WG3 MDI BDS/Phys. Meeting series
Brief summary and the way ahead

Roman Pöschl

IDT WG3 BDS/Phys Summary Meeting – February 20

Prologue

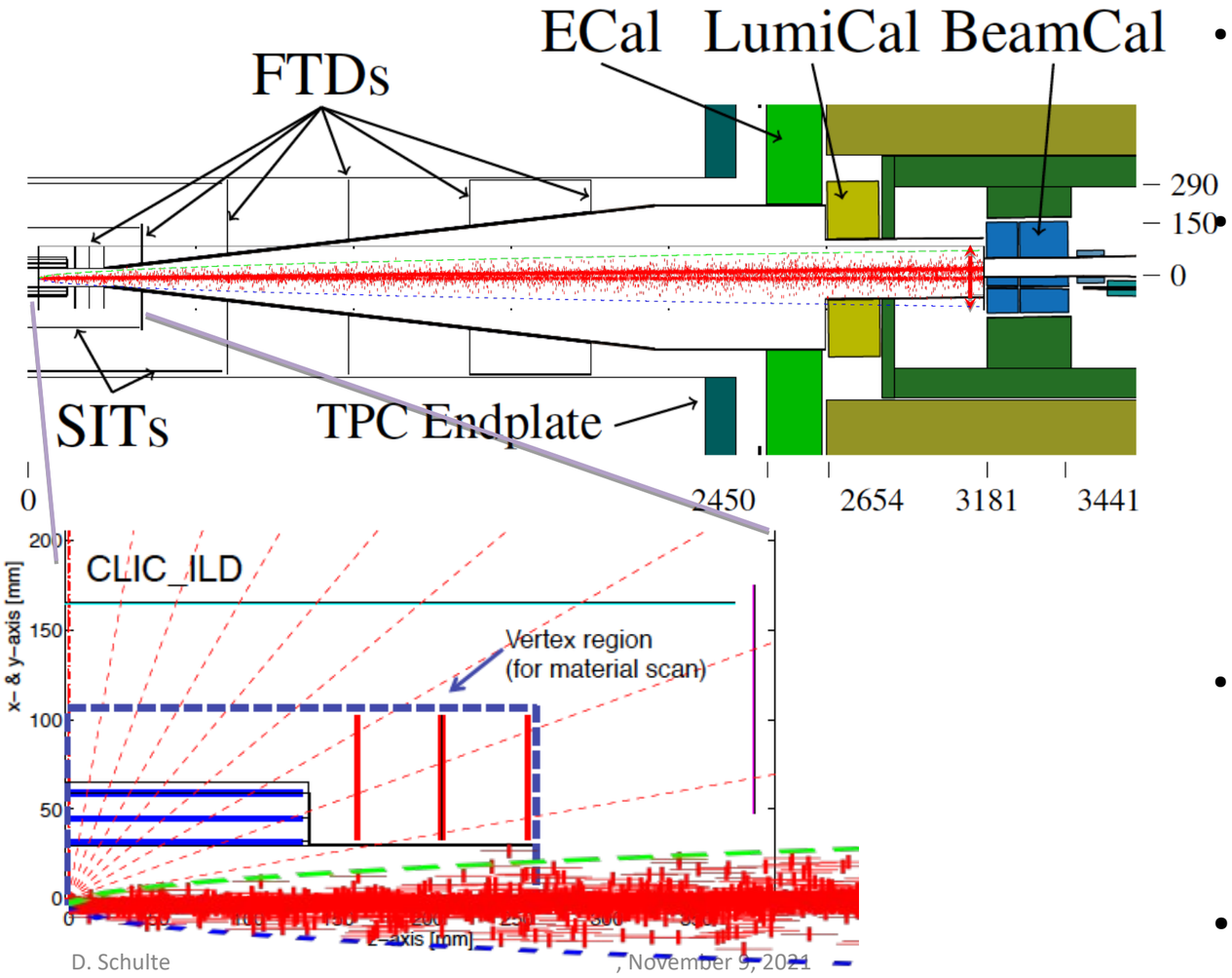
- We are at the end of a meeting series that revisited (still non-exhaustively) results/work relevant for MDI BDS/Physics issues
- Allow me to thank the participants and those who gave presentations, asked questions animated discussion
  - This turned this series into a quite successful event
- Let me also thank the “Core Team” Jenny, Benno, Claude, Karsten, Tom and Yasuhiro for their guidance during the last months.
- Today I will focus on the meetings at and after the ILCX and in particular on the way ahead

MDI-BDS/Physics – Meeting calendar and topics

- 17/9/21 – Layout of MDI region
- 30/9/21 – Software for and precision of/for background studies
- 14/10/21 – L*
- 26/10/21 - Intermediate report at ILCX
  - https://agenda.linearcollider.org/event/9211/contributions/49151/
  - Recommend to look also at “Lessons learned” session at ILCX
  - https://agenda.linearcollider.org/event/9211/sessions/5269/#20211027
- 25/11/21 – Beam calorimeters
- 09/12/21 – Beam pipe and vertex detectors
- 06/01/22 - Polarimetry and beam energy measurements
- 13/01/22 – Beam dump and detector magnets
- 27/01/22 – Detector alignment after push pull
- 10/2/22 – Summary session
- 11/02/22 – ...
  - Concluding phase

- https://agenda.linearcollider.org/category/270/
- 25 talks
- ~40 people on mailing list
- Average attendance of meetings: 15 people

All belongs together ...

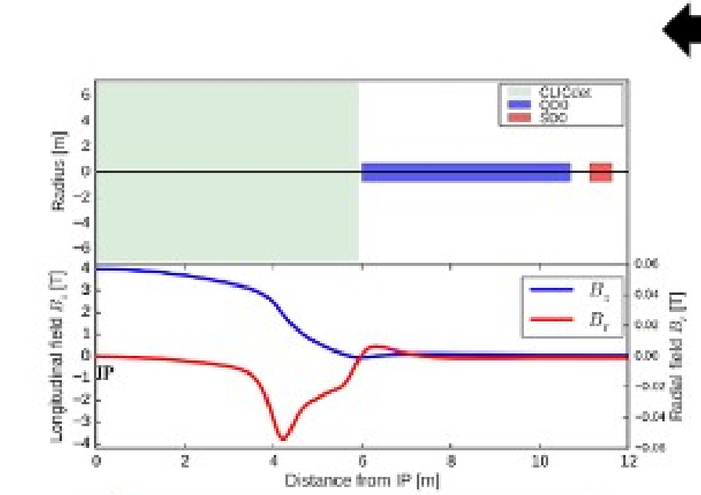


- Summary plot from D. Schulte talk on Guinea Pig
- Guinea Pig is our working horse for background studies and actively supported
  - Support “ensured” by ECFA Higgs Factory Study/Muon Collider
- Guinea Pig includes
  - Pinching of the beams
  - Emission of beamstrahlung
  - Initial state radiation
  - Production of incoherent pair background
  - Bremsstrahlung
  - Beam size effect
  - Production of coherent pair background
  - Production of hadronic background (also minijets)
- GUINEA-PIG++ (maintained?) also includes
  - Beam polarisation
  - Trident cascade process
  - but no hadrons
- Observations
  - Background limits vertex detector
  - Defines forward region detectors

