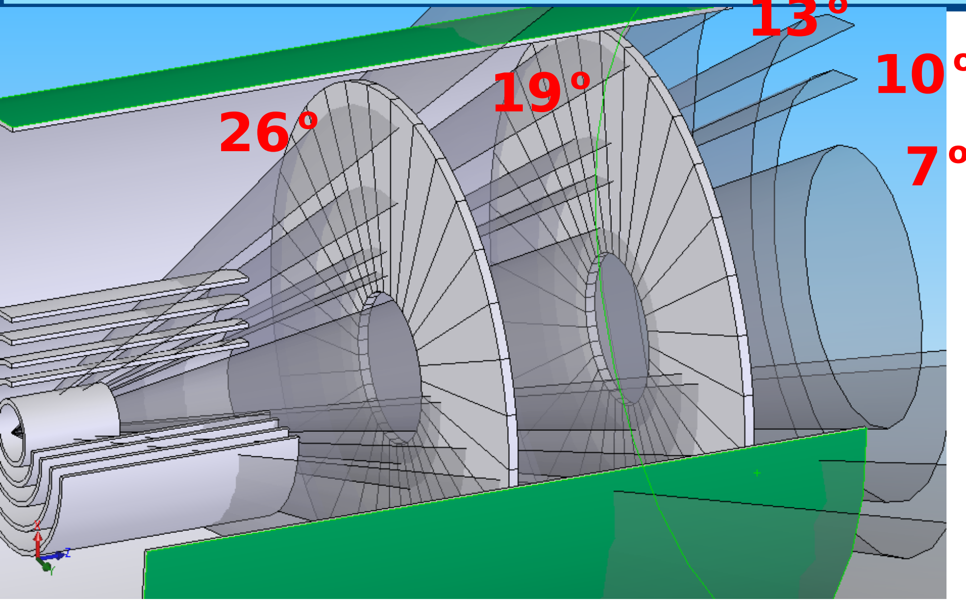
Flavour tagging performance



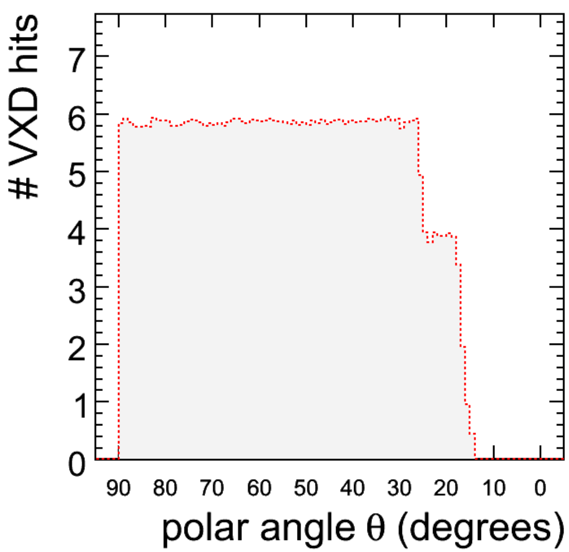


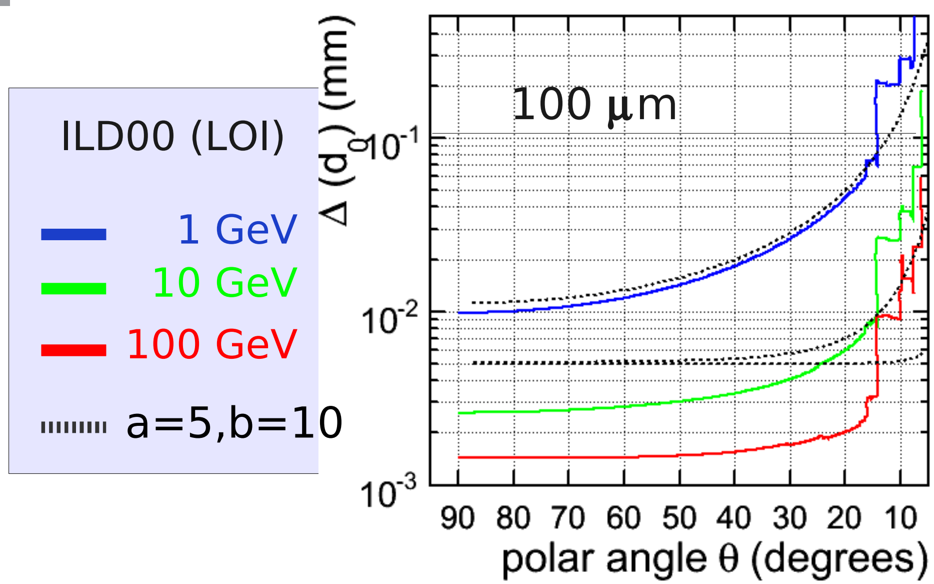
	GLD	GLD'	GLD4LDC	LDC4GLD	LDC'	LDC	ILD
	Jupiter			Mokka			Mokka
B-field	3.0 T	3.5 T	4.0 T	3.0 T	3.5 T	4.0 T	3.5 T
beampipe	15.0 mm	14.0 mm	13.0 mm	15.5 mm	14.0 mm	13.0 mm	14.5 mm
VXD	cylindrical geometry			ladders			ladders
layout	3 doublets			5 layers			3 doublets
R_{min}	17.5 mm	16.0 mm	15.0 mm	16.5 mm	15.0 mm	14.0 mm	16.0 mm

Coverage



Concep	Magnet Field	Angular Coverage 5-point	3-point
SiD	5 T	12.5 (43 barrel)	9
LDC	4 T	26	19
GLD	3T	26 (6 points)	18 (4 barrel + 2 di
ILD	3.5 T	26 (6 points)	17





VXD R&D

Section 4.1.3.1 of the LOI: The technologies presently concentrating most of the R&D effort within the ILD group are CMOS sensors [...], DEPFETs [...], FPCCDs [...], and ISIS [...]. Since recently, CMOS sensors exploiting vertical integration technology [...] are also developed. Alternative technological approaches mentioned in [*] may also be considered, though not currently developed inside the ILD group. The R&D achieved so far has already demonstrated that the goals of a single point resolution of (< 3 μm), double hit separation of (< 40 μm) and sensor thickness of (< 50 μm) are achievable.

