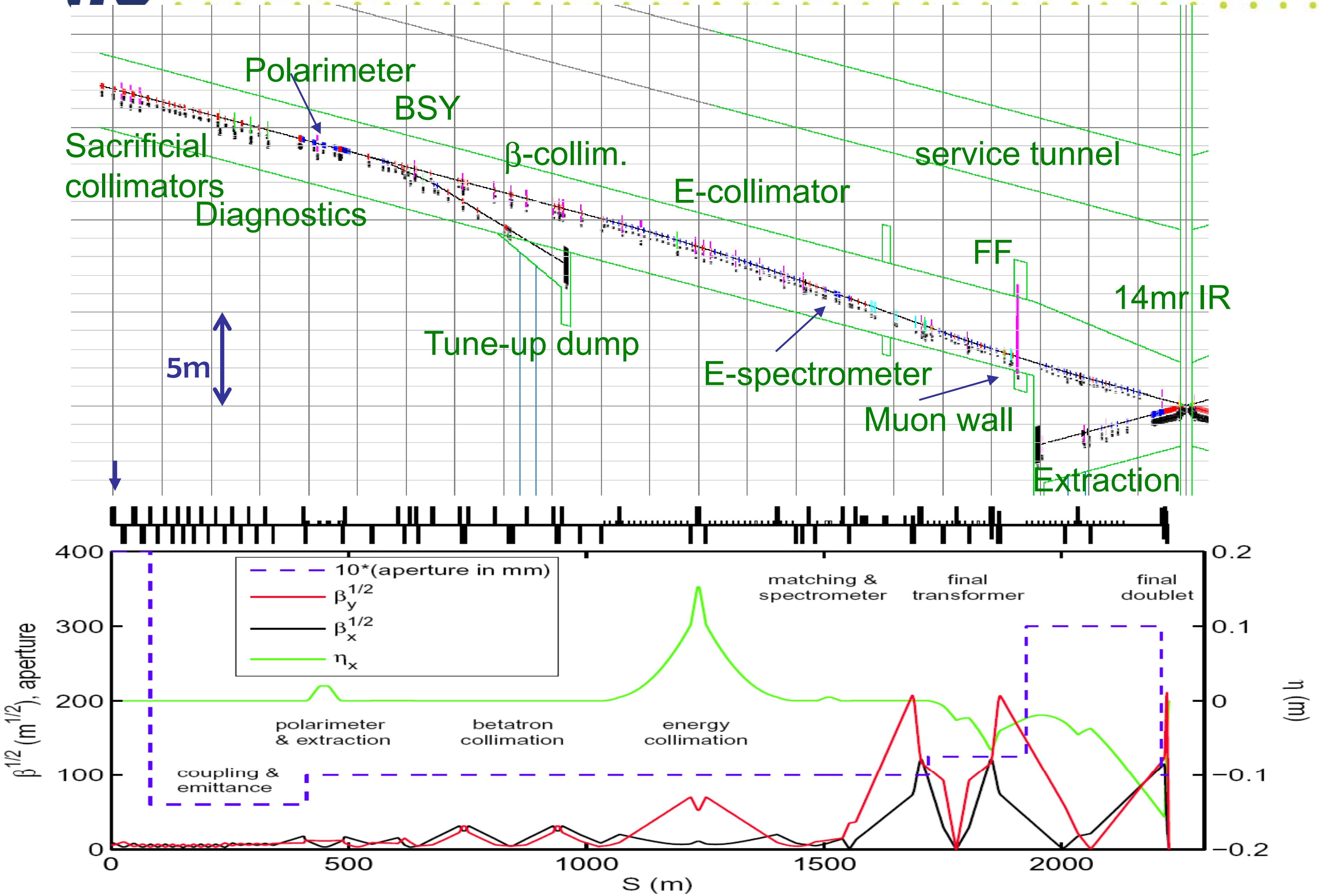
Accelerator and detector requirements specification and optimisation on example of interaction Region

Deepa Angal-Kalinin

On behalf of the BDS design team

RDR BDS Layout

single interaction region @ 14 mrad "push-pull" detectors



RDR (ILC2006e) Optics

- Hybrid system upgrade to 1 TeV CM involves adding magnets only
  - no geometry changes
  - no expansion into linac tunnel
  - dumps don't move
  - upstream polarimeters don't move
  - Upgrade to 1 TeV CM
    - additional dipoles, septa/kicker & replace FD/SC extraction line magnets

RDR (ILC2006e) Optics

- Emittance growth due to SR
  - @ 250 GeV, emit/emit0 = 1.0036
  - @ 500 GeV, emit/emit0 = 1.0078