D. Schulte , November 9, 2021 4

Update of the CLIC 3 TeV performance including the detector solenoid effects

- Tracking procedure in PLACET* including the detector solenoid map



→The beam is first tracked forward without SR, and without the solenoid field present (1).

→The ideal IP beam distribution is tracked backwards through the beam line, with the solenoid field turned on but still without SR (2).

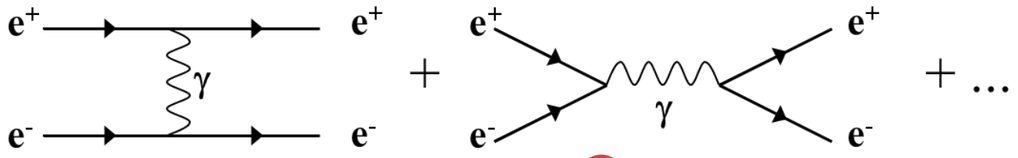
→Finally, the SR is turned on, and the beam is tracked forward through the solenoid (3).

* Y. Inntjore Levinsen, B. Dalena, R. Tomás, and D. Schulte. «Impact of detector solenoid on the Compact Linear Collider luminosity performance». Phys. Rev. ST Accel. Beams 17, 051002 – Published 27 May 2014; Erratum Phys. Rev. ST Accel. Beams 17, 079901 (2014)

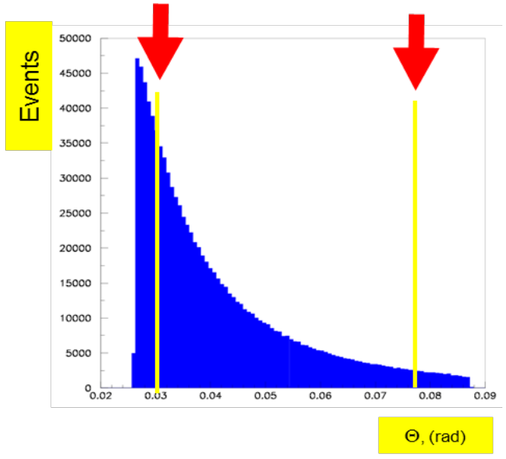
Luminosity measurements

Bhabha scattering at low polar angles is used as a gauge process

e+e- ⟶ e+e- (γ)



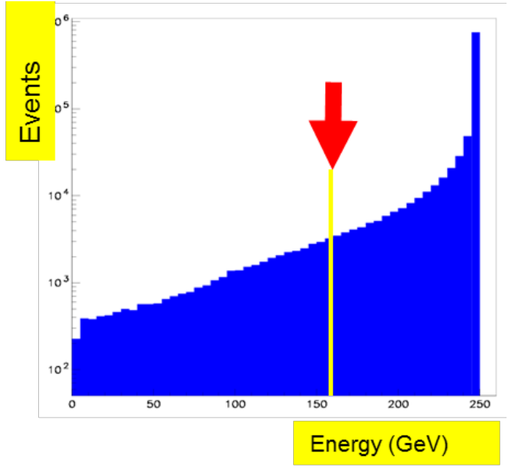
$$\frac{d\sigma_B}{d\theta} = \frac{2\pi\alpha_{em}^2}{s}\frac{\sin\theta}{\sin^4(\theta/2)} \approx \frac{32\pi\alpha_{em}^2}{s}\frac{1}{\theta^3}$$



$\mathcal{L} = N / \sigma$

Count Bhabha events

From theory



Theory uncertainties at higher energies at ILC/CLIC (S. JADACH, FCAL workshop Cracow **2006**):

...for polar angle range 25 – 100 mrad:

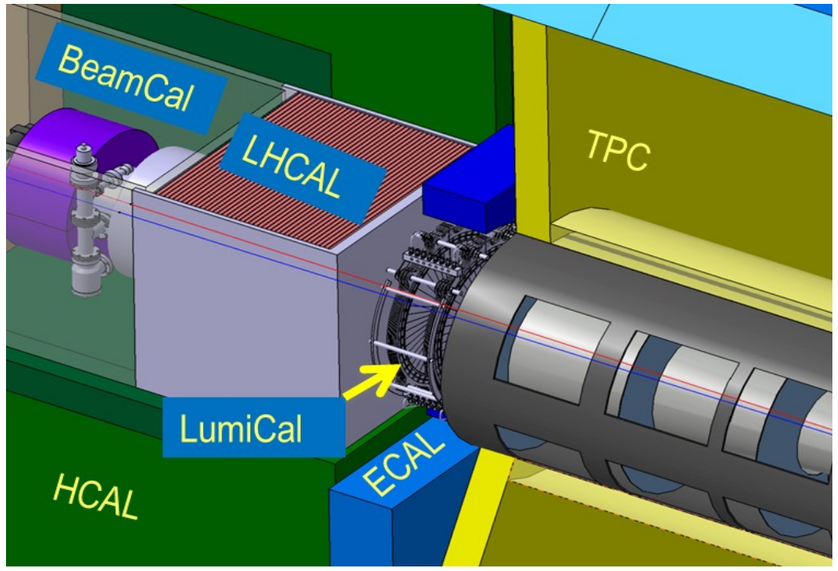
- Hadronic vacuum polarisation
- QED photonic corrections
- EW corrections to Z (t-channel)
- Light fermion pairs