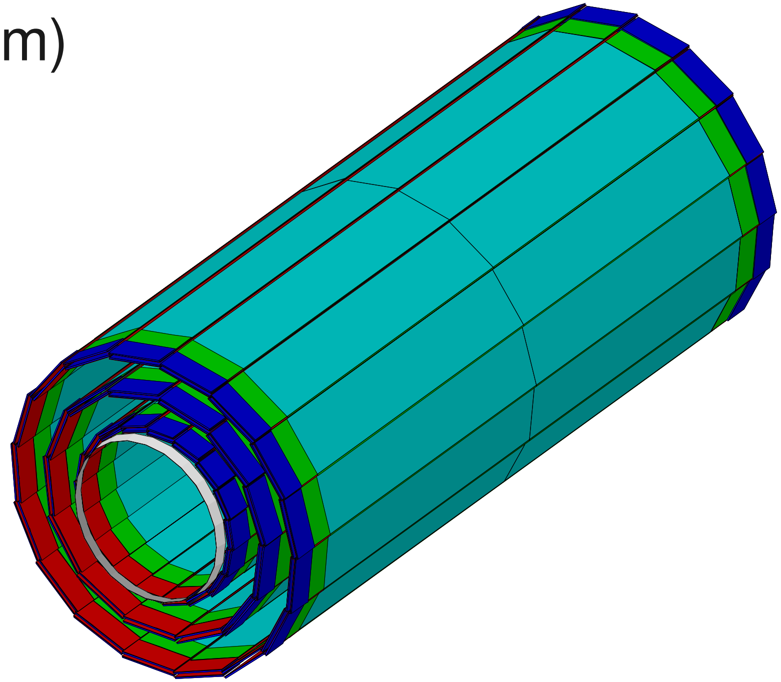
[*], vertex detector review: C. Damerell et al., “ILC Vertex Detector R&D - Report of Review Committee”. http://ilcdoc.linearcollider.org/record/17962/files/Vertex_Detector_Review-final.pdf?version=1. ILC-Report-2008-016, where a large number (~12) of VXD technologies were discussed.

Differences in the tracking between CLIC01_ILD and ILD00

•Larger radius of the beam pipe (30mm) inside the Vertex Detector (VXD)

•Larger radius for the VXD

- Double layer structure:
  - Radii 31, 33, 44, 46, 58, 60 mm
  - Length: Z= ± 125mm



Doubling the radius, choose either:

- Degradation of the angular coverage (and the whole purpose of a long barrel is to maximize the angular coverage of the barrel)
- or the long barrel becomes a very long barrel (no longer a natural ladder length for some technologies)

Vertex Detector

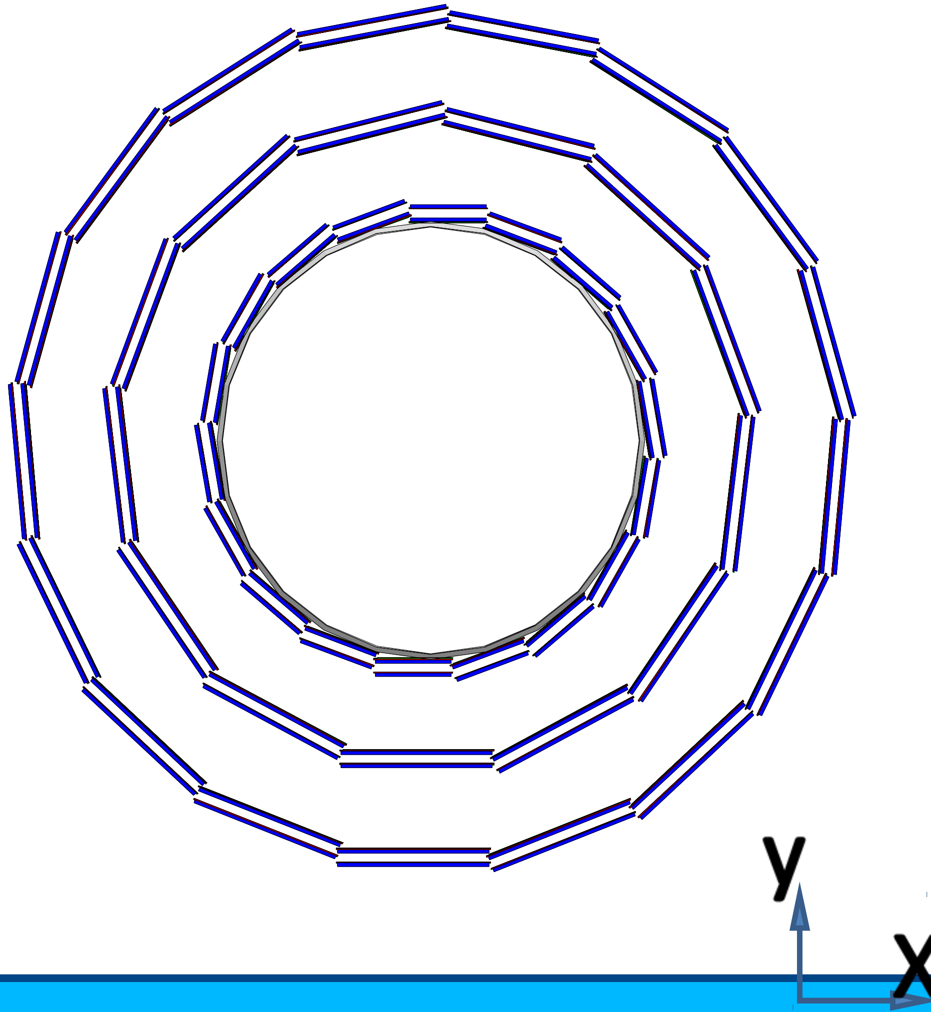
✔Size and number of ladders needs to be optimized

➔Tracks might miss one of the ladders

✔Ladders:

