

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

Roman Pöschl



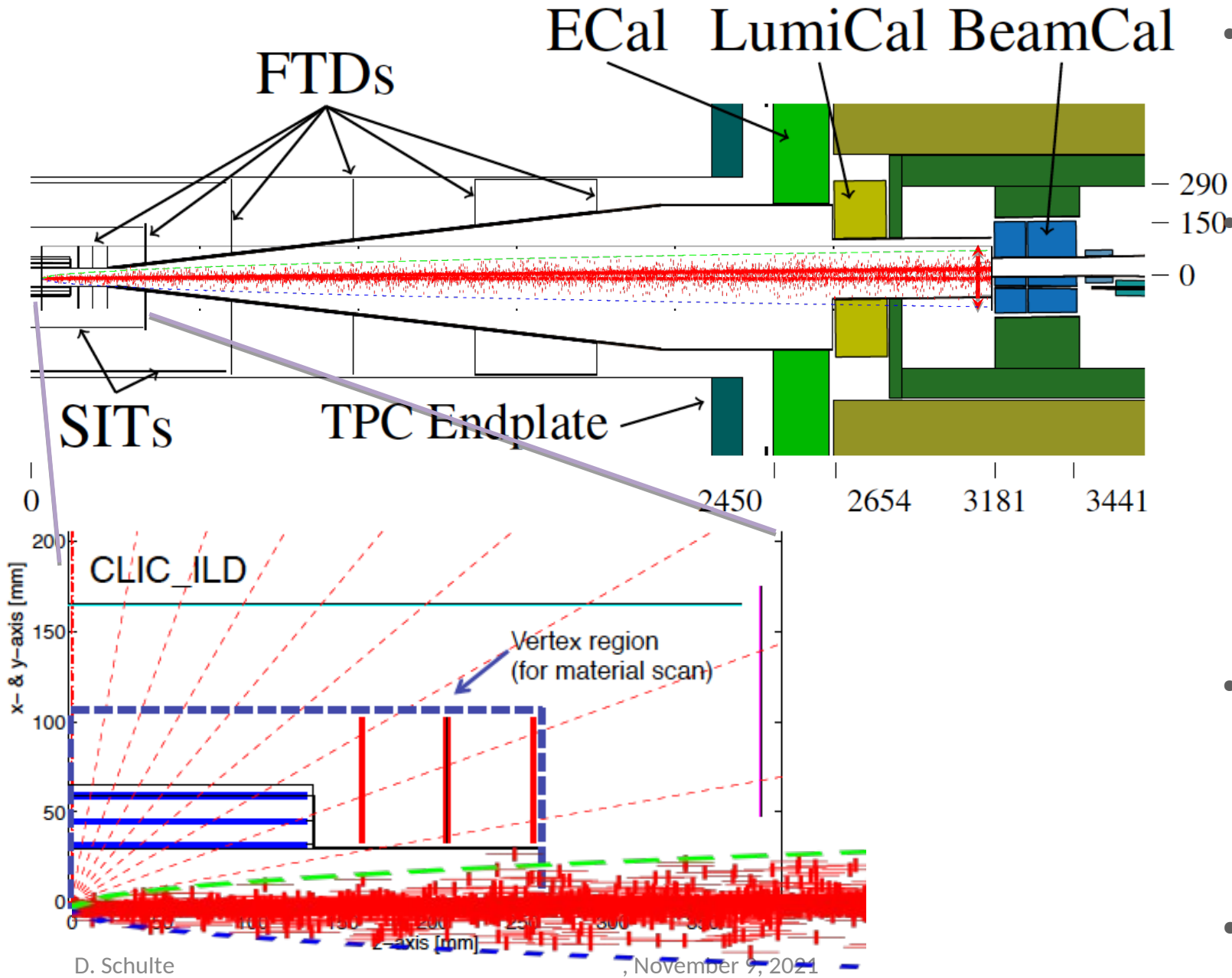
IDT WG3 BDS/Phys Summary Meeting – February 2022