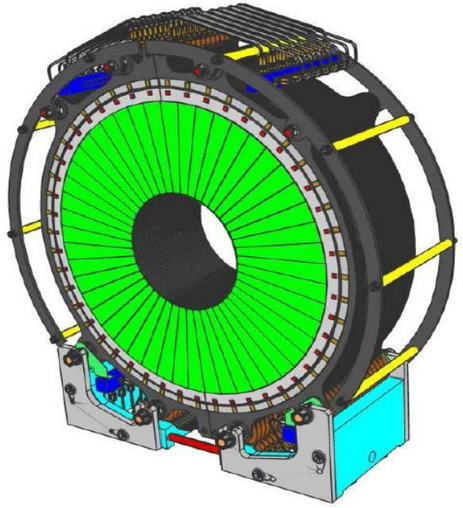
Further challenges: Beamstrahlung – luminosity spectrum

- Precision of luminosity is open question
  - General feeling is dL/L ~10^{-3} in continuum
  - At least Z-pole running would require better precision

This slide represent the need for theoretical input and the need of tight interplay with physics studies

Luminosity measurements - Detectors





LumiCal

- Si or GaAs/W sandwich calorimeters
- Compact (small Moliere radius)
- Thin detector planes
- W plates, 1 X_0 thick, highly planar

Recent (=last years to now) developments

- Beam tests with prototypes
- Development of dedicated front end electronics (FLAME ASIC)
- Able to “digest” high event rate during ILC bunch trains
- Detector developments continues in frame of LUXE Experiment at DESY
- Similar observation hold for BeamCal (see next slide)

- Strong theta dependance requires precise alignment of detectors

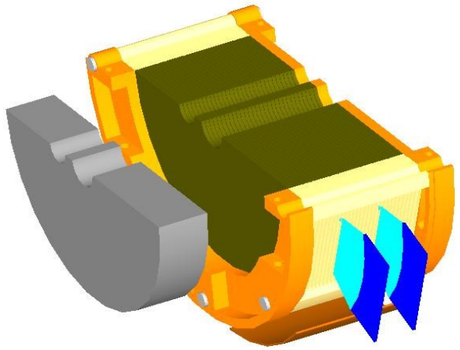
- Comment during sessions:
  - Bunch-by-bunch luminosity would be very useful tool

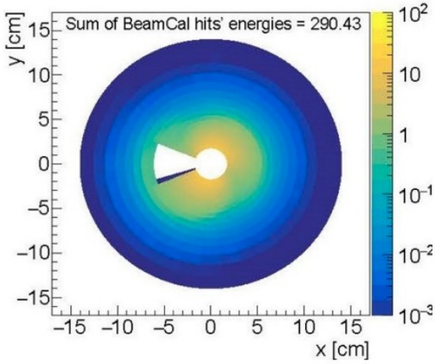
W. Lohmann/M. Idzik/V. Ghenescu

Beam diagnostics

Detectors

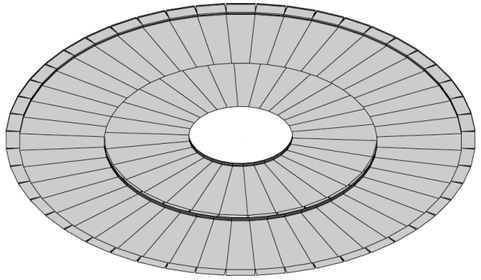
Beamcal *W. Lohmann/M. Idzik/V. Ghenescu*

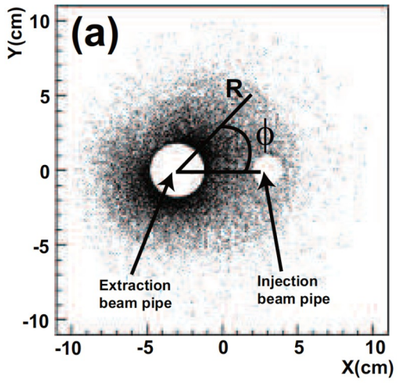




"Similar" to lumical

Pair Monitor





Silicon disk in front of Beamcal

H. Yamamoto

$$O_{\text{meas}} = \mathbf{M}^{(1)} \cdot (P_{\text{act}} - P_{\text{nom}}) + O_{\text{nom}}$$

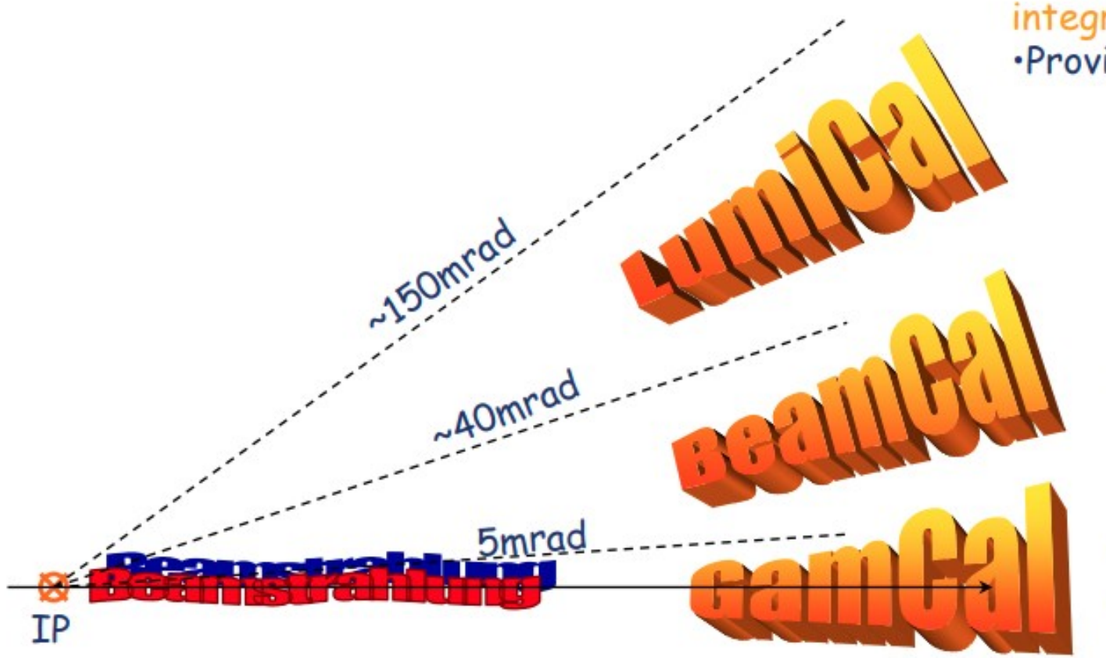
Measurement — Parameters

Parameters to be measured:

- $\sigma_x, \sigma_y, \sigma_z$ — bunch sizes in x, y and z
- $\varepsilon_x, \varepsilon_y$ — emittances in x and y
- $\Delta x, \Delta y$ — beam offsets in x and y
- W_x, W_y — waist shifts, horizontal and vertical
- α_h, α_v — bunch rotations in horizontal and vertical planes
- ϕ — bunch rotation around the beam axis
- N — number of particles per bunch

- Questions:
  - Single vs. Multi-parameter determination
  - Can modern tools e.g. machine learning help to improve the measurements?