➔50 micron Silicon

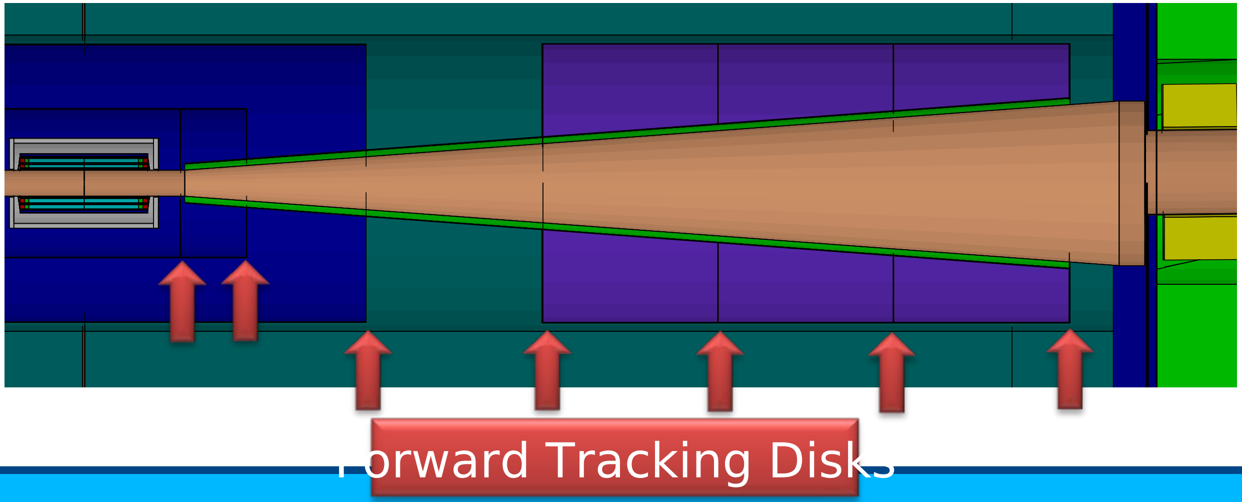
➔Material Budget per Layer: 0.11% X_0



Beam Pipe and Forward Tracking Disks

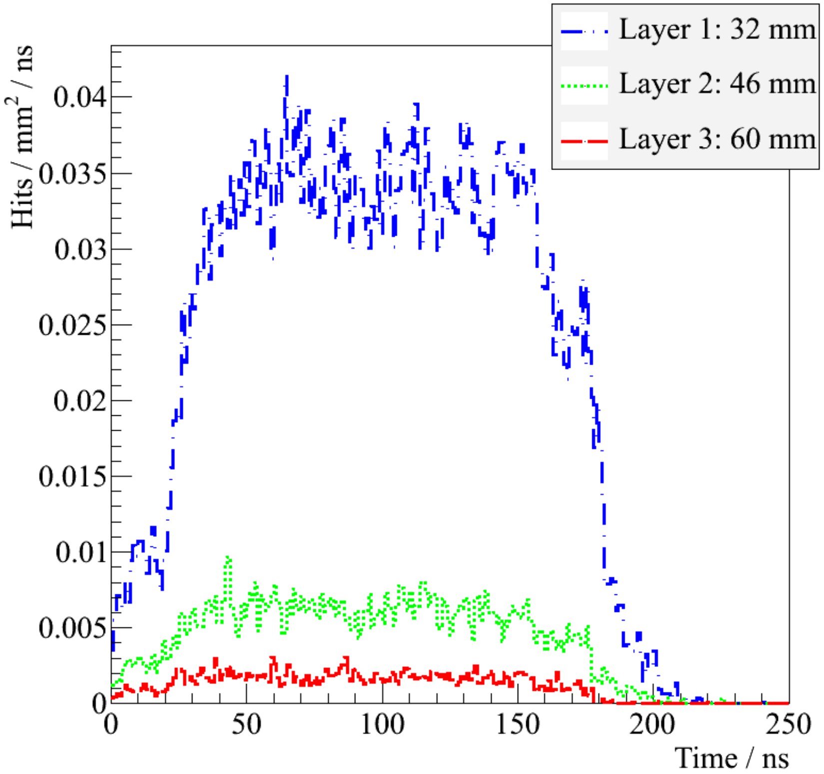
- ✔ Central cylinder
  - ➔ Radius 30mm
  - ➔ Length 230 mm
- ✔ Conical Section
  - ➔ Z: 230 to 2400 mm
  - ➔ Outer Radius: 30 to 184 mm

- Inner Radius/mm:
  - 45, 55, 75, 104, 133, 162, 191
- Outer Radius/mm:
  - 164, 164, 308, 309, 309, 309, 309
- Z-Coordinate/mm:
  - 220, 371, 645, 1046, 1447, 1849, 2250



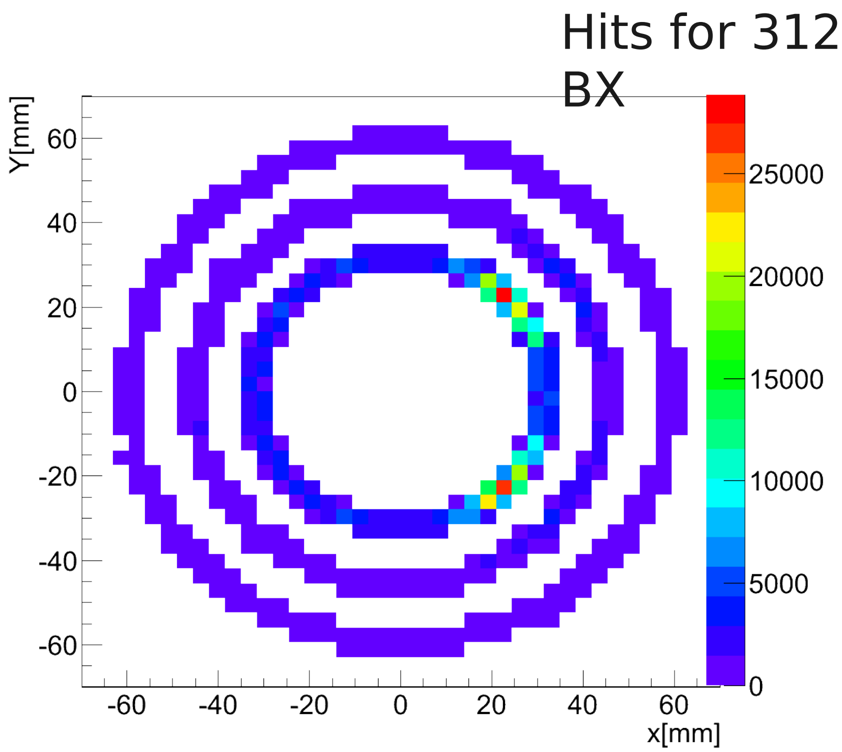
Hit Density in VXD from pair production

- ✔Overlapping hits
- ✔A few clean ns, before hits from back-scatters set in
- ✔Need fast readout to limit integration time
- ✔For a full bunch train:
  - ➔1st: 5.4/mm²
  - ➔2nd: 1.0/mm²
  - ➔3rd: 0.3/mm²

