IDT WG3 – MDI Activities

Detector (Tracker) Alignment in ILD*

Another trip into the past

Roman Pöschl

I am grateful to **Alexandre Gonnin** (IJCLab) who has digged out the material for me
All mistakes are mine

IDT-WG3 MDI-BDS/Physis – Topical Meeting 27/1/22

*For SiD see e.g.
https://agenda.linearcollider.org/event/7014/contributions/34575/attachments/30232/45191/SiD_vtx_trk_santander16.pdf

Prologue

Lots information is taken from these documents

arxiv:2003.01116

International Large Detector

INTERIM DESIGN REPORT

The ILD Concept Group

Attached to indico page

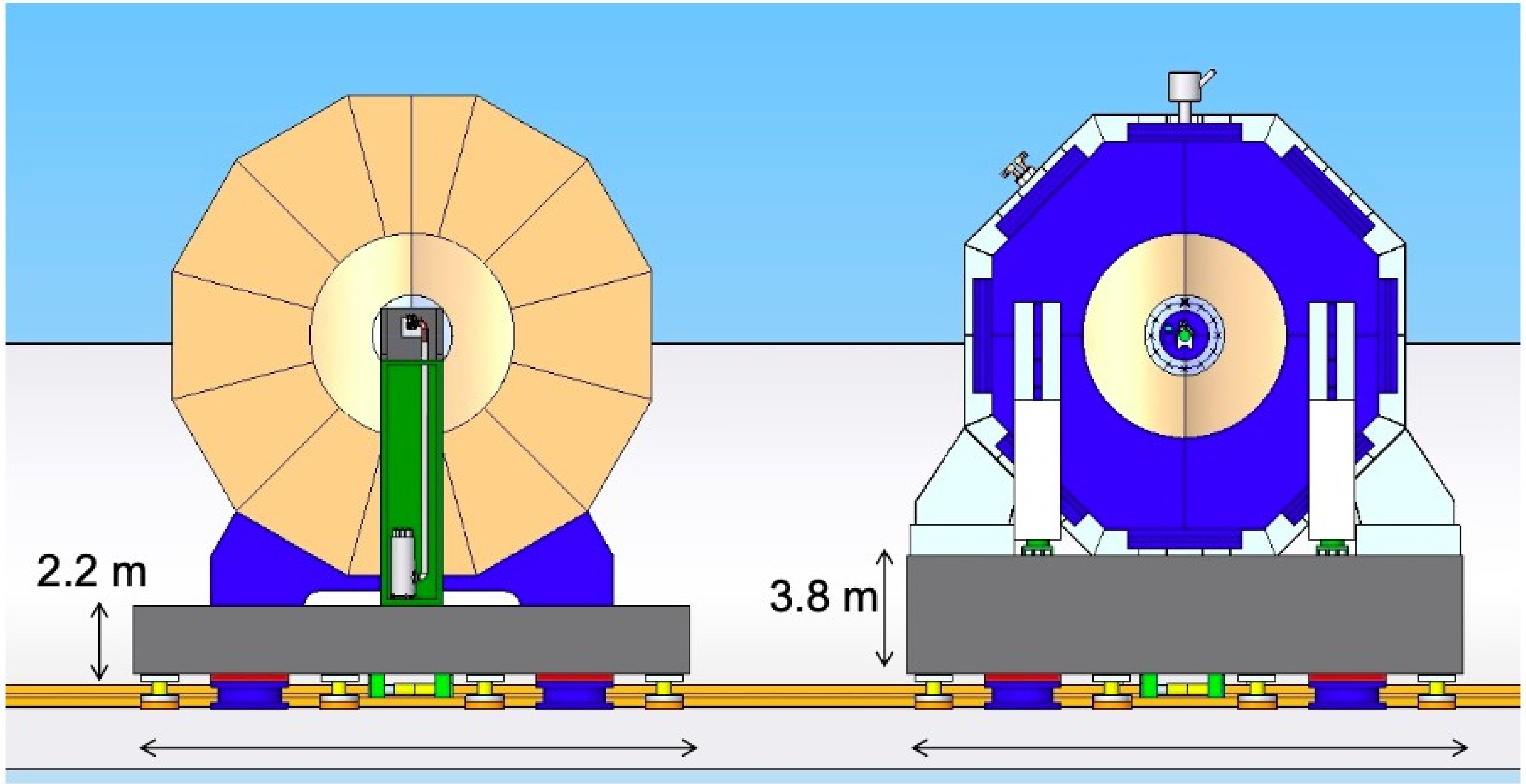
LETTER OF INTENT

Aligning the ILD Tracker:
Status Report and Answers to IDAG

The ILD concept group

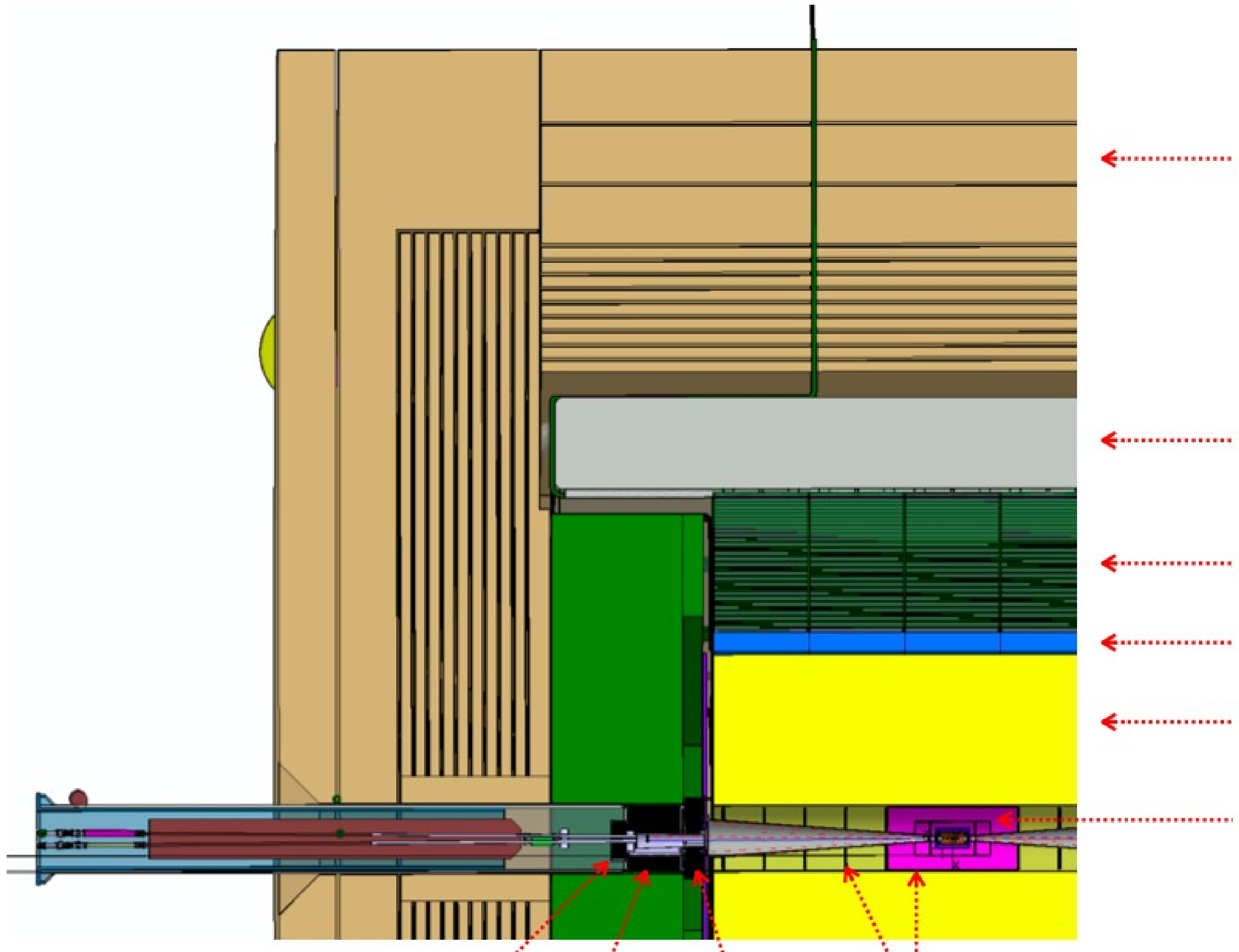
The ILD tracker alignment task force:
T. Behnke, R. De Masi, M. Fernandez, D. Gamba, D. Imbault, T. Matsuda, P. Mereu, D. Peterson, Y. Sugimoto, A. Savoy-Navarro, R. Settles, J. Timmermans, M. Vos, M. Winter, H. Yamamoto