Forward region Summary



•Precise measurement of the integrated luminosity ($\Delta L/L \sim 10^{-4}$)
•Provide 2-photon veto

Covered

•Provide 2-photon veto
•Serve the beamdiagnostics using beamstrahlung pairs
Complemented by Pair Monitor

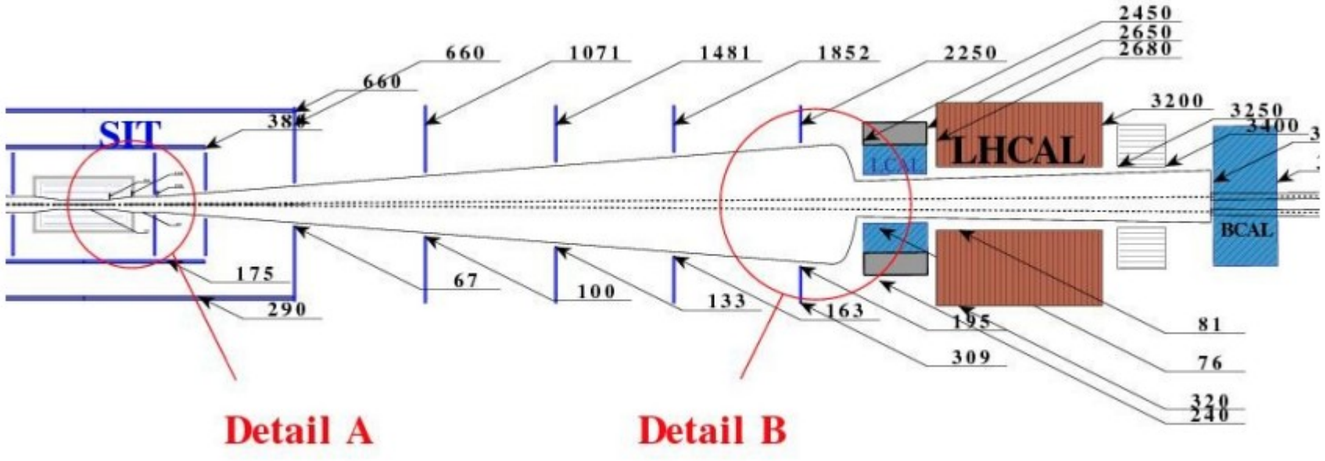
Covered

•Serve the beamdiagnostics using beamstrahlung photons

Entirely uncovered

Cartoon: C. Grah 2007

Beam pipe (of ILD)



- Mechanical model from 2009 (Videau, Anduze, Joré):
  - Beryllium, thickness between 0.5 and 1.5 mm
  - Total weight 4 kg
  - Max displacement 30um
  - Von Mises constraint 30MPa
  - Buckling safety factor 6
  - Ambitious design, requires serious R&D
    - ,,, that nobody did since 2009

Beam pipe design with vacuum pump that was removed after change to L*=4.1m
Dedicated (engineering) studies on consequences for vacuum in 2015

- Beam pipe cone acts as RF cavity
  - ... and can dissipate heat into material, estimation from 2009 20-24°C
- Air cooling seems to be ok but requires revision
  - Belle II or FCCee have or are imagined to have water cooled beam pipes due to synchrotron radiation
- Are there other sources of heat, should one include safety factors?
  - Note that synchrotron radiation was a problem at SLC

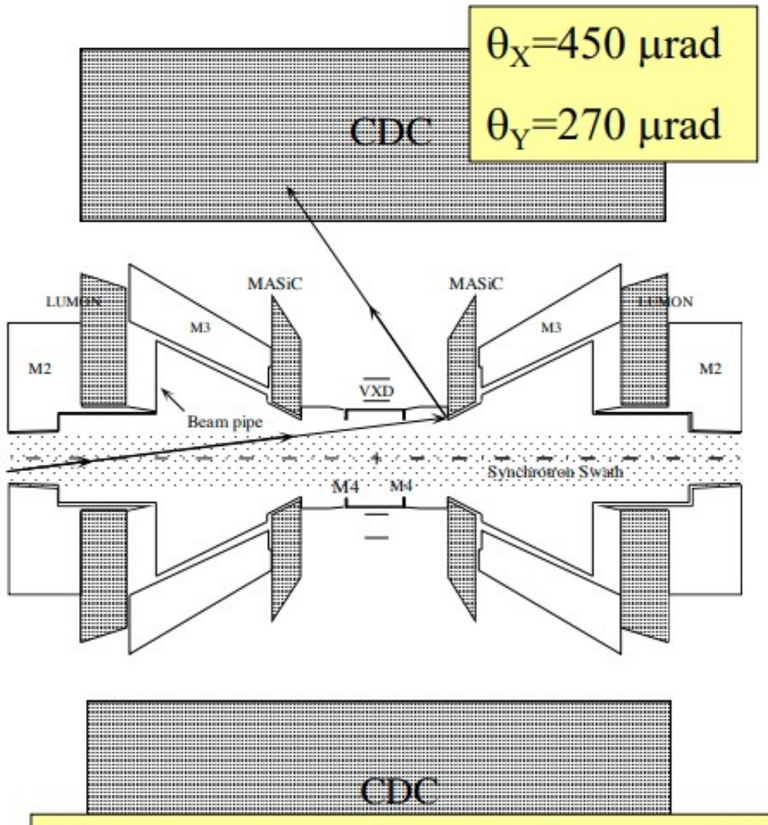
Lessons learned … Synchrotron radiation at SLD