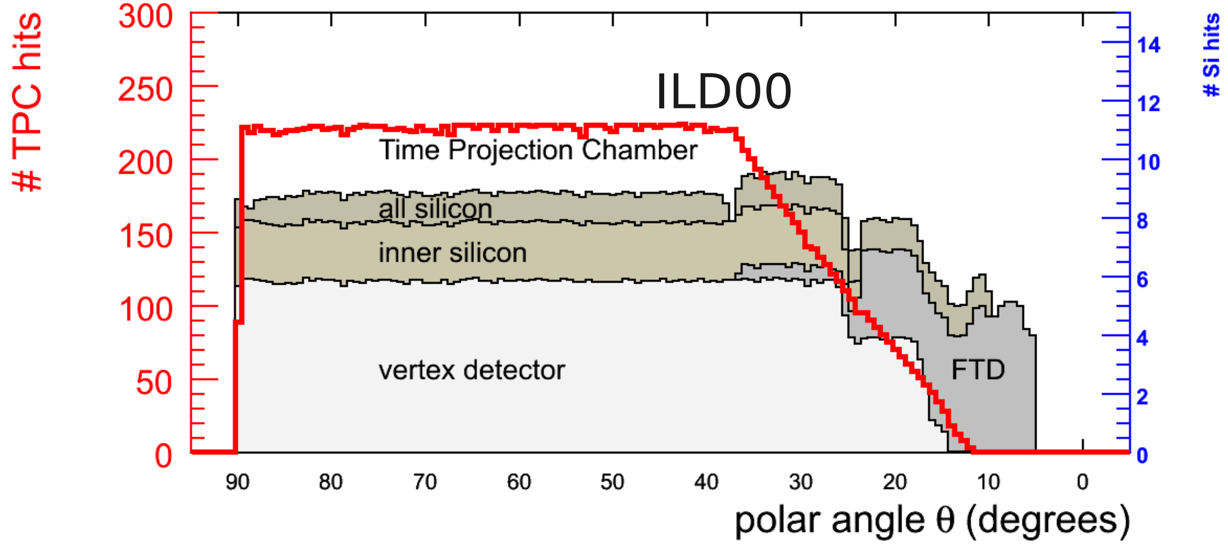


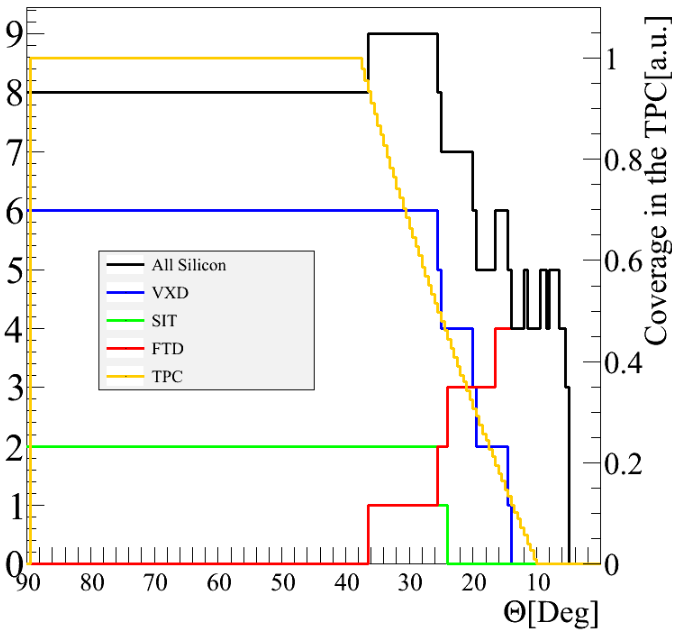
XY Distribution in VXD

- ✔Inhomogeneous distribution of hits in phi for the first layer of the VXD
- ✔Reminder: Not using AntiDID
- ✔Highest hit rate limits detector lifetime
- ✔(See Talk by A. Sailer @ LCWS10)

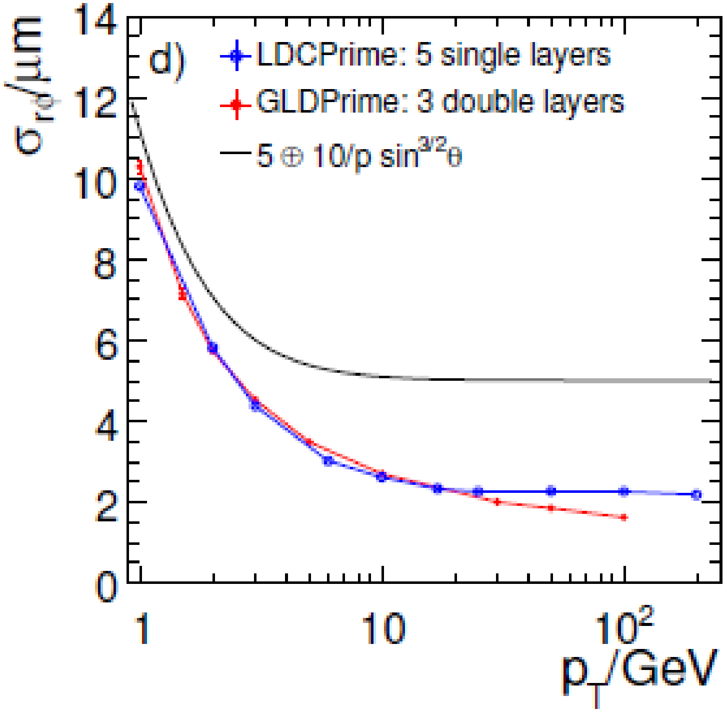


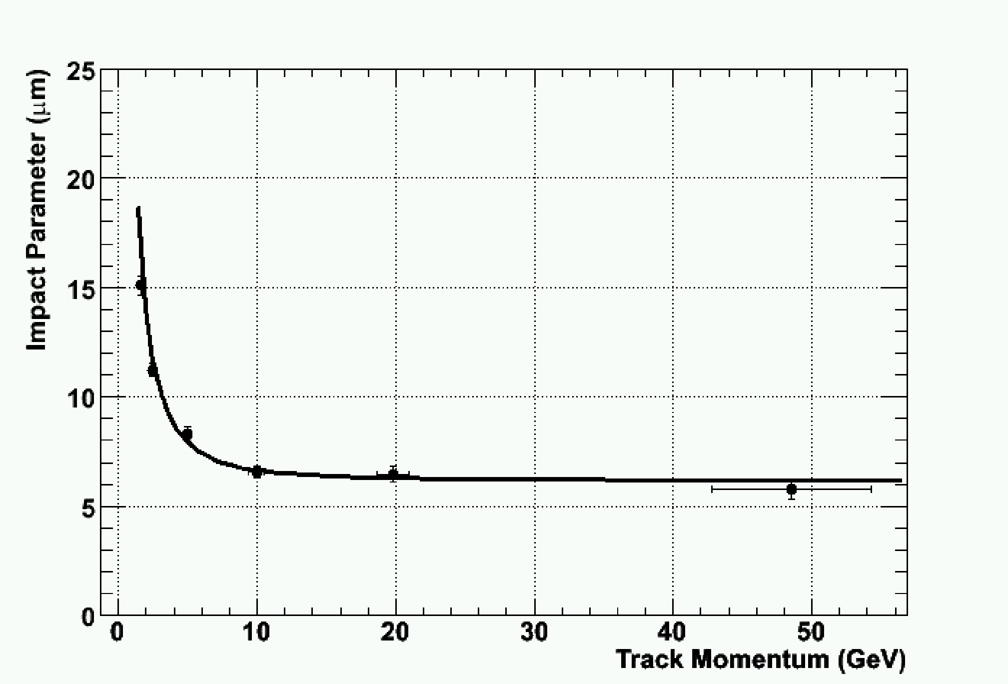
ILD-CLIC vs. ILD00





The main features (good and bad) of the ILD00 hits vs. polar angle plots are maintained





CLIC01-5layer (M. Battaglia)

Vertex-Forward Tracking

SiD (barrel+end-cap) and ILD (long barrel + FTD) have chosen very different layouts for the vertex detector and innermost forward tracking system