- 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



- 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



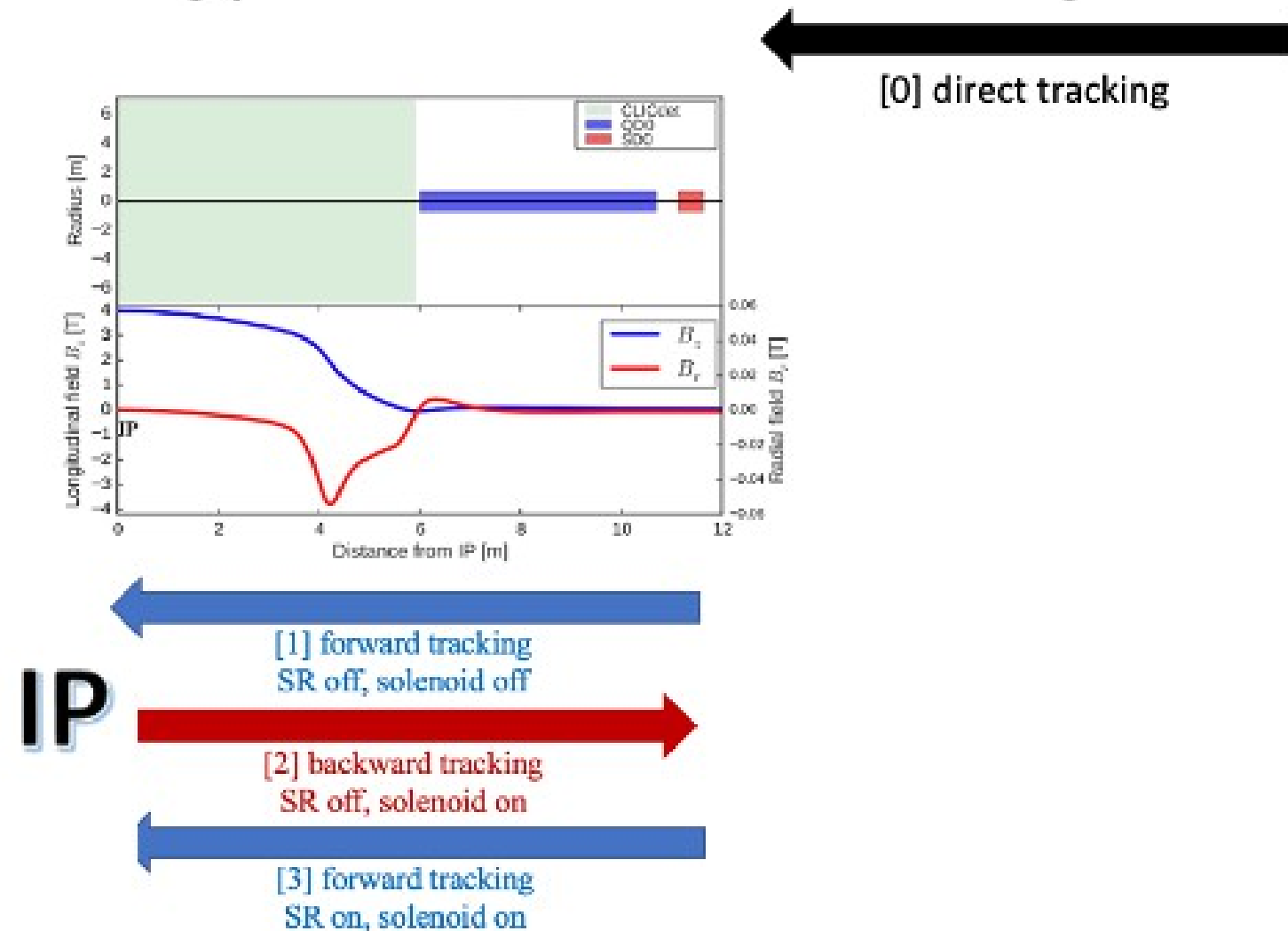
D. Schulte

, November 9, 2021

- 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

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

- Tracking procedure in PLACET* including the detector solenoid map

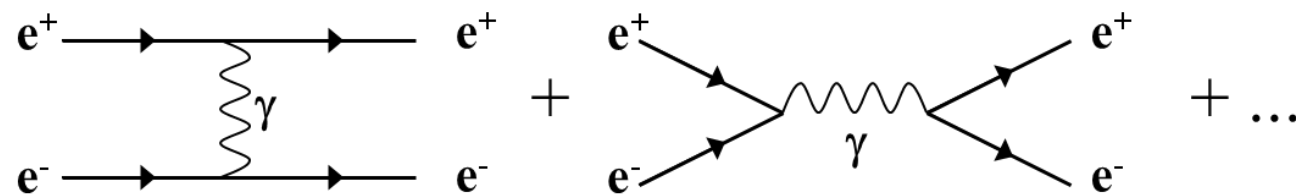


→ The beam is first tracked forward without SR, and without the solenoid field present (1).
 → The ideal IP beam distribution is tracked backwards through the beam line, with the solenoid field turned on but still without SR (2).
 → Finally, the SR is turned on, and the beam is tracked forward through the solenoid (3).

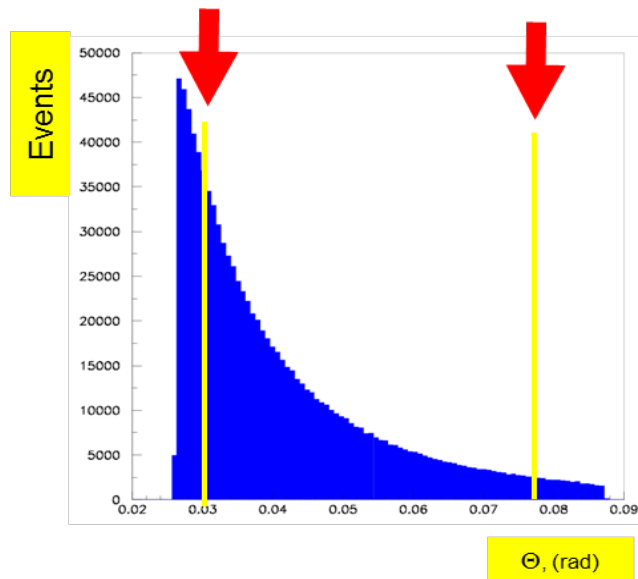
* Y. Inntjore Levinsen, B. Dalena, R. Tomás, and D. Schulte. «Impact of detector solenoid on the Compact Linear Collider luminosity performance». Phys. Rev. ST Accel. Beams 17, 051002 – Published 27 May 2014; Erratum [Phys. Rev. ST Accel. Beams 17, 079901 \(2014\)](#)

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

$$e^+e^- \longrightarrow e^+e^- (\gamma)$$

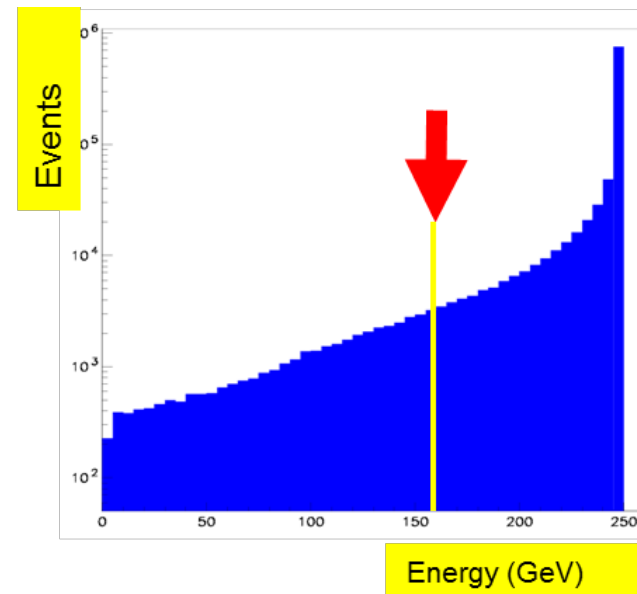


$$\frac{d\sigma_B}{d\theta} = \frac{2\pi\alpha_{em}^2}{s} \frac{\sin\theta}{\sin^4(\theta/2)} \approx \frac{32\pi\alpha_{em}^2}{s} \frac{1}{\theta^3}$$