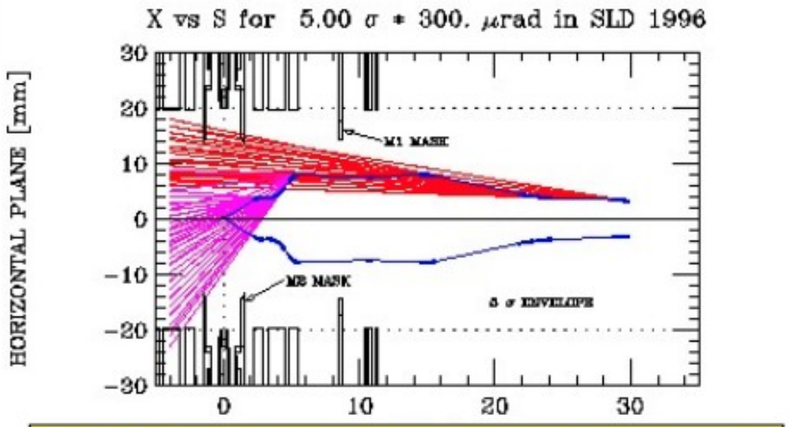
Synchrotron Radiation

At SLD/SLC SR WAS THE PROBLEM — T. Markiewicz

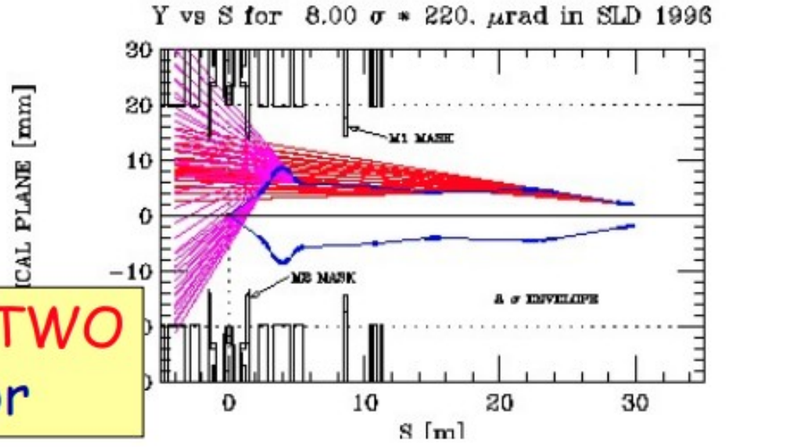
Synchrotron radiation photons from final focus magnetscould reach the detector

- minimum two bounces, but it happened…





SR Fans from Halo in Final Focus

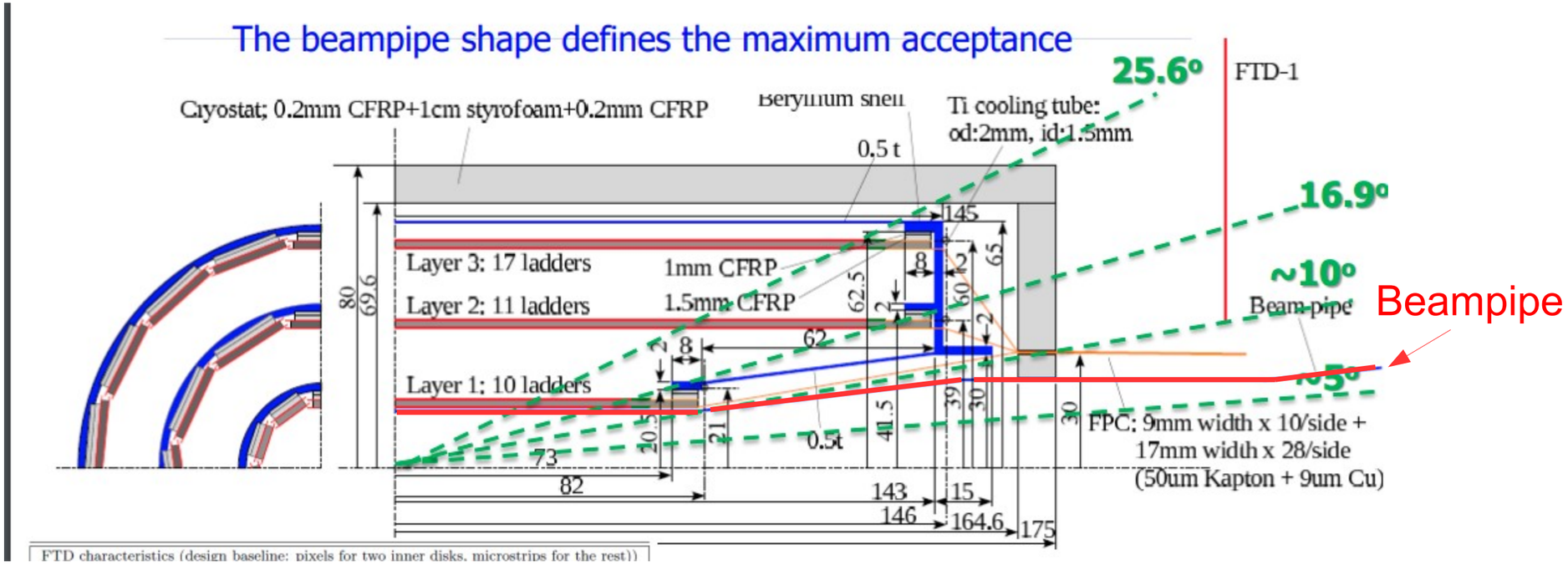


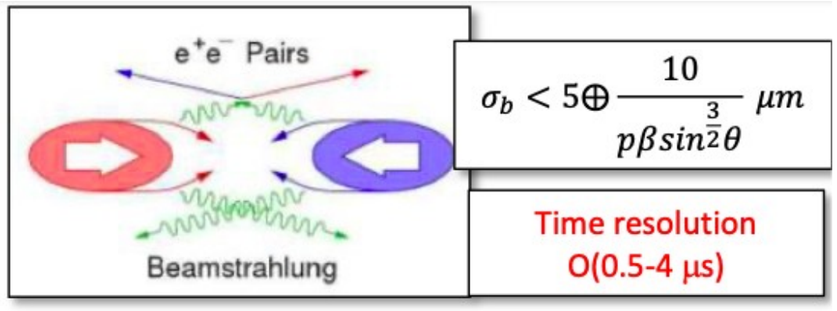
Photons need a minimum of TWO bounces to hit a detector

- Design IR Region carefully
  - Prepared for the unexpected?
- Diagnostics are critical
- Stability is paramount
- Build your subdetector with background issues in mind
  - Don't build devices which can fail catastrophically