Establish strengths and weaknesses of different solutions by comparing the impact parameter resolution of toy geometries

CAVEAT: We're not comparing SiD and ILD (too many differences)

- Simplify the problem, reduce the number of observables
  - Vertexing is more than just flavour tagging.
  - Flavour tagging is more than just impact parameter resolution
- Simplify the problem, reduce the number of degrees of freedom
  - Uncertainty in the material budget (services!)
  - Uncertainty in the envelope of the pair background (B-field, machine parameters)
- Simplify the problem, software limitations
  - conical beam pipe (with thicker conical sections) not yet implemented

Tools – track fitting

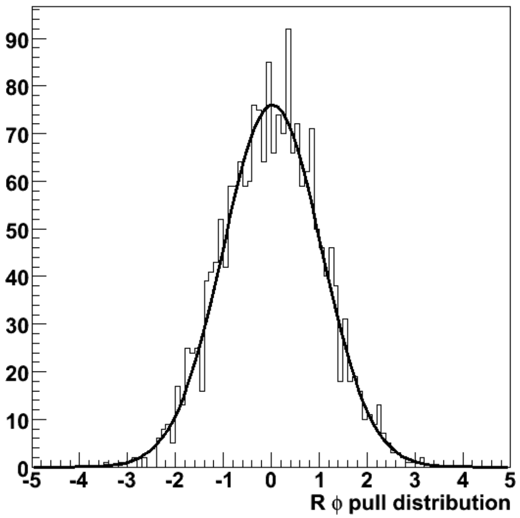
CMS Kalman filter tool-kit.

The result of years of work by a lot of people. Validated in large-scale MC productions.

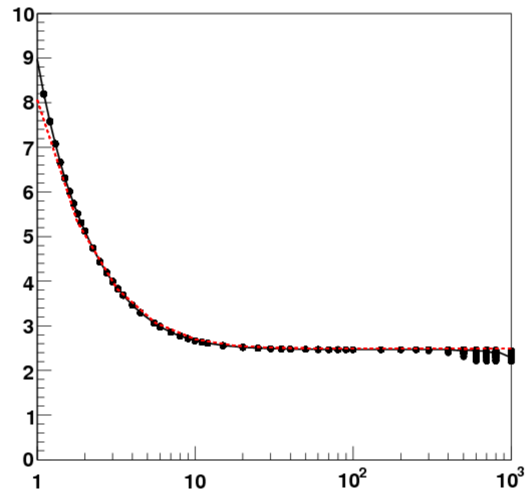
Extracted all relevant code in a series of libraries with limited external dependencies (CLHEP, ROOT).

Interfaced to toy geometries in standalone programme. Tested results for internal consistency and against existing fast-simulation packages.

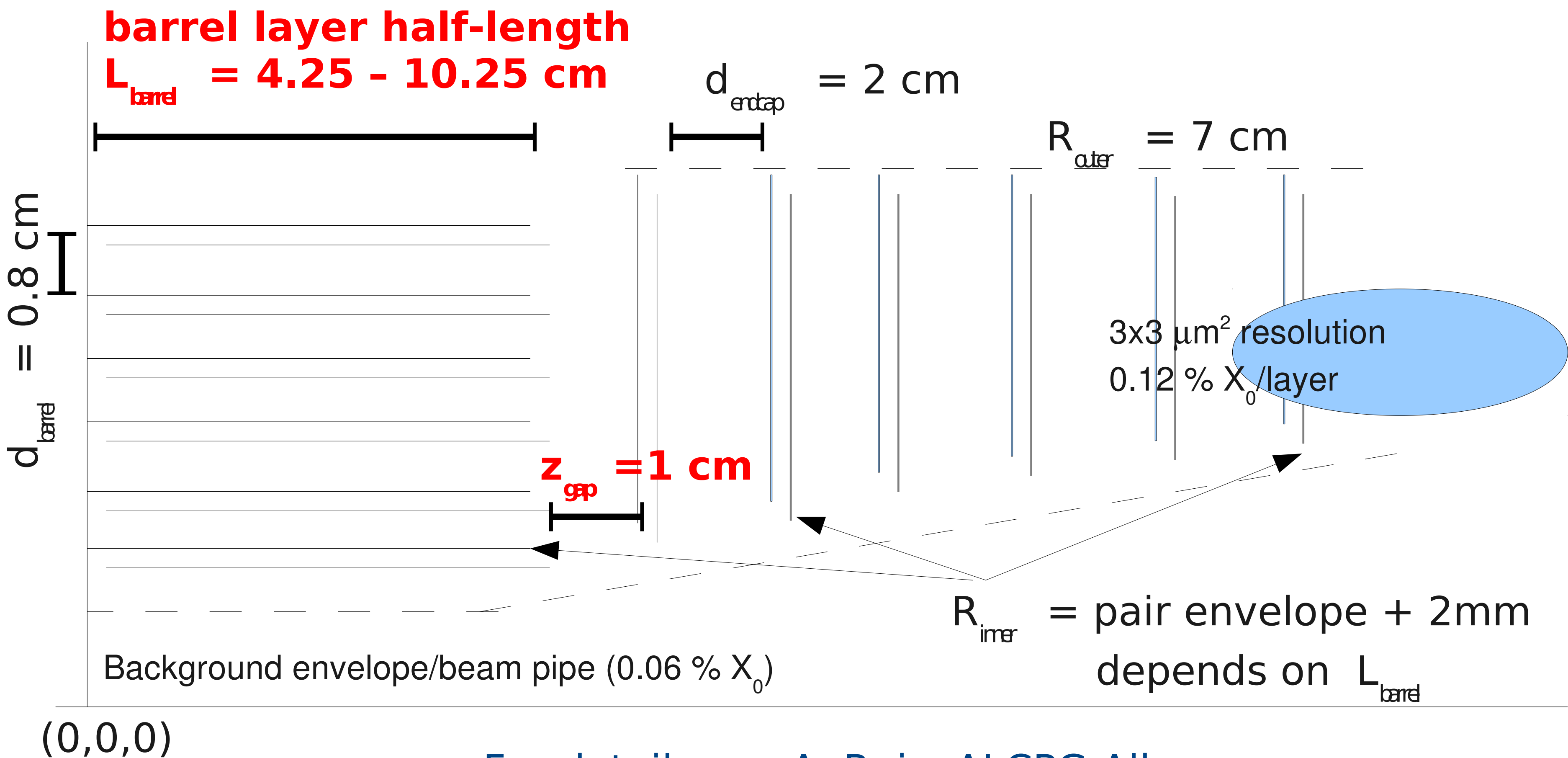
Interfaced to MarlinReco (GEAR geometry, LCIO hits)