$$L = N / \sigma$$

Count Bhabha events \longleftarrow N
 σ \longleftarrow From theory



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

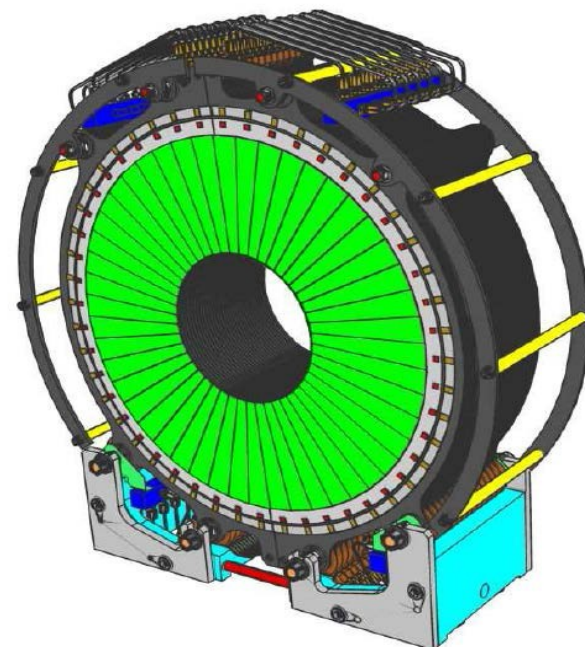
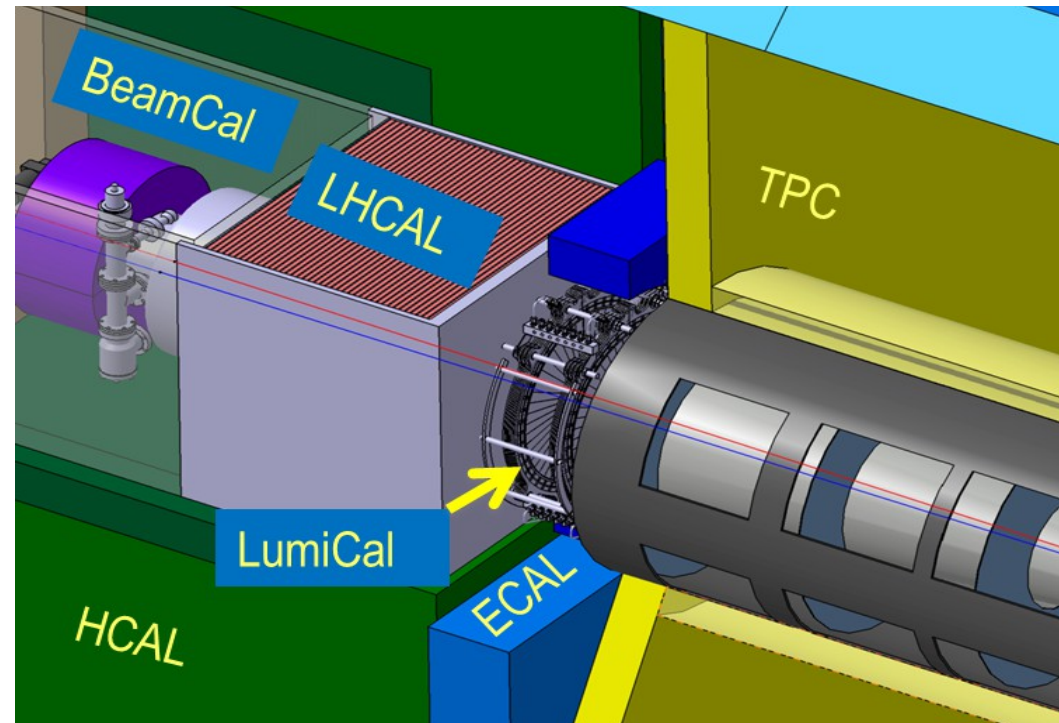
...for polar angle range 25 – 100 mrad:

- 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 $dL/L \sim 10^{-3}$ 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



LumiCal

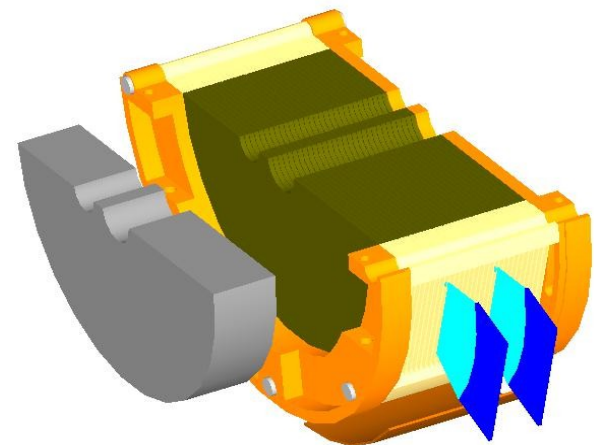
- Si or GaAs/W sandwich calorimeters
- Compact (small Moliere radius)
- Thin detector planes
- W plates, 1 X_0 thick, highly planar

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

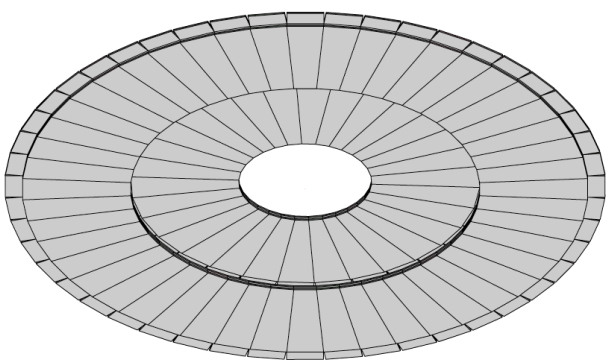
Detectors

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



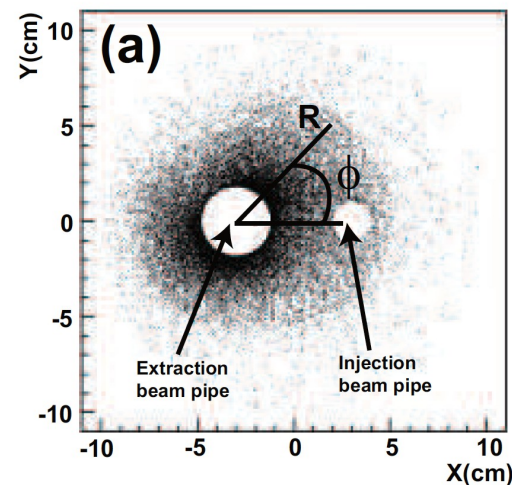
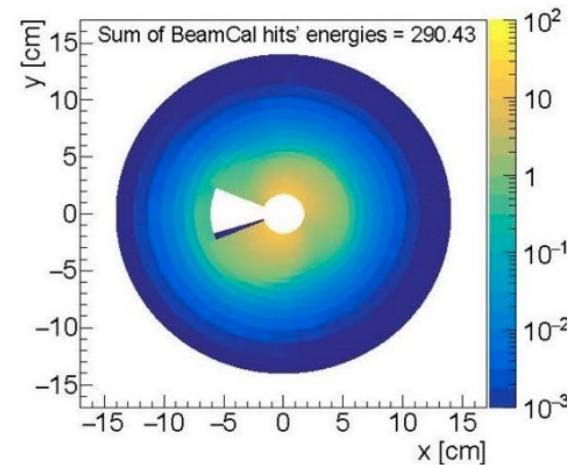
“Similar” to lumical