Büßer/Markiewicz and SLD Team

Vertex detector and forward tracking





A. Besson/M. Winter

Apologises for not having invited a dedicated forward tracking talk

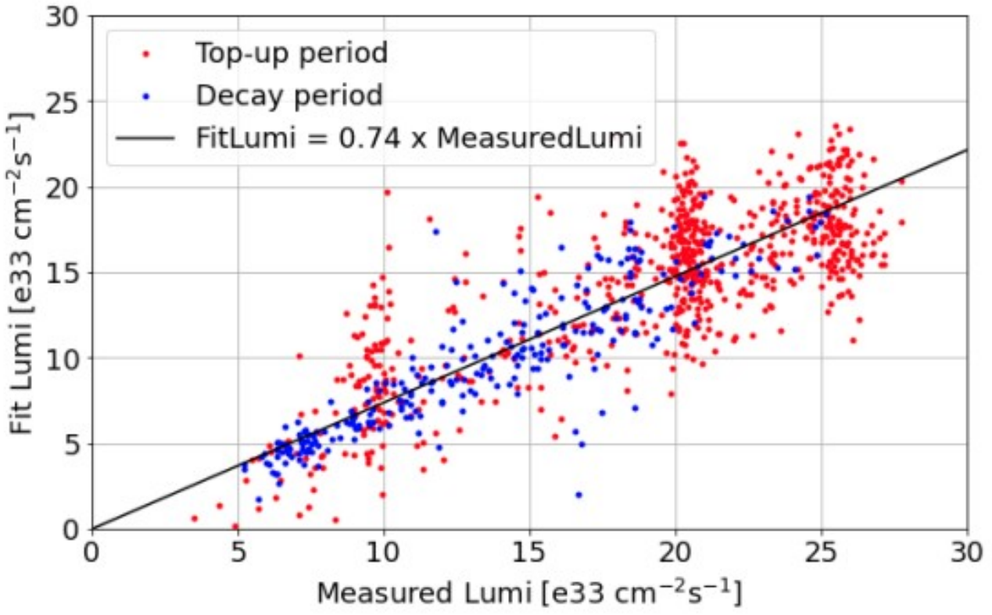
- Beam related background dominates hit rate and determines layout of vertex detectors and forward tracking
- Today few percent occupancy considered as acceptable (at time resolution of 3-4us
  - During the meeting is was pointed out that modern pixel detectors can stand high background rates than assumed so far
  - => smaller inner radius of vertex detectors and forward tracking disk(s)
- What role of the vertex detectors for determination of beam parameters?
  - At first sight rather limited since slow detector but should be revisited

Data MC/ratio for luminosity background

- FitLumi ∝ MeasuredLumi (intercept is fixed at 0)
- Average occupancy in Data = occupancy in MC scaled to fitLumi
- Average occupancy in MC = occupancy in MC scaled to MeasuredLumi
- Using the above formula,

$$\frac{\text{Data}}{\text{MC}} \equiv \frac{\text{average occupancy in Data}}{\text{average occupancy in MC}} = \frac{\text{FitLumi}}{\text{MeasuredLumi}}$$

- Data/MC = 0.74



"Real life" experience with background studies at circular machine

2022/01/06

Zihan Wang

ILC Physics targets – Energy requirements

Core Program

Observable	M_H	M_t	M_W	M_X
Method	Recoil mass	Scan	Reconstruction	Scan?
Best $\sqrt{s}$ [GeV]	250	350	250	Highest?
Current precision [MeV]	170	300	12	–
Target precision [MeV]	10	20	2	?
$\sqrt{s}$ contribution [MeV]	3	6	0.5	?
$\sqrt{s}$ uncertainty goal [ppm]	100	200	10	100?

Ultimate Impact/Reach

Observable	M_W	M_Z	Γ_Z	A_{LR}
Method	Scan	Scan	Scan	Count/Scan
Best $\sqrt{s}$ [GeV]	161	91	91	91
Current precision	12	2.1	2.3	1.9×10^{-3}
Target precision	2 MeV	0.2 MeV	0.11 MeV	3.5×10^{-5}
$\sqrt{s}$ contribution	0.8 MeV	0.2 MeV	small	1.8×10^{-5}
$\sqrt{s}$ uncertainty goal [ppm]	10	2	5*	10

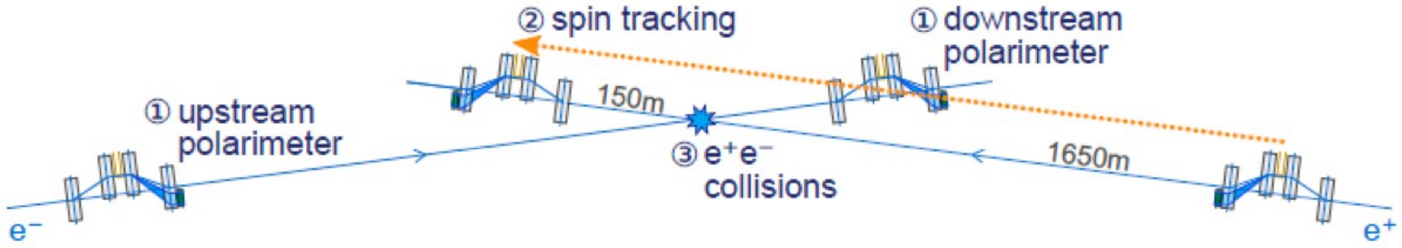
Shopping list for MDI/BDS

- Assess and plan for global energy/luminosity/ beam diagnostics analysis and insights
- Upgrade beam-beam studies/generatirs to
- Representative complete machine and variations
- thereof
- Assess and plan for ultimate beam-spot/luminous
- Region diagnostics including vertexing
- How we deal with E-z correlations?
  - Beamstrahlung depend on z-position in bunch
- Can we go beyond 100pm for energy spectrometers
  - Energy spectrometers were one of the big absents in the meeting series

G. Wilson

Polarimetry

Elements of polarimetry at ILC



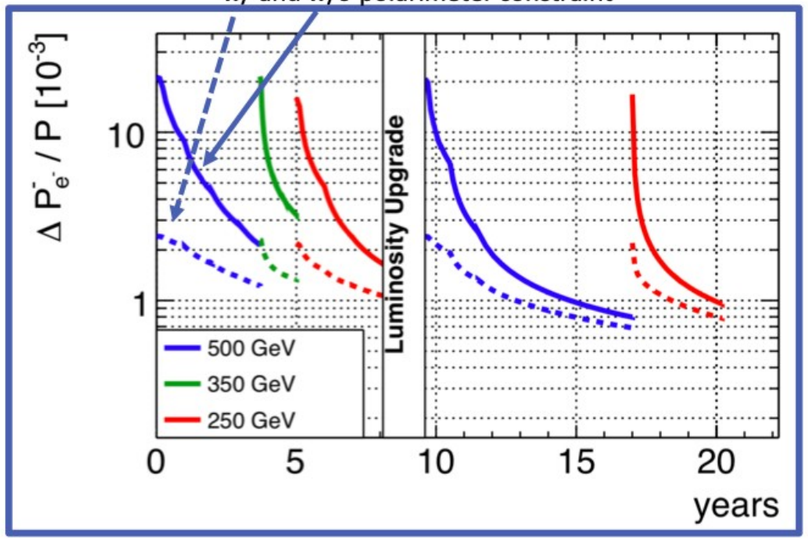
Per mill polarimetry by ...