Detector concepts and alignment



- According to the previous documents two “operation principles” have an impact on alignment
  - Push-pull operation
  - Power pulsing of detectors
- Both may require different approaches for alignment

ILD Detector



Parameters of tracking detectors

Barrel system

System	r_{in}	r_{out} [mm]	z_{max}	technology	comments	
VTX	16	60	125	silicon pixel sensors	3 double layers at $\sigma_{r\phi,z} = 3.0$ µm σ_t = 2-4 μs	$r_0 = 16, 37, 58$ mm (layers 1-6)
SIT	153	303	644	silicon pixel sensors	2 double layers at $\sigma_{r\phi,z} = 5.0$ µm σ_t = 0.5-1 μs	$r = 155, 301$ mm (layers 1-4)
TPC	329	1770 *1427*[s]	2350	MPGD readout	220 (*163*[s]) layers 1×6 mm^2 pads	$\sigma_{r\phi} \approx$ 60-100 µm
SET	1773 *1430*[s]	1776 *1433*[s]	2300	silicon strip sensors	1 double layer at $\sigma_{r\phi} = 7.0$ µm	$r = 1774$ mm $\phi_{stereo} = 7\,^{\circ}$

End cap system

System	z_{min}	z_{max} [mm]	r_{in}	r_{out}	technology	comments	
FTD	220 645	371 2212		153 300	silicon pixel sensors silicon strip sensors	2 discs 5 double discs	$\sigma_{r\phi,z} = 3.0$ µm $\sigma_{r\phi} = 7.0$ µm $\phi_{stereo} = 7\,^{\circ}$

Envisaged resolution sets boundary conditions for needs on alignment

Remark: Do focus on trackers here but I don't forget that also the calorimeters in particular The LumiCal need a "diabolic" precision (see Wolfgang's talk in earlier meeting)