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

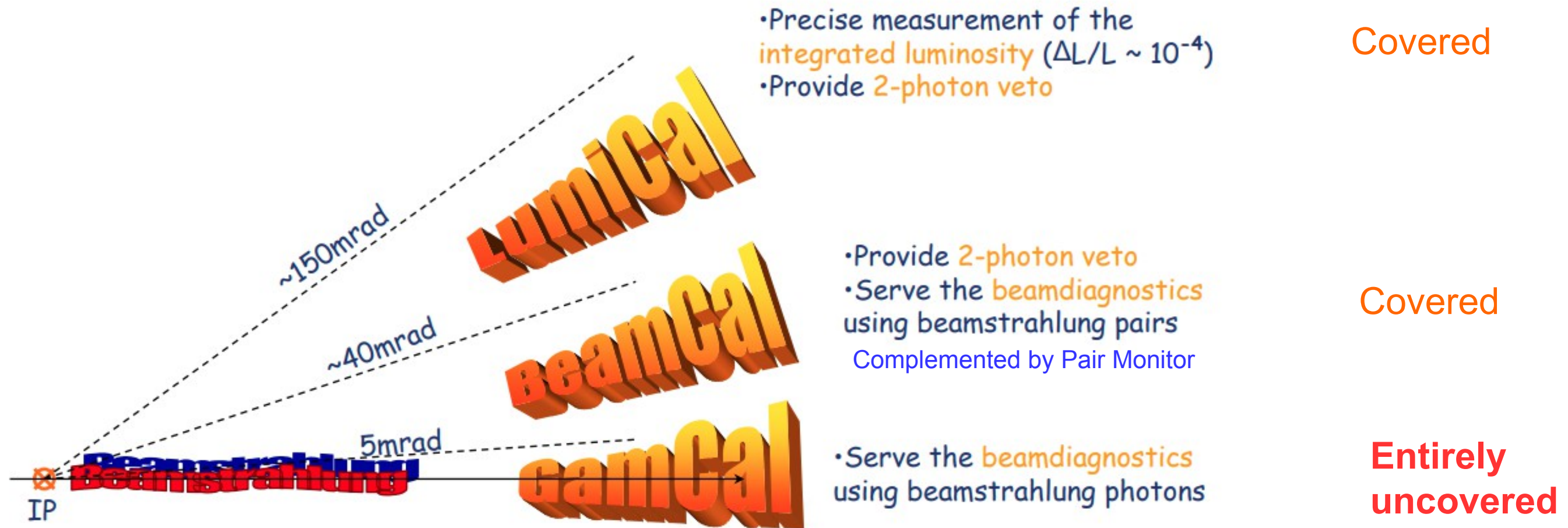
Parameters

Parameters to be measured:

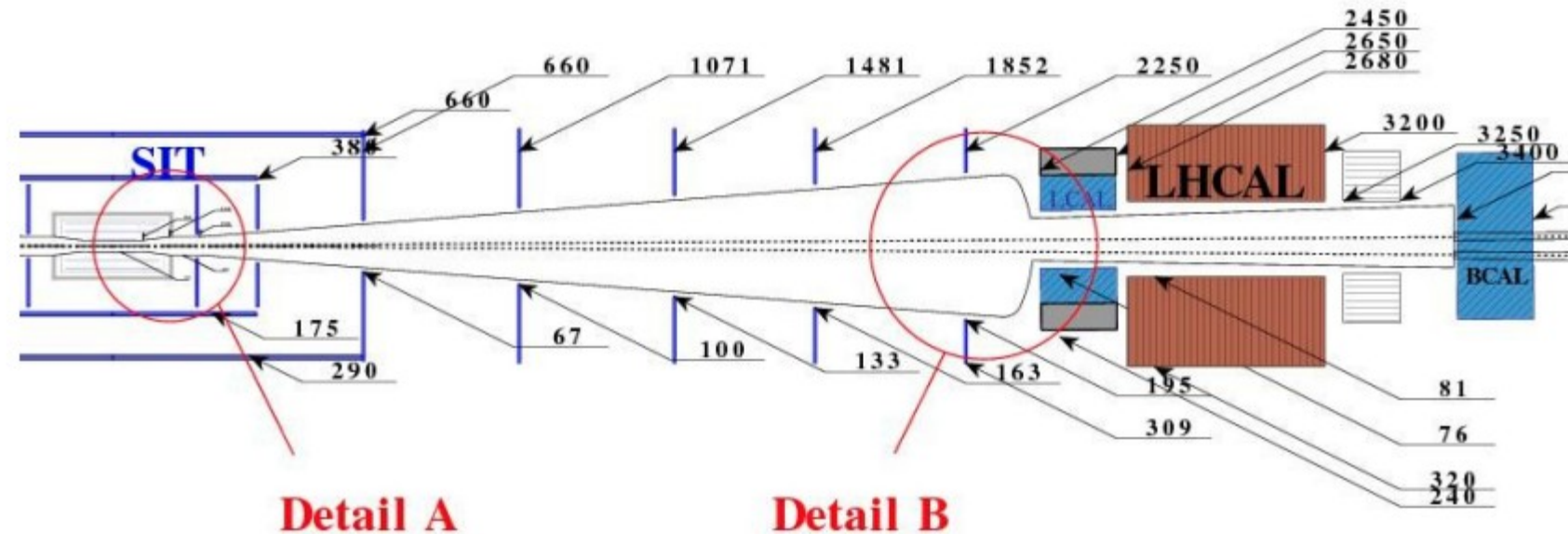
- $\sigma_x, \sigma_y, \sigma_z$ — bunch sizes in x, y and z
- ϵ_x, ϵ_y — emittances in x and y
- $\Delta x, \Delta y$ — beam offsets in x and y
- W_x, W_y — waist shifts, horizontal and vertical
- α_h, α_v — bunch rotations in horizontal and vertical planes
- ϕ — bunch rotation around the beam axis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

• **Questions:**

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



Cartoon: C. Grah 2007



- 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 $L^*=4.1\text{m}$
 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