- Compton polarimeter measurements upstream and downstream of e+e- interaction point
  - Downstream polarimetry on spent beam is major challenge
- Spin tracking to relate these measurements to the polarisation and the e+e- interaction point
- Long term average determined from e+e- collision data as absolute scale calibration

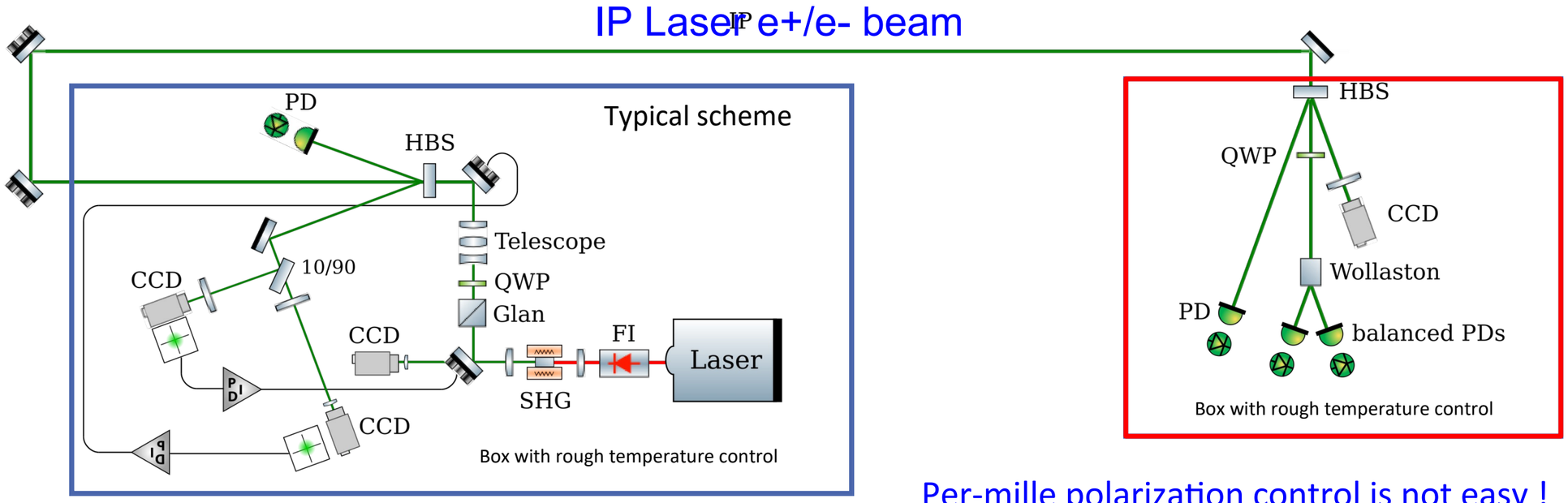
Polarisation measurement – Error budget

source of uncertainty	$\delta\mathcal{P}/\mathcal{P}$ SLC	ILC goals
laser polarisation	0.1%	0.1%
detector alignment	0.4%	0.15 – 0.2%
detector linearity	0.2%	0.1%
electronic noise and beam jitter	0.2%	0.05%
Total	0.5%	0.25%

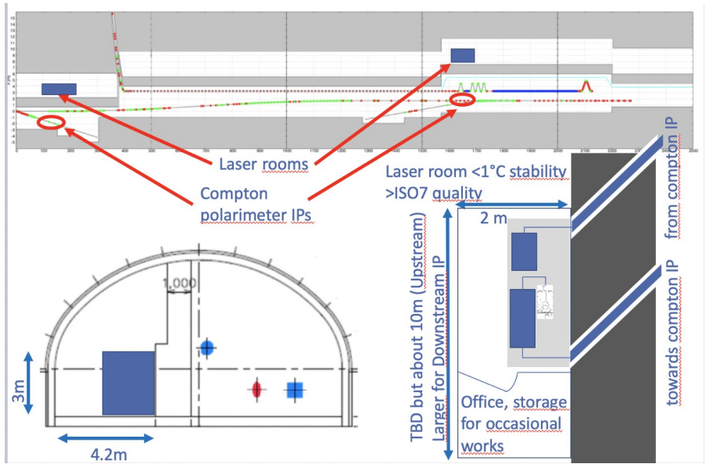
Beam polarisation determination with total x-section w/ and w/o polarimeter constraint