  - *To shorten the length of the BDS*
    - *How much increase in emittance can be tolerated?*

    (TESLA TDR had 14% at 800 GeV CM which was acceptable)
    - *Strong bends will increase the SR load at few locations for vacuum design, which will lead to increase in vacuum system cost but SR will improve the conditioning (will depend on how long the BDS will be conditioned)*
    - *SR losses per meter and corresponding radiation conditions*

RDR (ILC2006e) Optics

- Laserwire Spot Sizes @500 GeV
  - "nominal" vertical spot size =1.5 um (x √2 @250GeV)
  - "worst case" vertical spot size =1.15 um (x √2 @250GeV)

To shorten the length of beam diagnostics section

- *UV light will be required to measure with any precision (<~30%?)*
- *This will need further laser R&D; which is currently not funded*

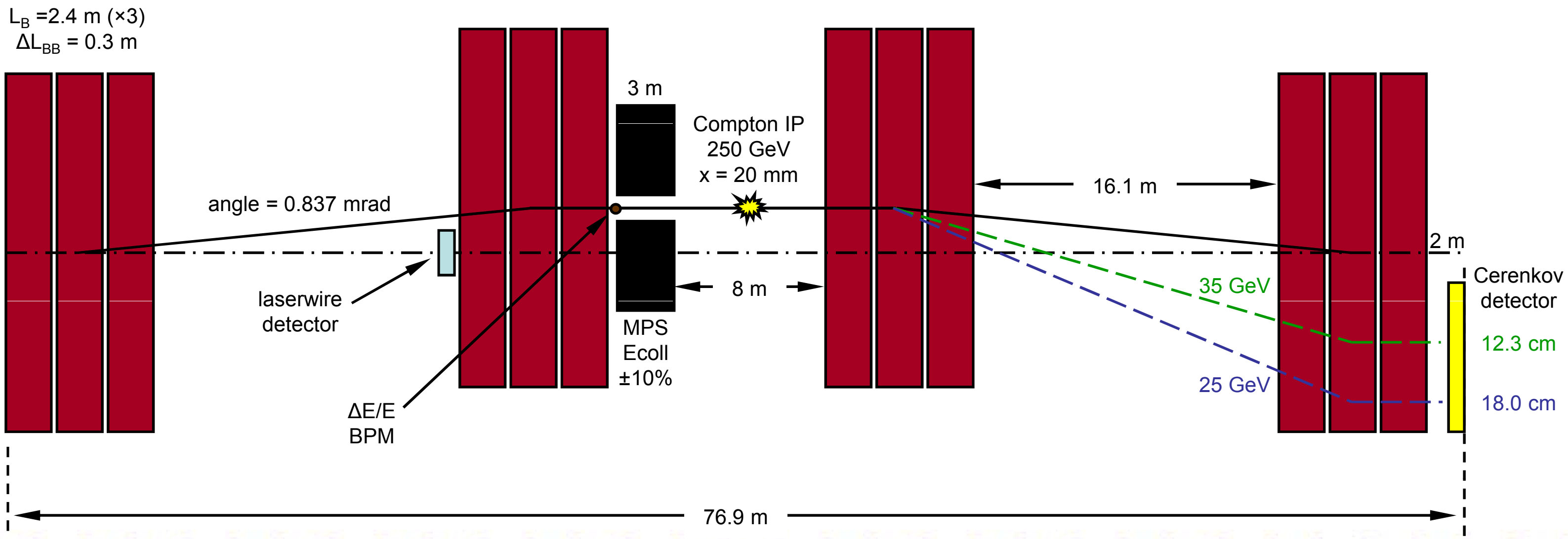
RDR (ILC2006e) Optics

- Extraction/tune-up
  - ±10% dE/E acceptance
  - Required transverse separation at beam dump> 3m
  - Rastering to achieve 3cm beam spot radius at dump window

    - *Can the energy acceptance reduced?*
    - *Optimisation of abort kickers/septa with real estate*
    - *Full power tuning dump (cost scaling against power)*