Synchrotron Radiation

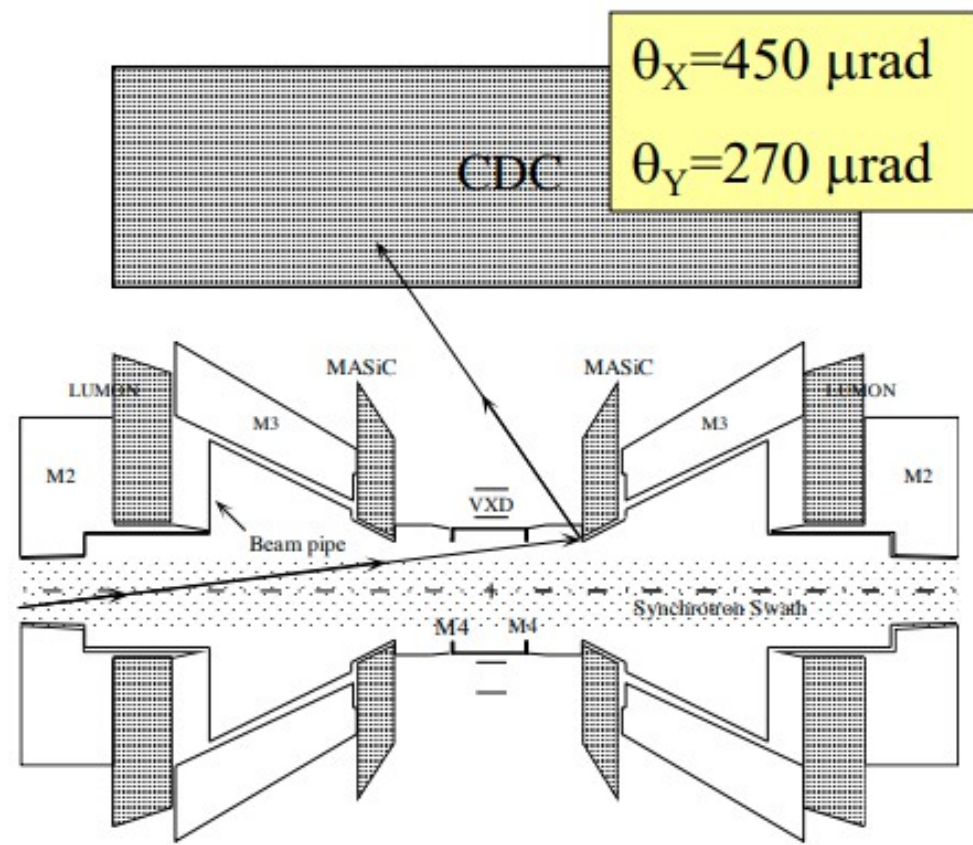
At SLD/SLC SR WAS THE PROBLEM

T. Markiewicz

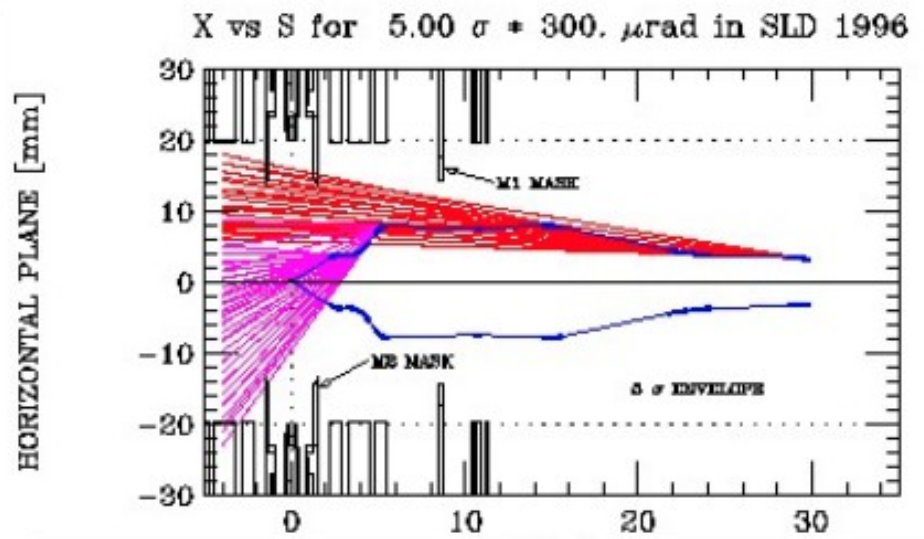
Synchrotron radiation photons from final focus magnets could reach the detector

- minimum two bounces, but it happened...

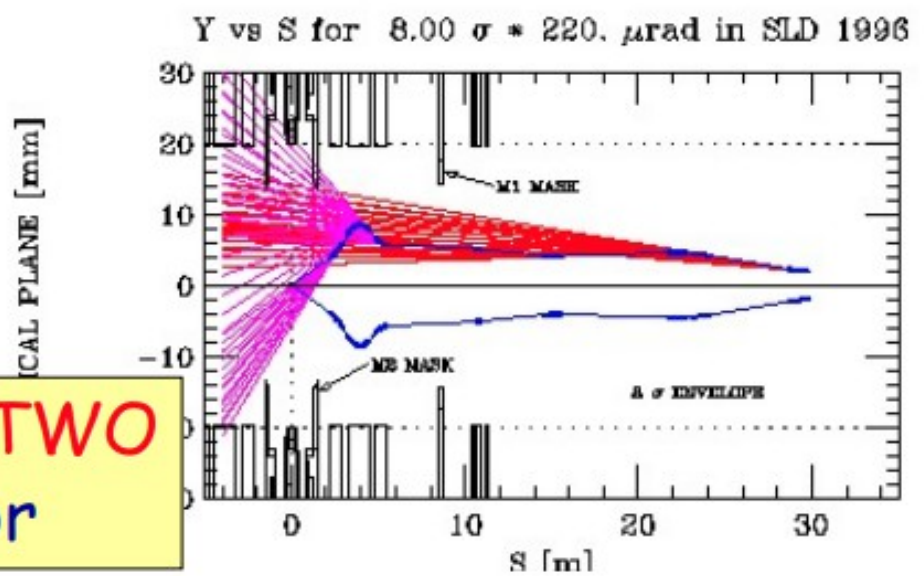
- Design IR Region carefully
 - Prepared for the unexpected?
- Diagnostics are critical
- Stability is paramount
- Build your subdetector with background issues in mind
 - Don't build devices which can fail catastrophically

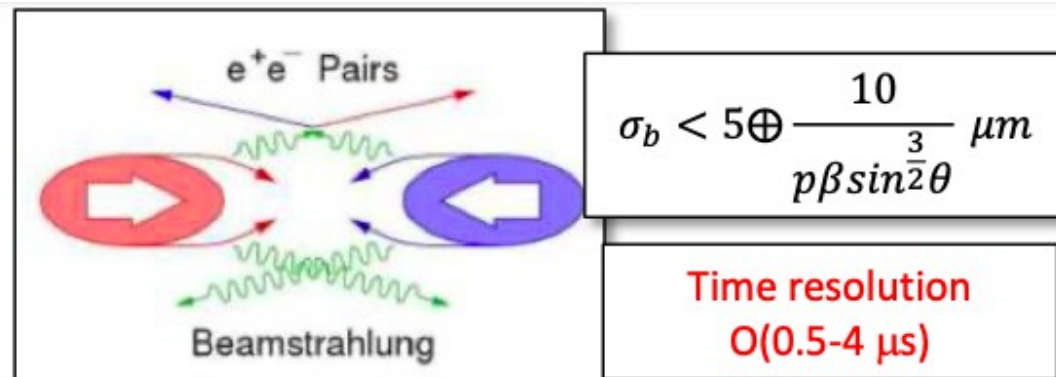
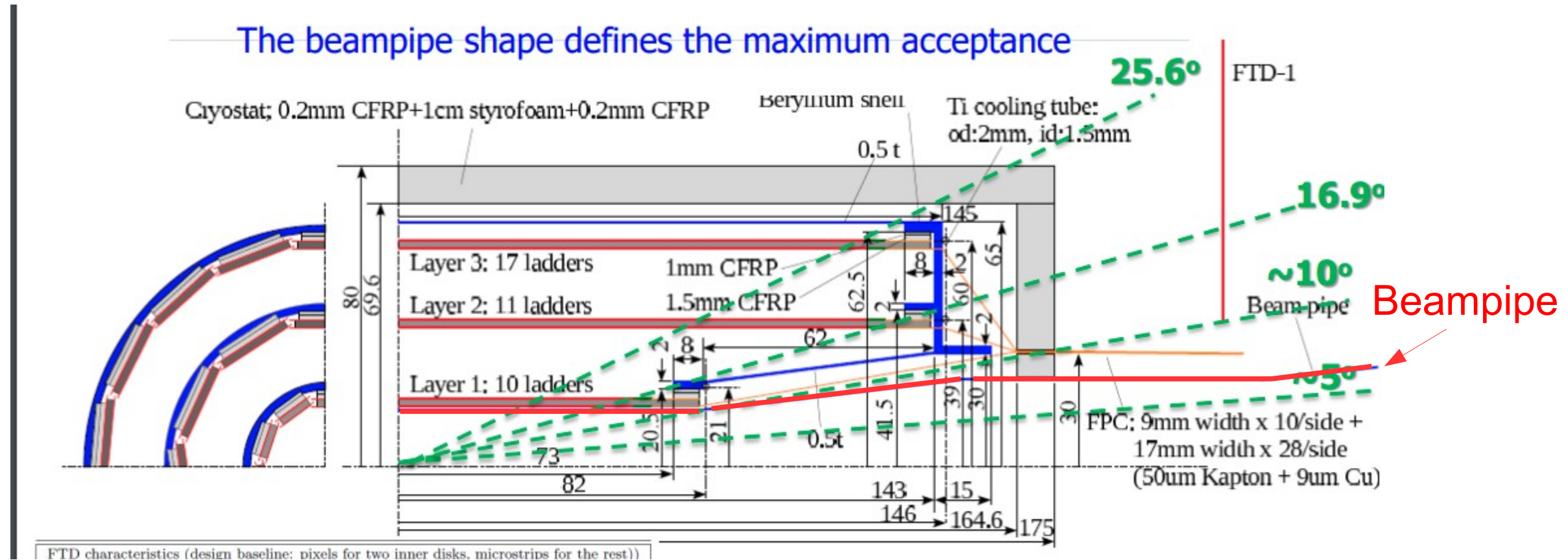