Laser polarisation and shaping control



Modern lasers => Laser can be put in service tunnel



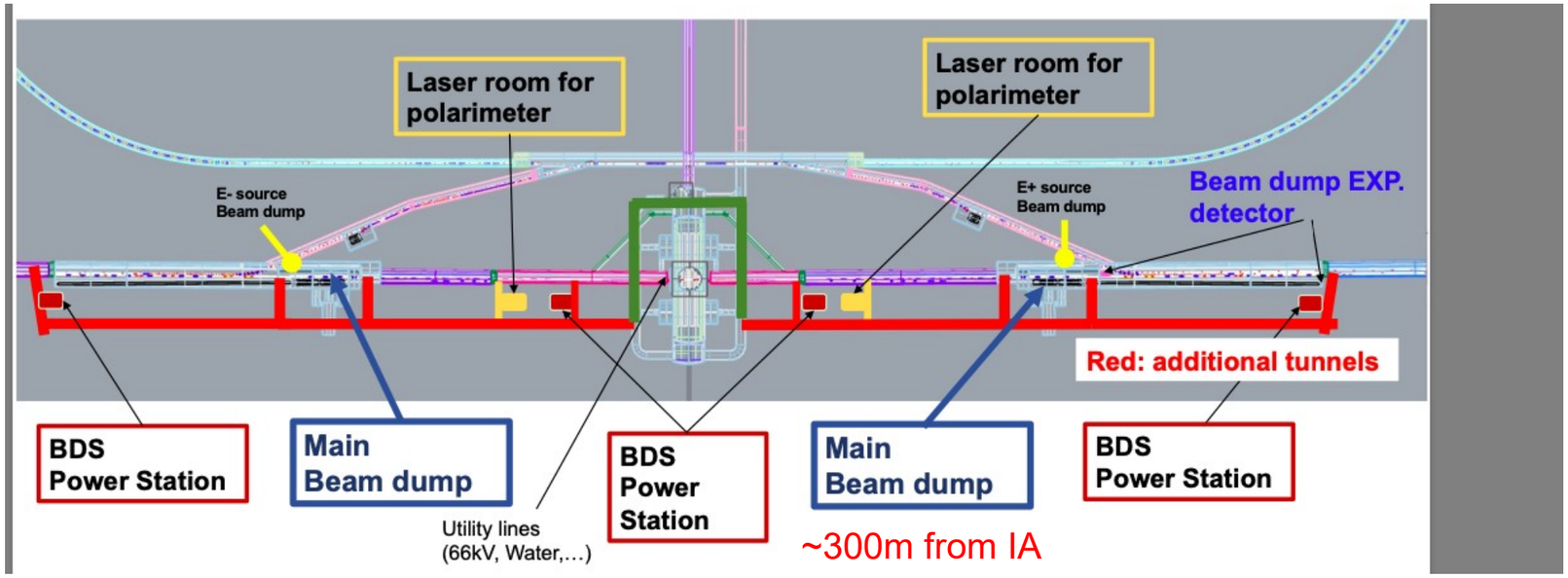
Per-mille polarization control is not easy !

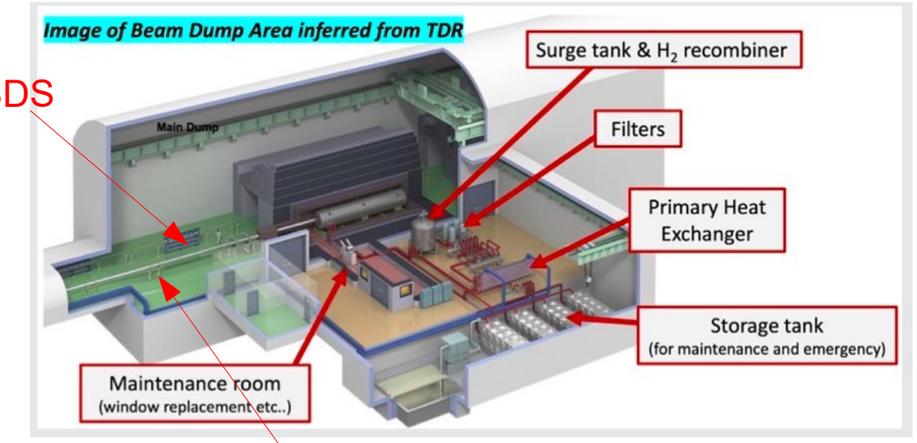
- Control optical birefringence of all optical elements
  - Mechanical stress, Temperature, Rouhgness defects,
  - Thickness defects
- Internal reflections and interferences in waveplates
- Detailed model used succesfully at HERA
- What about laser-induced thermal effects at tens of Watts ?

- Intensive R&D on laser control at IJCLab
  - ILC should/could benefit from development of polarimeter for SuperKEKB

Beam dump

Nobuhiro Terunuma





- Beam dump designed for 1 TeV, layout for 17MW of beam energy
- Most important for MDI
  - Sets constraints for BDS System, 3m concrete shield between BDS and BDS
  - Would have to be taken into account in case of change of crossing angle
  - It is a source of neutron background
    - See talk by M. Stanitzki in Kick-off meetings
    - Future studies have to follow beam dump development
    - Background studies require FLUKA which was not discussed in meeting series
      - Need expertise for ILC
- In case of beam dump experiments have to become part of MDI working group

Alignment

- 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
  - New ideas: Use also soft tracks from beam strahlung or soft hadrons for alignment,
    - In this case we would have “zillions” of events
- 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
- Meeting with Armin Reichold 2/2/22
  - Alignment has to be seen as an holistic approach and requires tight interaction between
  - the machine and the detector
  - It is a specific project on its own and it's difficult to apply concepts for e.g. LHC experiments
    - LHC has much more tracks

Next steps

- Objective
  - Seek for explicit encouragement for the continuation of MDI activities in an uncertain environment

- Actions
  - Short term: Coordinate with IDT Management
    - Input to IDT Management for ICFA Meeting
  - Medium Term: Summary of meeting series and (lightweight) workplan

- Procedure
  - Core team will ensure input to IDT Management and initial drafting of summary document
  - During drafting phase of summary document we will get in touch with experts
  - Advanced draft of summary document will be distributed to the mailing list used for this meeting series
  - Need to clarify things like authorship or simple expression of interest etc.

Summary Document – Preliminary structure and comments

- Preliminary structure
  - Introduction
  - Section 1: Layout of MDI regions
  - Section 2: IP Collision feedback and collimation system
  - Section 3: Software and precision of background studies
  - Section 4: Beam polarisation, polarimetry, energy measurements
  - Section 5: Alignment and push-pull
  - Conclusions
- The sections could form the basis of a workpackage structure
  - Remark: If your favorite topic is not among the titles don't worry all topics discussed in the meeting series will be part of the document
  - Details will be worked out in the next weeks, stay tuned

Summary of the summary

- The meeting series was a rich forum of discussion on the status of MDI for the ILC
  - ... and it allowed assembling a good fraction of today's know-how at one place
  - It was also good to see that at least some talks were given by young colleagues

- It allowed already for free thinking and development of new ideas
  - If all questions and open (and uncovered) topics would translate into studies we would have "out of the box" a rich working programme
  - Need still to identify priorities and be in phase with the general development of ILC (Linear Colliders)

- Have to document the action in a way that could serve as a first input to motivate support for MDI related work
  - .. and to allow us to react quickly if miracles happen
  - May also be input to ECFA Higgs study (and Snowmass even if late)
  - We may distinguish between ongoing work, i.e. Work that will happen independently whether there is a pre-lab or not (and where ILC related studies could sail in the wake field) and work for which the existence of a pre-lab and funding is mandatory since otherwise work is entirely stalled

- The most important thing is now to "keep the band together" (and enlargen it) in a dire phase
  - Topical meetings in case of relevant developments?
  - Will inform in any case on the status of the documentation
  - An encouragement from the IDT or even ICFA management would certainly very helpful even if it's not resource loaded
  - Explore opportunities to attract and train people

Backup