Misalignment – Limits and effects

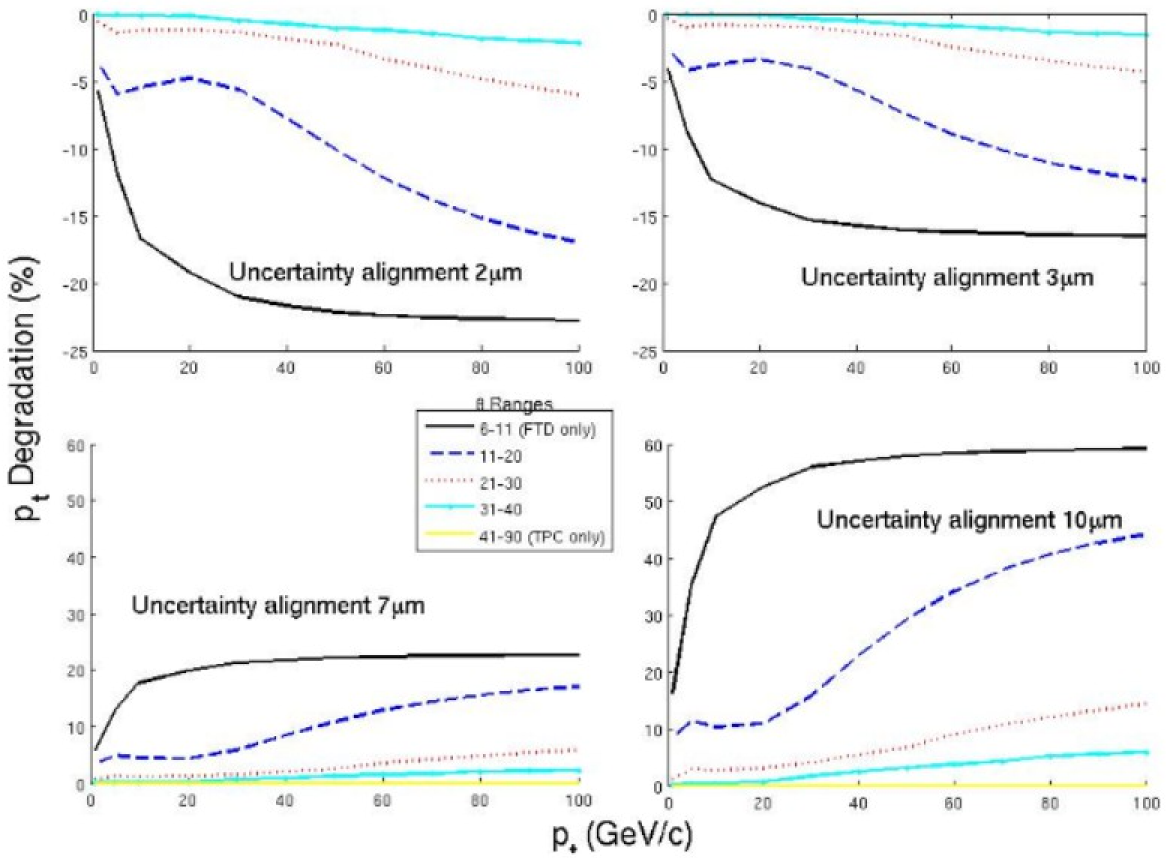
- coherent displacement of the VTX, 2.8 μm;
- coherent displacement of the SIT, 3.5 μ;
- coherent displacement of the SET, 6 μm; and
- coherent displacement of the TPC, 3.6 μm.

+ distortions that results in a sagitta in the TPC of 20um

- “Intrinsic alignment” of the detecotors has to be controlled extremely well
- Reduction of degrees of freedom from ~100000 to 26