Upstream Polarimeter Chicane

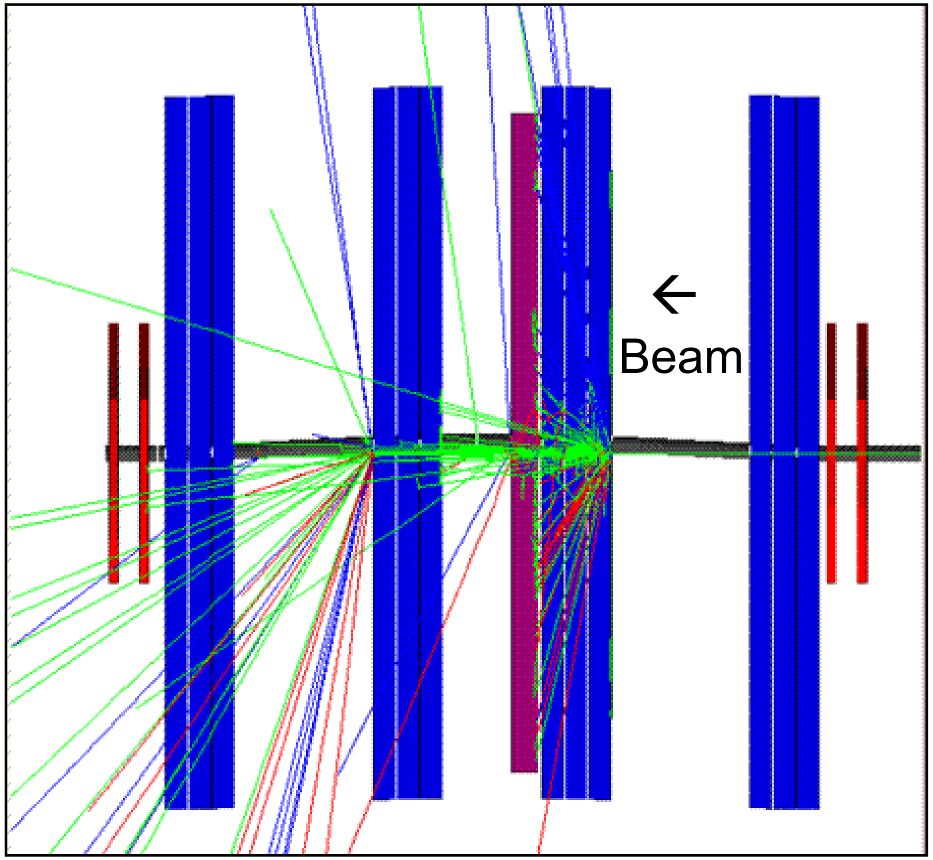
- Constant integrated strength dipoles (B = 0.97 kG)
- Dispersion: 20mm @ 250GeV, 10mm @ 500GeV, 110mm @ 45GeV
- Can the polarimeter chicane be used by the laser-wires and the ΔE/E detection system as envisioned over the full energy range?
- Magnet, vacuum chamber and diagnostics engineering issues?



Upstream Polarimeter Chicane

- Whether backgrounds from laser wire affect the polarimeter measurements? : First signs show that there is no interference
- The current layout has implications on whether both polarimetry and laser-wire can run on the same bunches.
- Transverse space for laser wire detector @ 500 GeV? (~ 2.5 mm)

LW team in not completely happy with this layout and using ATF to study the detector issues in details



BDSIM simulations – L.Deacon

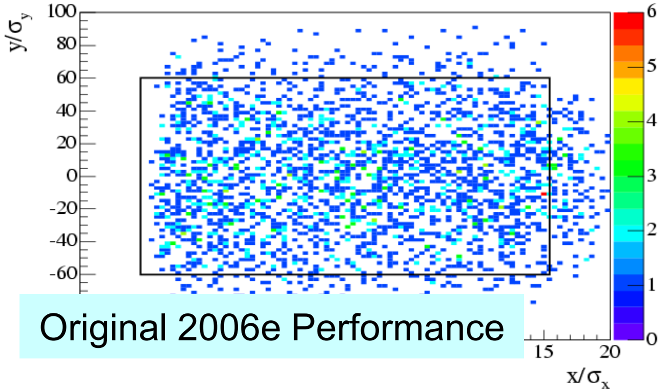
Upstream Energy measurements

- Upstream Spectrometer
  - Constrained by allowed emittance growth from SR
  - Constrained by available real estate in BDS, overall size
  - Other issues drive systematic errors, diagnostics
- Scanning B-field and its effect on beam line?
  - Betatron phase issues?

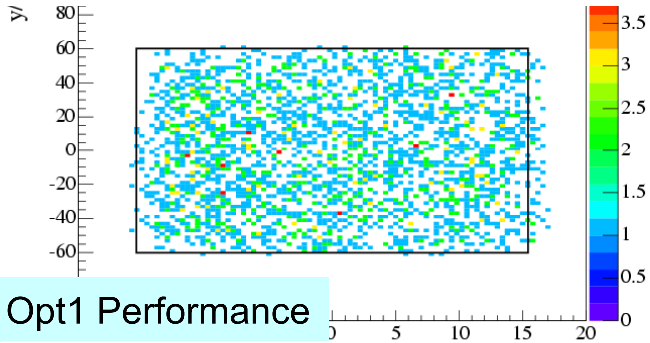
How much increase in emittance can be tolerated?