pull distribution R ϕ coordenate at last measurement plane


LCDTRK vs. KF: Transverse impact parameter resolution vs p_T

Choosing a toy geometry

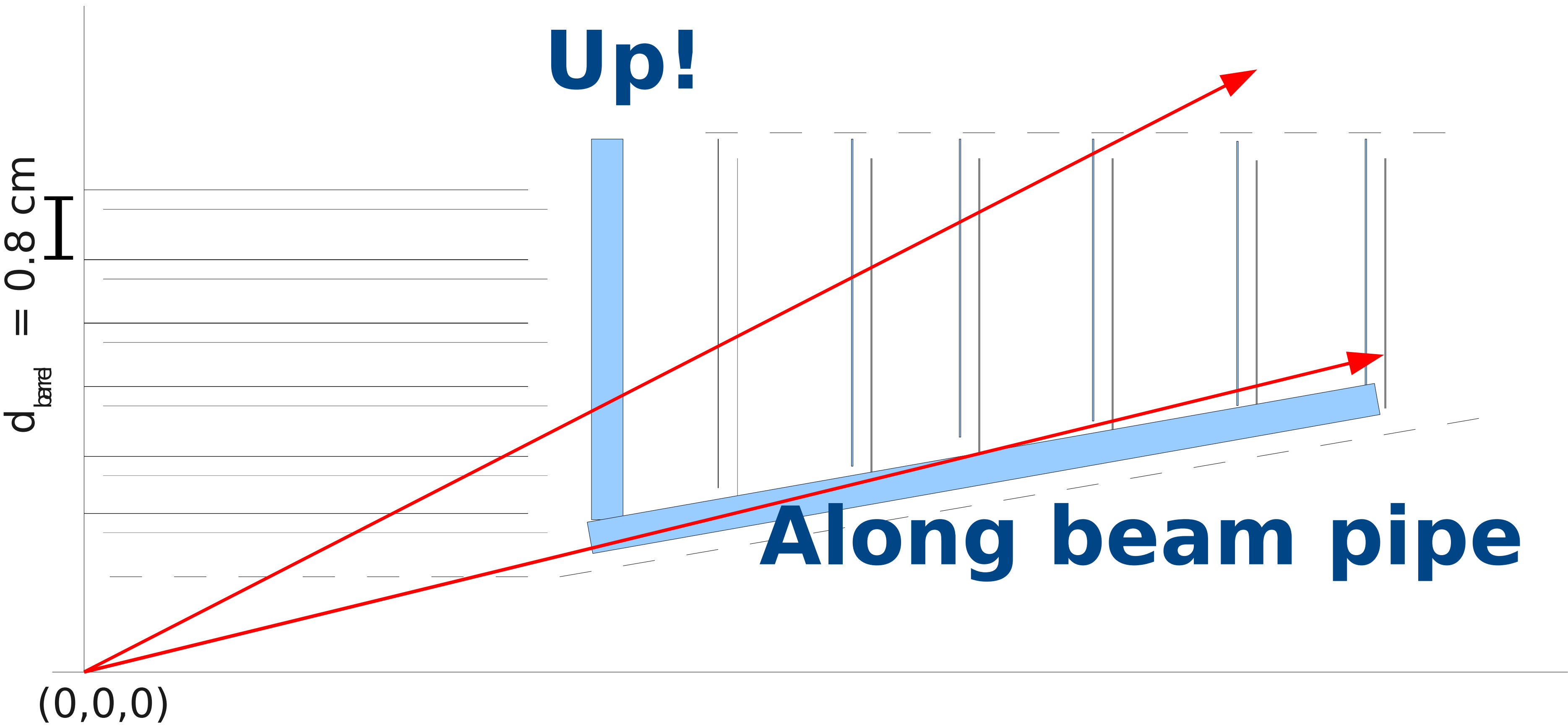


For details see A. Ruiz, ALCPG Albuquerque

SiD: L_{barrel} ~ 6.25 cm, z_{gap} ~ 1 cm

ILD: L_{barrel} ~ 12.5 cm, z_{gap} ~ 10 cm

Choosing a toy geometry



Add 3 % X_0 (on perpendicular crossing) of barrel VXD services

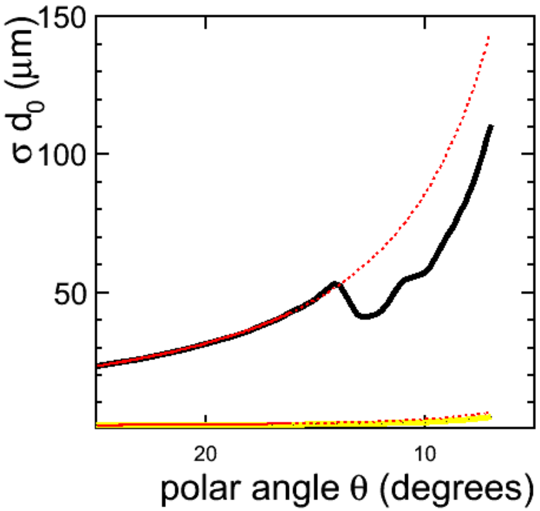
Two routing options

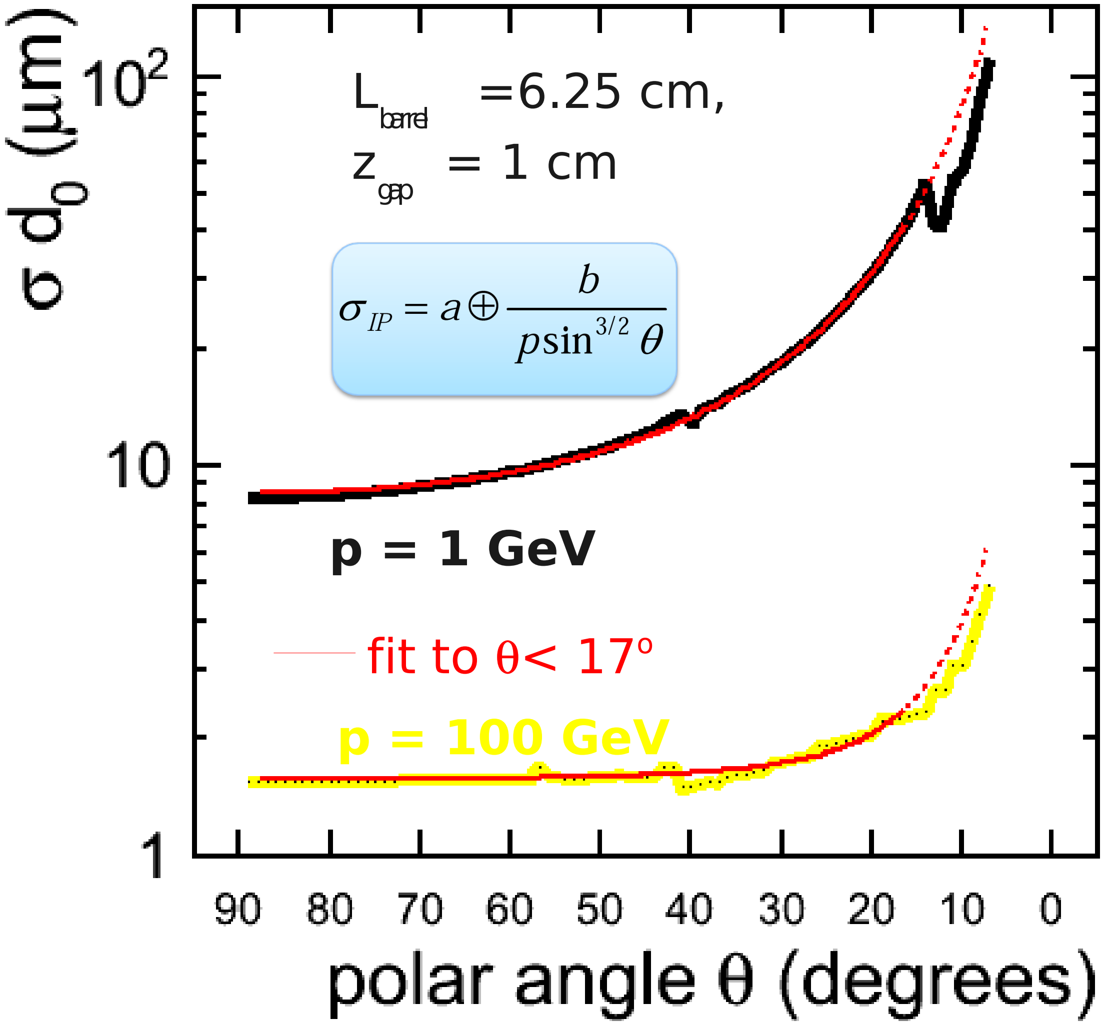
Transverse impact parameter resolution