Photons need a minimum of **TWO** bounces to hit a detector



SR Fans from Halo in Final Focus





A. Besson/M. Winter

Apologies for not having invited a dedicated forward tracking talk

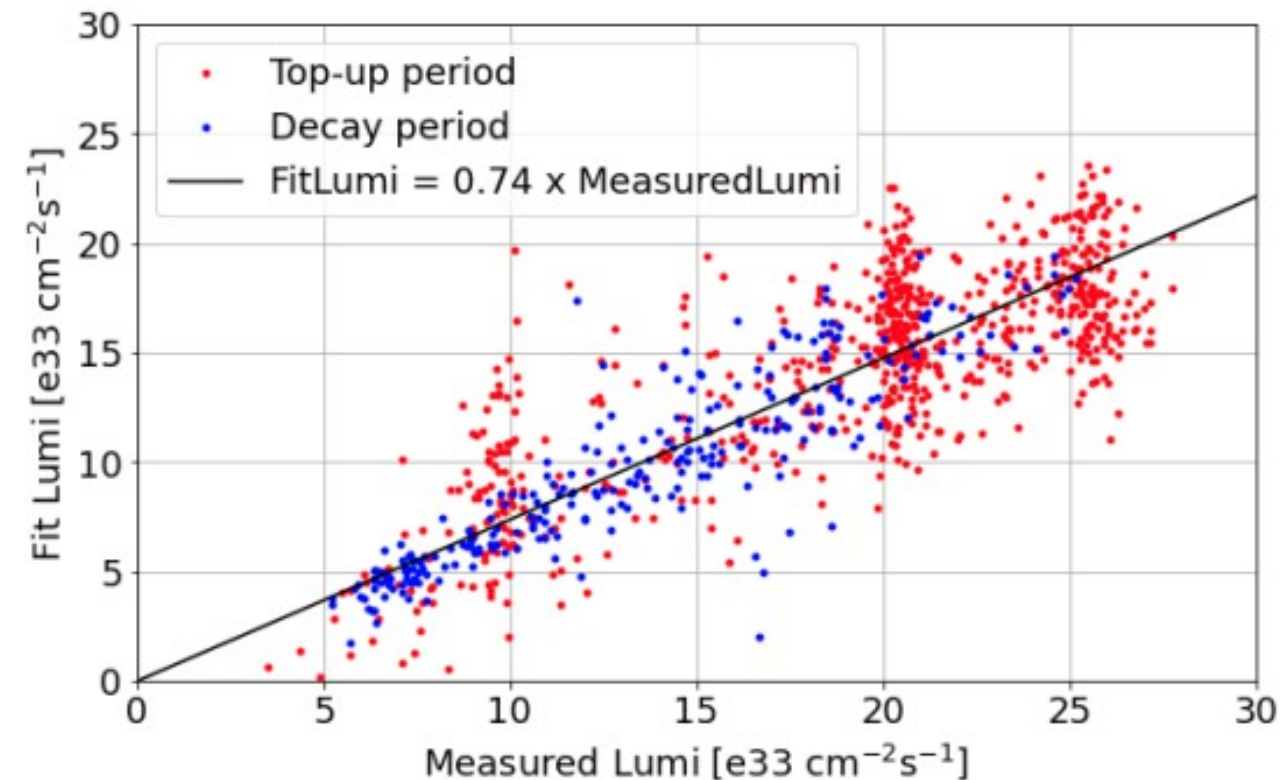
- Beam related background dominates hit rate and determines layout of vertex detectors and forward tracking
- Today few percent occupancy considered as acceptable (at time resolution of 3-4us)
 - During the meeting it was pointed out that modern pixel detectors can stand high background rates than assumed 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

- $\text{FitLumi} \propto \text{MeasuredLumi}$ (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,

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

- $\text{Data/MC} = 0.74$



“Real life” experience with background studies at circular machine

2022/01/06



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?

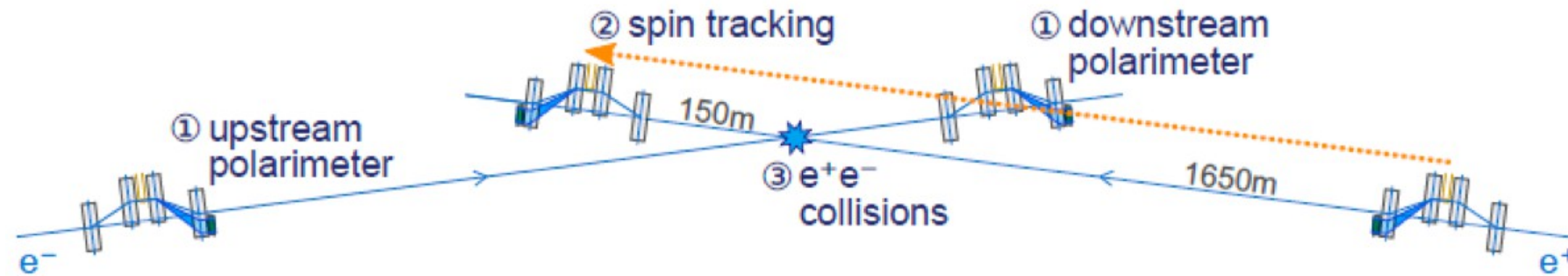
Ultimate Impact/Reach

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/generators 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**