Effect on misalignment of forward disks

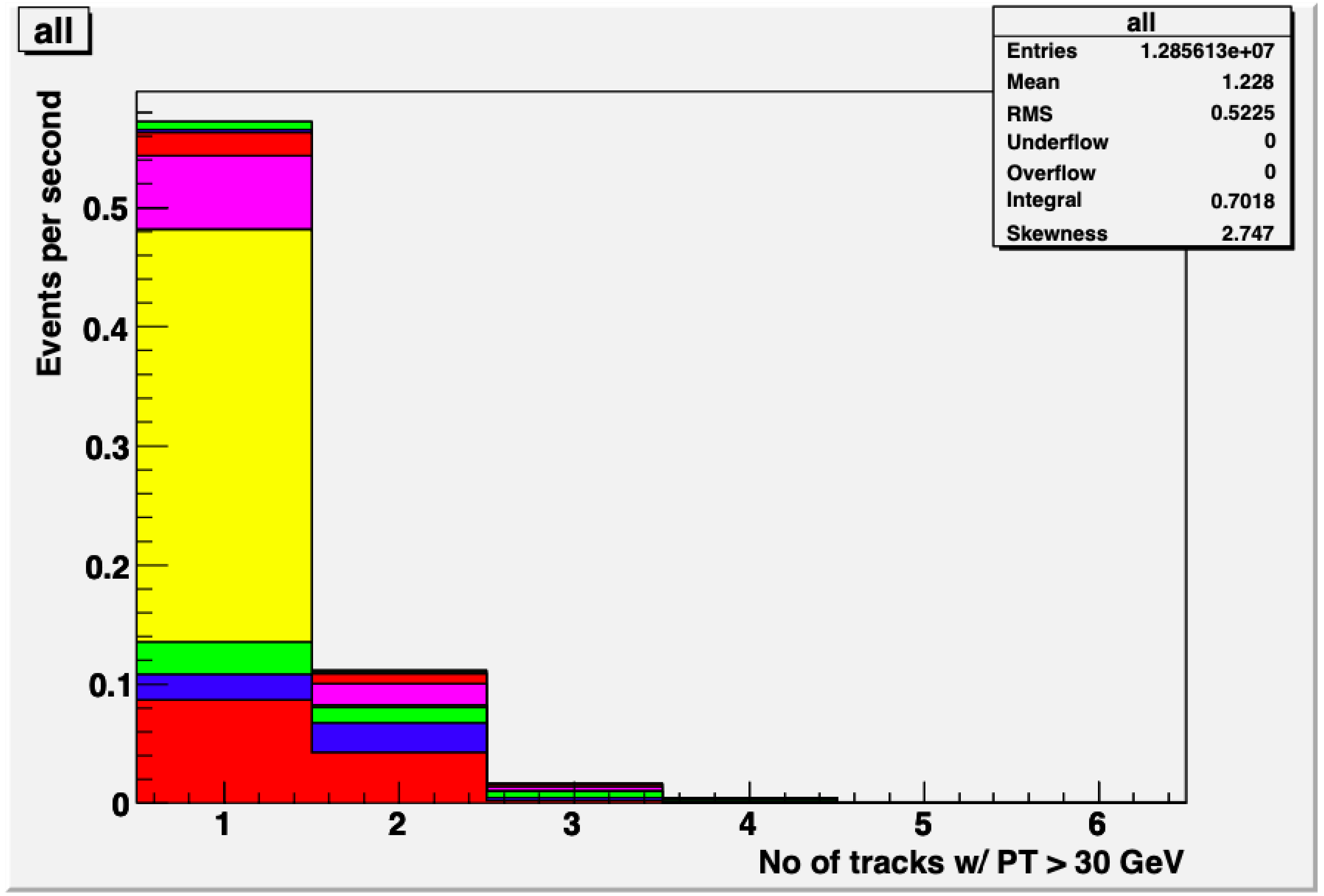
(relative to “tolerated” misalignment of 5um)



Mis-alignment +/- 2um around “tolerated” value changes track resolution by ~30%

Alignment Methods – Track based alignment

Number of tracks for 500 GeV running
(color coding see attached note)