Transverse impact parameter resolution vs. polar angle

Barrel-dominated part well-described by the standard formula.

Deviations in the very forward region (as expected)

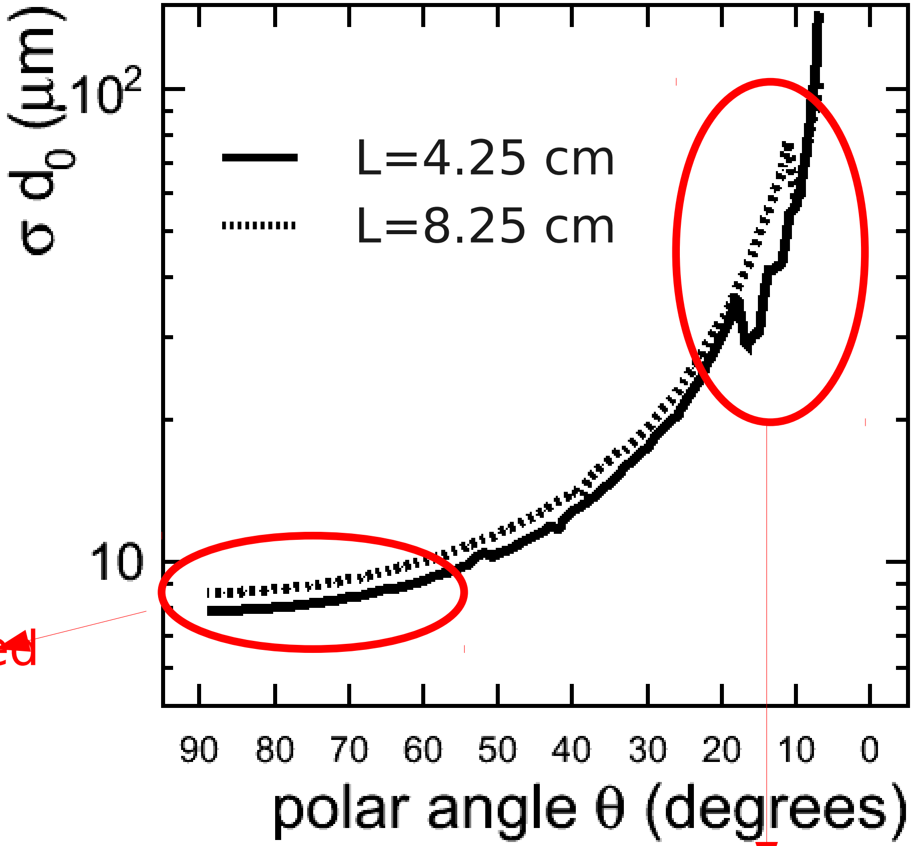




Comparison of different layouts

Longer barrel
→ worse performance

But, let's repeat with material for barrel services



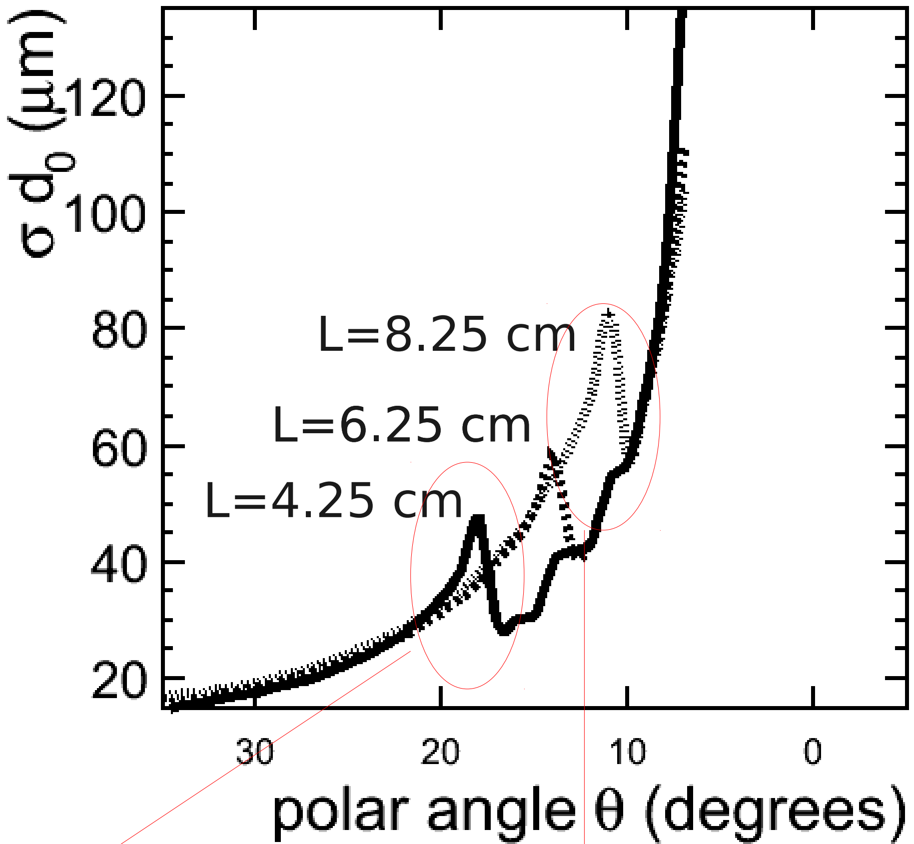
Central performance degraded due to larger radius

Barrel-endcap transition moved to smaller angle

Comparison L_{barrel}

A longer barrel removes the "material bump" from the central region...