Elements of polarimetry at ILC

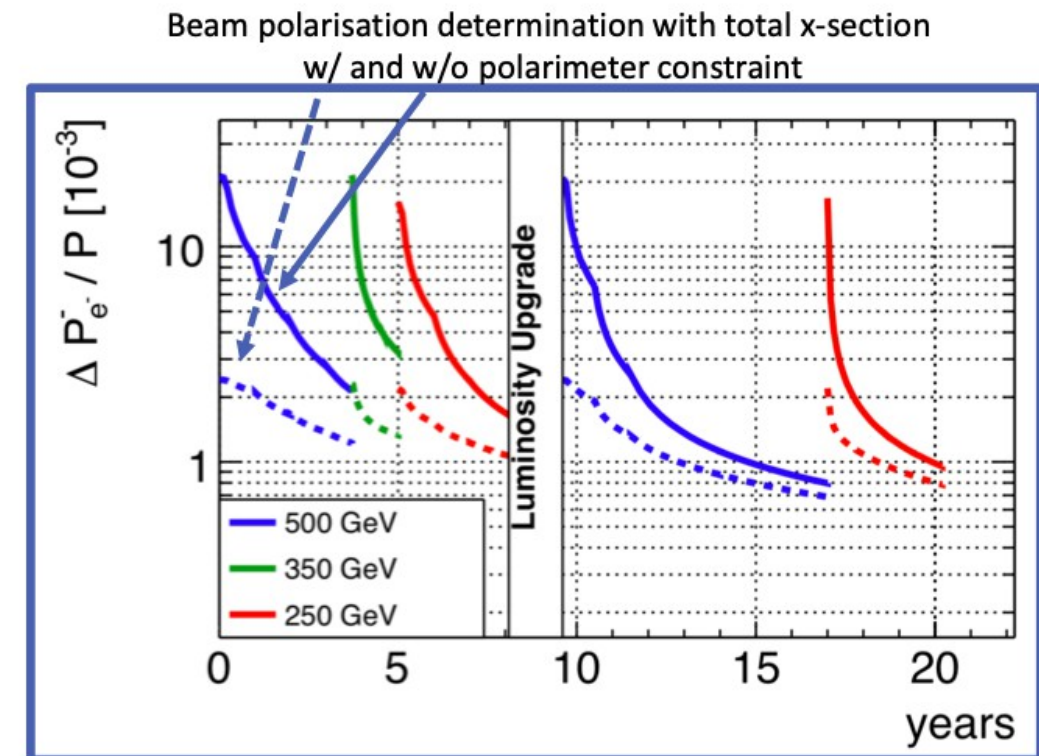


Per mill polarimetry by ...

- 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

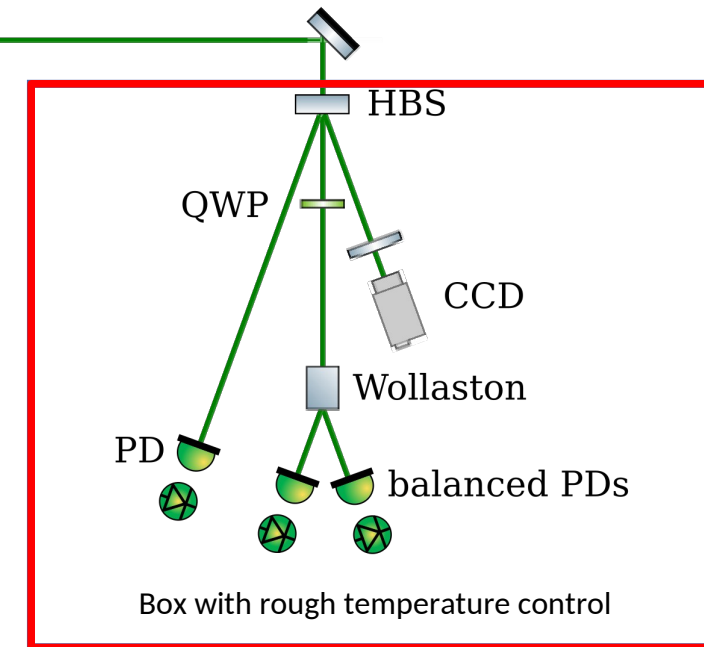
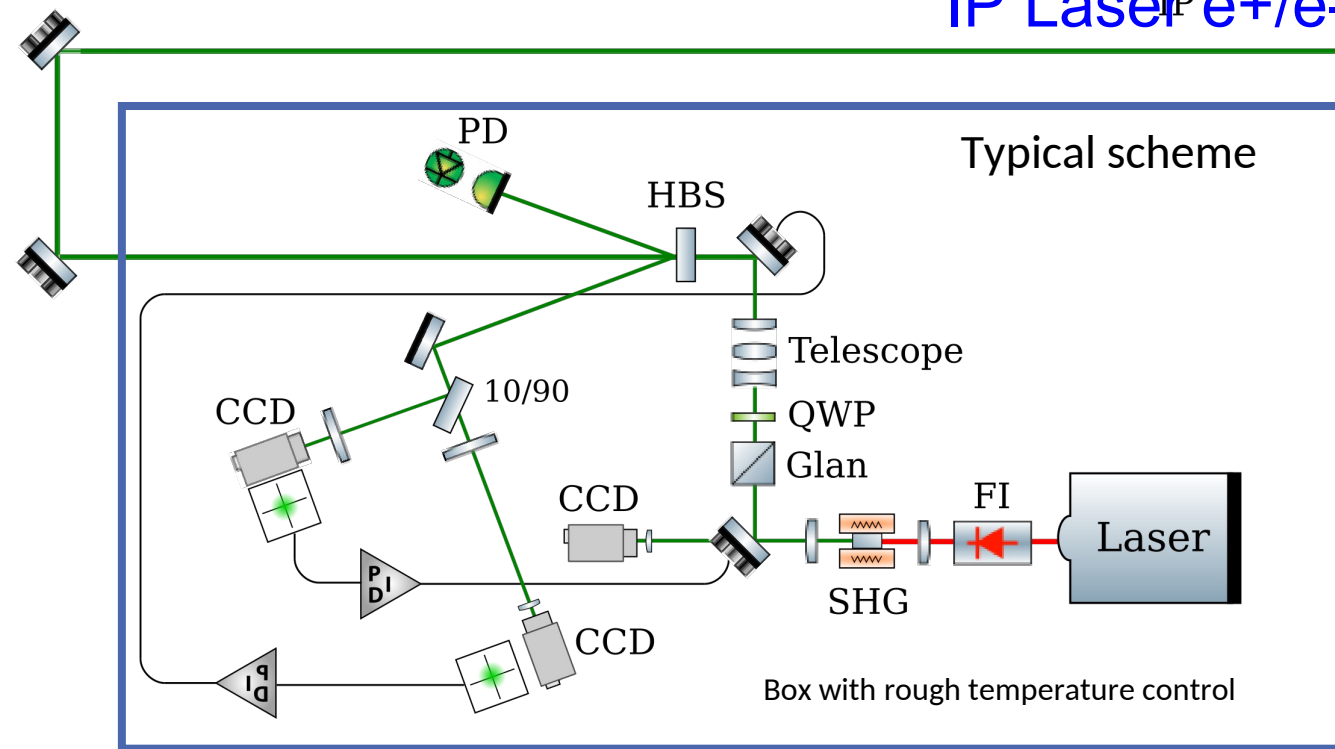
Polarisation measurement – Error budget