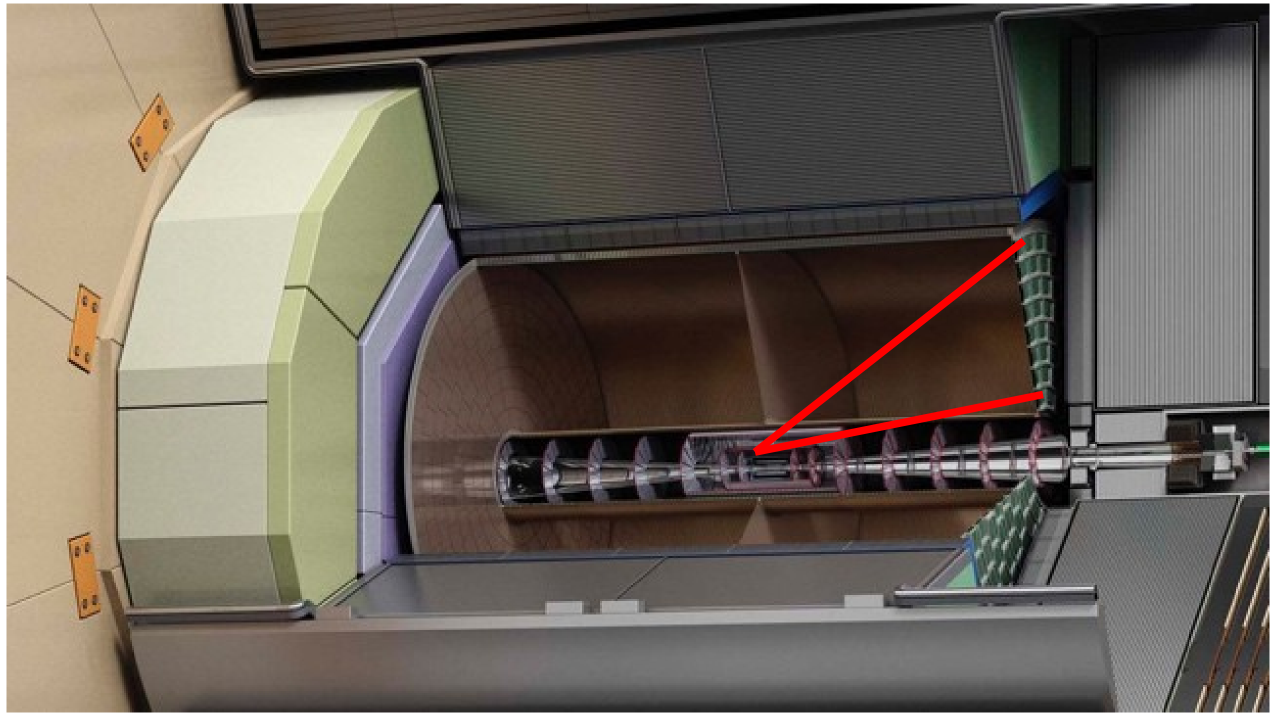


- ~10^6 tracks with p_T > 30 GeV (for L=$2x10^{34}$ $cm^{-2}s^{-1}$)
- Compare with 60000 muon pairs/running year
- At 250 GeV maybe some more but number of hard tracks should decrease
  - Needs to be studied

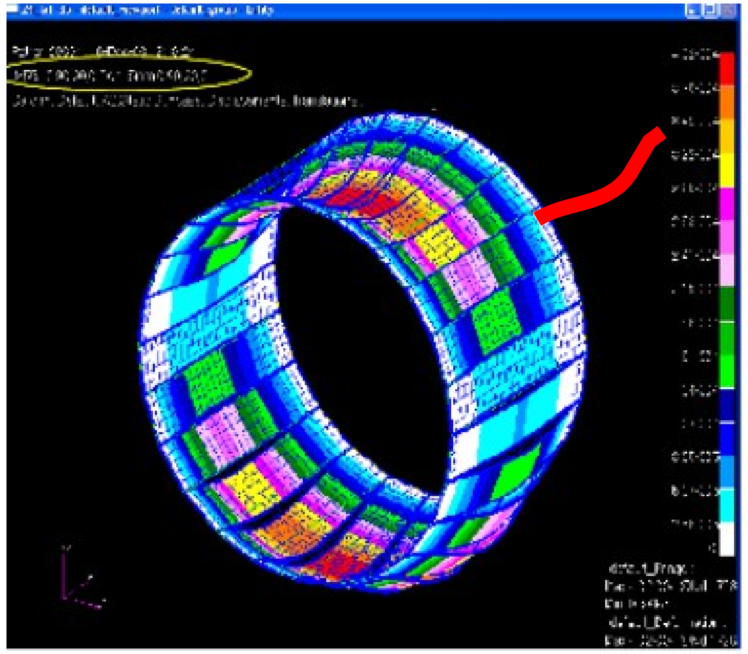
Z-pole running for alignment?

- Short (~1 day) running on Z pole after each push-pull operation
- L=1pb^{-1} <=> 30000 Z events yielding around 1000 muon pairs
  - Felt to be feasible in IDAG Document
- Caveats
  - Not enough for full calibration
  - Requires that machine can switch quickly between Z pole running and nominal running