Of course, the material comes back - with a vengeance – at smaller angle



Save a little here....

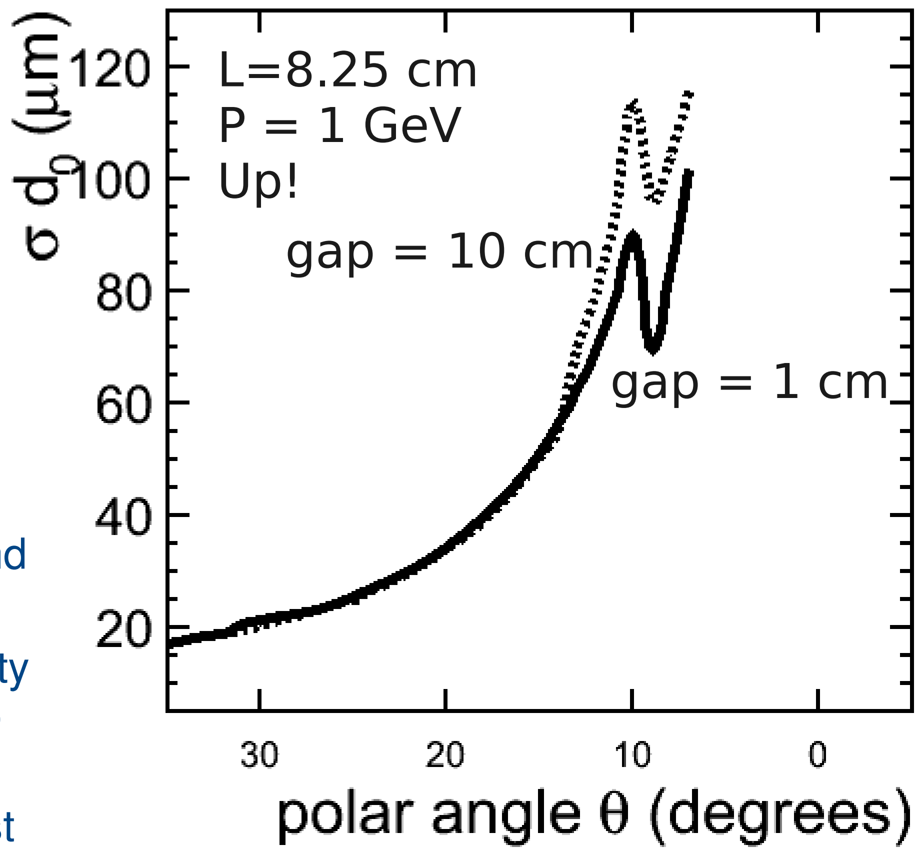
Large distance, shallow angle

Comparison z_{gap}

Minimize the gap! *

But: if we route the services along the beam pipe, the forward vertexing performance is terrible and essentially insensitive to z_{gap}

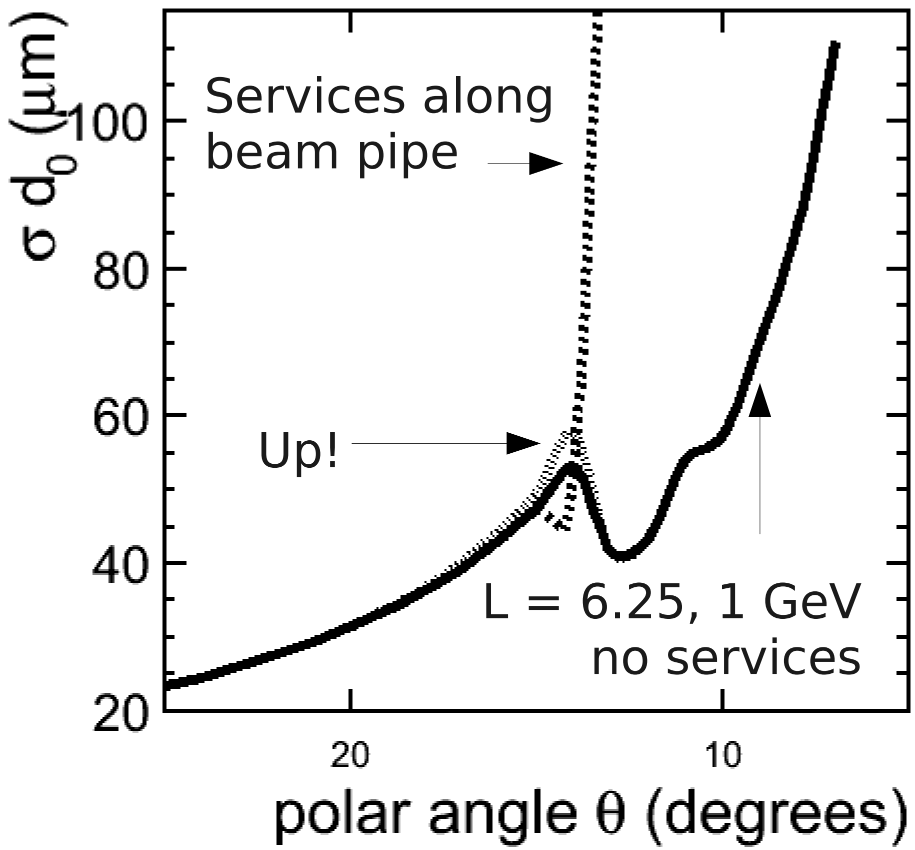
* In ILD the distance between VXD and innermost FTD is close to 10 cm. This clearance is motivated by the possibility to fit in a VXD cryostat. If a "cold" VXD technology is chosen, a short gap implies one has to install the innermost disks inside the cryostat.



Up! or along beam pipe?

The forward region clearly does NOT like the services routed along the beam pipe

If anything close to a few radiation lengths comes in the way between endcap and interaction point we can forget about forward vertexing



CLIC-VXD inspired by ILD

The CLIC VXD has many challenges in common with ILC:

- 3 double layers vs. 5 single layers
- Space point resolution
- Material budget
- Mechanics, cooling (?)

Some aspects have already been adapted (Andre Sailer):

- inner radius (background AND physics)
- A time-slicing device (integrating 150 BX) at the ILC becomes an integrating VXD at CLIC (integrating full 312-BX train). Background studies: many done, more to come.

Transform CLIC01-ILD in an optimal CLIC VXD

- Improved integration with FTD
- Long/very long barrel?