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%



Laser polarisation and shaping control

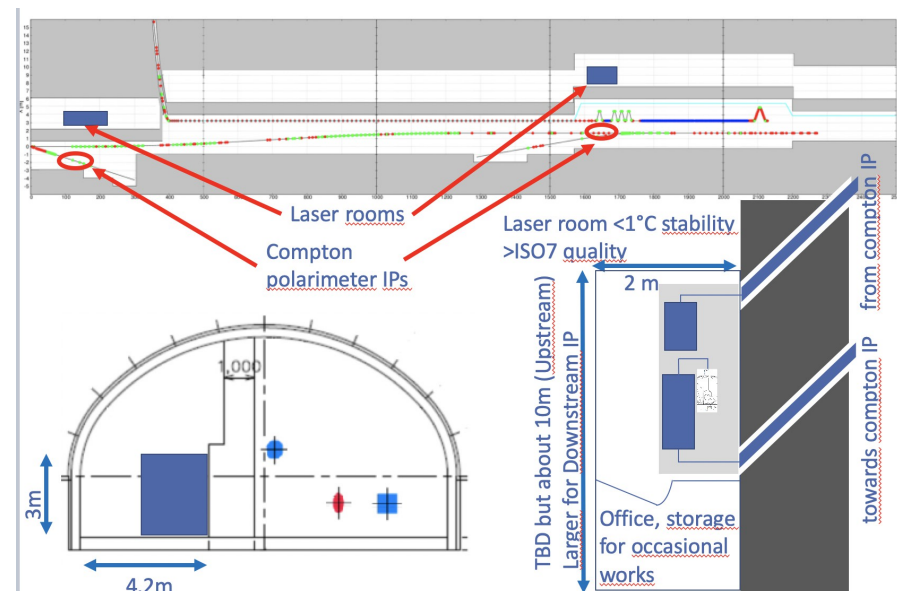
IP Laser e+/e- beam



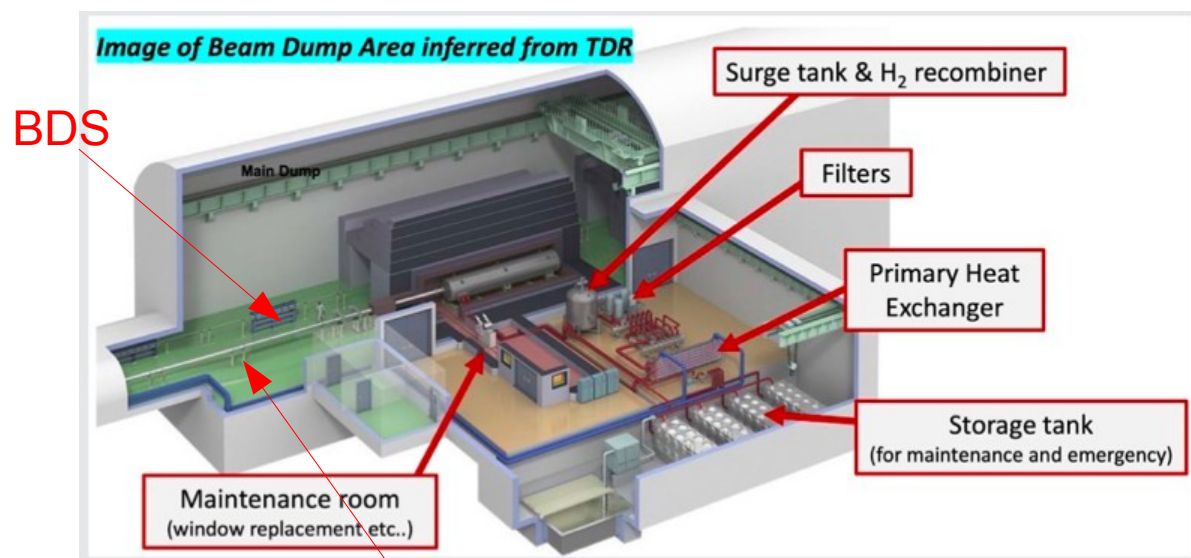
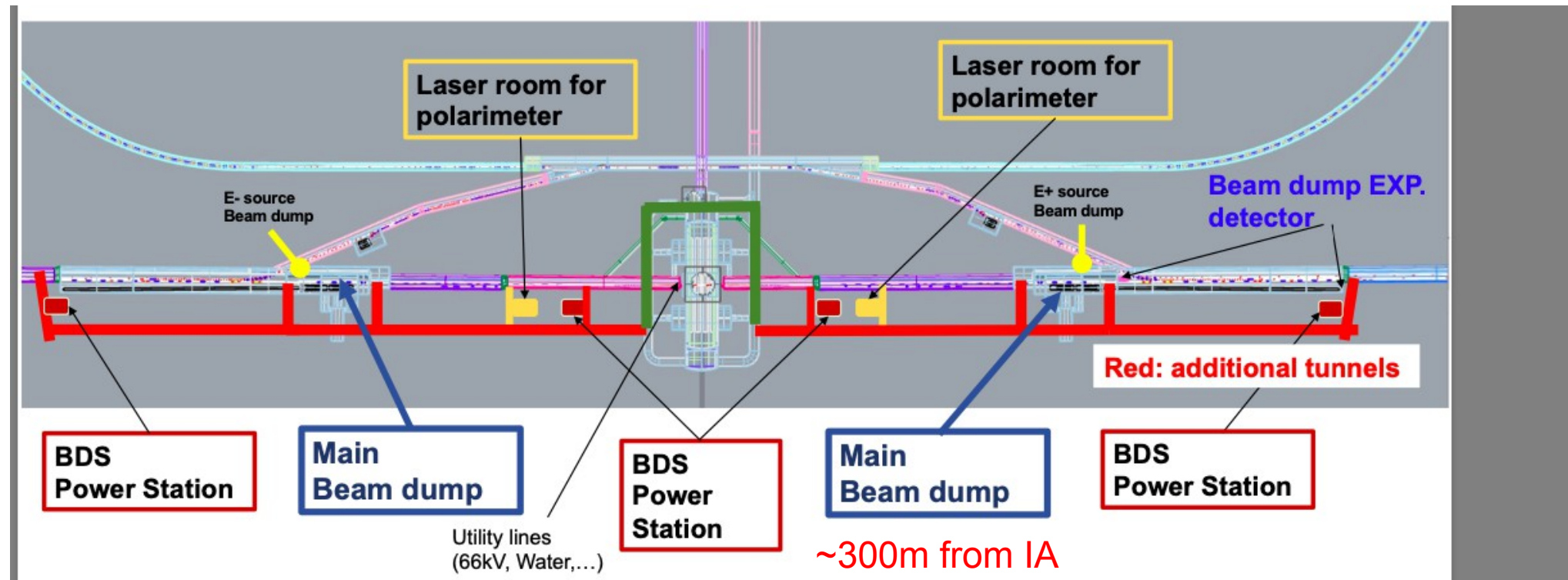
Per-mille polarization control is not easy !

- Control optical birefringence of all optical elements
 - Mechanical stress, Temperature, Roughness defects,
 - Thickness defects
- Internal reflections and interferences in waveplates
- Detailed model used successfully 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

Modern lasers => Laser can be put in service tunnel



Nobuhiro Terunuma



Beam dump beampipe

- 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 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



- **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.



- 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



- 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