Alignment Methods – Laser based alignment



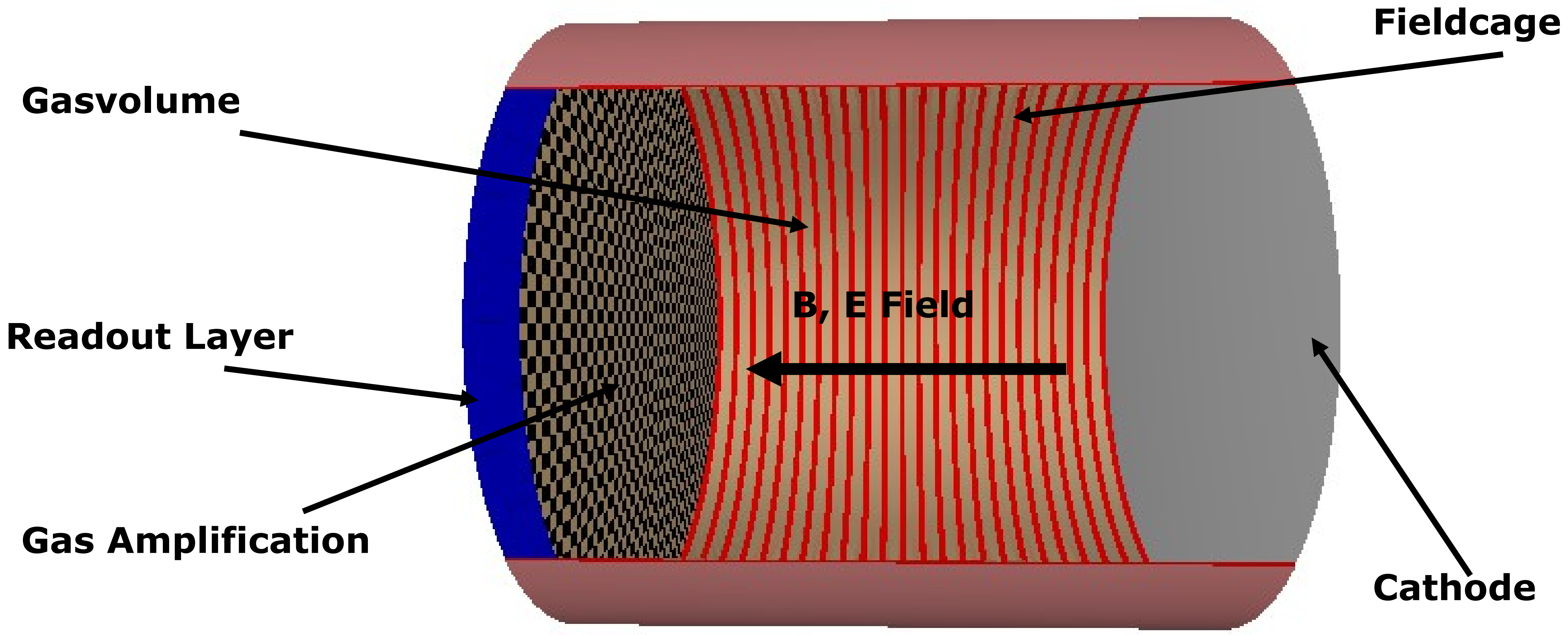
- Laser Based System
- Crosses layers in inner silicon dectors
- Require special pixels in outer silicon detectors



- Fibre Bragg System to monitor deformations

- Optical alignment system have to receive a a special attention due to the limited capacities for track based alignments
- They have to react quickly (Order of seconds) to impact during push-pull and on power pulsing
- The integration of the alignment system requires skillful engineering work
- Misalignment can compromise the precision measurements
  - Corrective measures if a misalignment is measured?

Alignment Methods – Alignment of ILD TPC



- TPC components can be manufactured to a precision of 60um and better
- Laser system to mimick straight tracks
- Light shone on cathode surface to create a charge pattern with the help of an appropriate coating
- Don't forget that a precise field mapping of of B-Field is required dB/B ~10^{-4}

Summary and outlook

- Short and for sure highly incomplete overview on ideas and studies on the alignment of the ILD Detector
- Alignment strategy needs to take push-pull and power pulsed operation into account
- Limited possibilities for track based alignment
  - Relatively small statistics
  - Alignment with Z-Pole events requires flexibility of machine
- Precise and fast reacting optical alignment systems will become of paramount importance
- The capability to align the detectors after push-pull will have an impact on the operation mode of the Project
- News: The preparation of today's meeting brought us in contact with Armin Reichold (Oxford)
  - Achim developed and commercialised an alignment system for ATLAS and has recently implemented an alignment system at FAIR (I don't know details at the moment)
  - Meeting with Achim on Feb. 2nd 5pm CET
  - Thanks to Tom and Phil for having established this contact

Backup