Collimation Performance Improvement

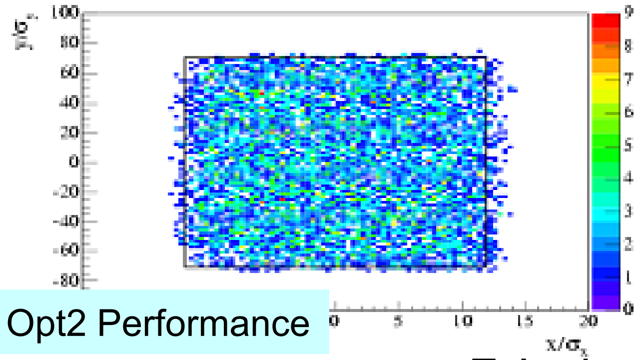
- Restore phase advances to “NLC-like”, using matching quads strengths and separations
- Opt1 : New lattice is 26 m longer
- Opt2 : Additional quads and phase matching including energy spoiler
- Matching section need to be changed to get smooth beta function;cover all parameter sets
- Use flexibility of adjusting the phase advances (& to obtain better bandwidth for better collimation efficiency) including the energy spectrometer which comes after the energy collimation section.



Original 2006e Performance



Opt1 Performance



Opt2 Performance

F.Jackson

Collimation Optimisation :Apertures

- Recent optimisations of 2006e lattice have not been tested with full simulation
  - Absorber apertures not defined yet
  - But simpler particle tracking (no secondaries) suggests spoiler can be opened (e. g. no vertical SPEX aperture required)
- Tail folding octupoles are presently zeroed in the 2006e deck. Check the performance with these octupoles for the optimised deck
  - Does it still give better performance as shown by Andrei et al for the NLC?

	2006c 9sigx 65sigy	2006e optimised(opt2) 11.9sigx 70.7sigy
AB2	2.0 x 2.0	?????
SP2	0.9 x 0.5	1.35 x 0.65
PC1	3.0 x 3.0	?????
AB3	2.0 x 2.0	?????
PC2	3.0 x 3.0	?????
PC3	3.0 x 3.0	?????
AB4	2.0 x 2.0	?????
SP4	0.7 x 0.5	1.35 x 0.65
PC4	3.0 x 3.0	?????
PC5	3.0 x 3.0	?????
AB5	2.0 x 2.0	?????
PC6	3.0 x 3.0	?????
PDUMP	2.0 x 2.0	?????
PC7	60.0 x 5.0	?????
SPEX	1.0 x 0.8	4.5 x OPEN
PC8	3.0 x 3.0	?????
PC9	3.0 x 3.0	?????
PC10	3.0 x 3.0	?????
ABE	2.0 x 2.0	?????
PC11	3.0 x 3.0	?????
AB10	7.0 x 7.0	?????
AB9	10.0 x 4,.5	?????
AB7	4.4 x 1.6	?????
MSK1	7.8 x 4.0	?????
MSK2	7.4 x4.5	?????

Collimation : other issues

- IR beam orbit
  - Detector field correction schemes (anti-solenoids, Anti-DID) perturb the beam orbit and direction of the SR rays
  - Max orbit perturbations of the order ~100 μm, 100 μrad(!) Could lead to ~1 mm deviations in SR rays at apertures
- Margins – how much SR can be tolerated on apertures?
- Realistic beams and IR geometry
  - Energy spread, jitter, halo population
  - Magnet and mask misalignment, beam pipe thickness
- Is it possible (or worthwhile) to include precise estimates of all effects – or only consider worst-case scenarios/biggest effects?

Backgrounds and Issues : N.Mokhov

- Pairs
  - **Beam pipe design**
  - **LumiCal, BeamCal acceptance and design**
  - **Mask design**
  - **Occupancy**
  - **Neutrons in VXD**
  - **Power load in QD0/QDEX cryostat**
- Sync radiations
  - **Apertures**
  - **Mask design**
  - **Power load in QD0/QDEX cryostat**
- Disrupted beam, beamstrahlung photons, radiative Bhabhas
  - **Extraction line apertures**
  - **Beam loss in extraction line and background in diagnostic systems**
  - **Power load in QD0/QDEX cryostat**
  - **Neutrons from the beam dump**
- $\gamma\gamma \rightarrow$ hadrons/$\mu\mu$/$\tau\tau$
  - **Dominant background in r>10 cm**
  - **Occupancy**
  - **BeamCal design, veto efficiency**
- Beam gas
  - **Vacuum requirement**
  - **Occupancy**
- Muon production
  - **Occupancy in muon system**

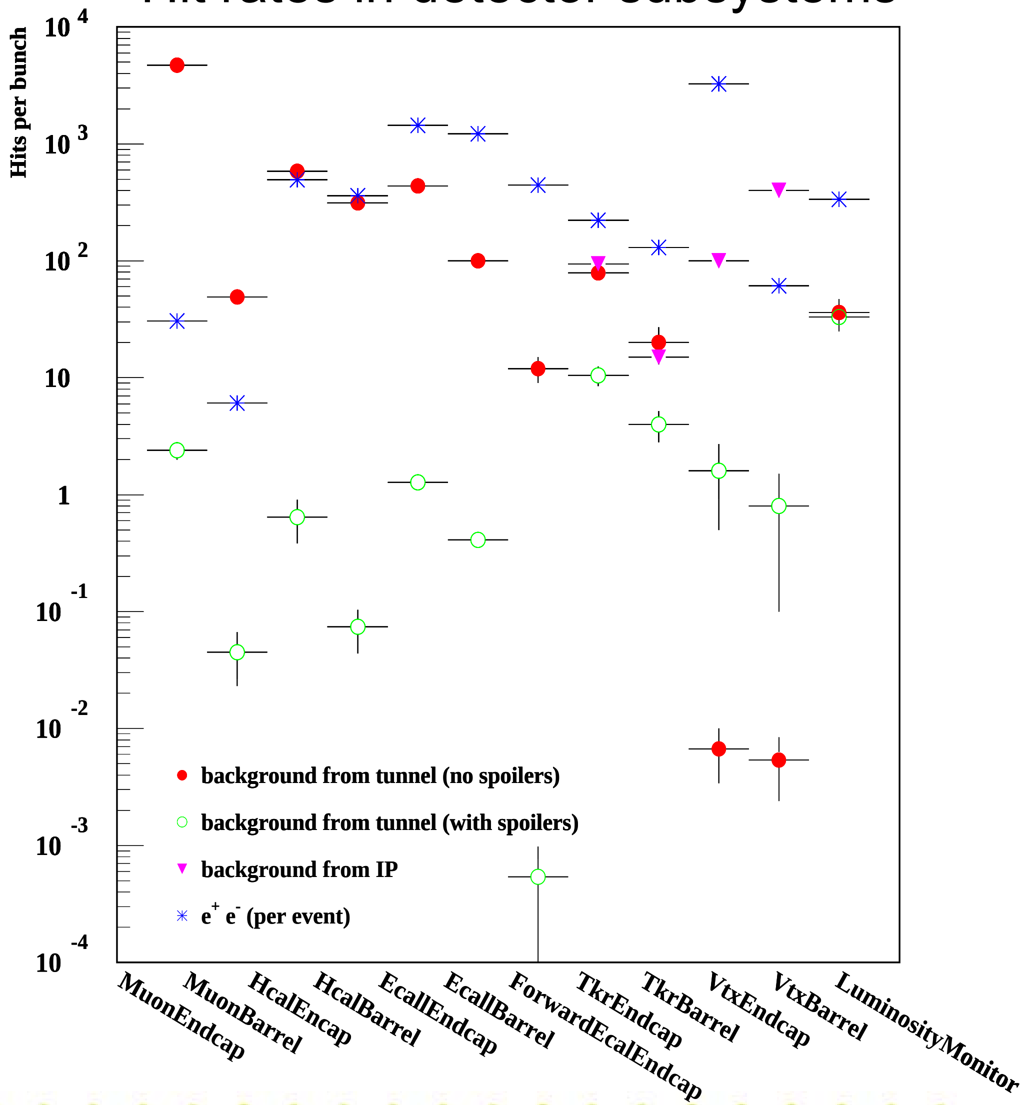
T. Maruyama
IRENG07, WG-D Meeting
15^{th} August

BACKGROUND TOLERABLE LIMITS SUMMARY

Denisov, Mokhov, Striganov, Kostin, Tropin (2006, JINST-1-P12003)

Muon system: the RPCs (sensitive media) need 1 ms to re-charge a 1 cm^2 area around the avalanche, therefore, the hit rate in excess of 100 Hz/cm^2 would result in an unmanageable dead time. With typical 80 sensitive layers in a Muon Endcap, it corresponds to a muon flux at its entrance of about 1 $m/cm^2/s$.

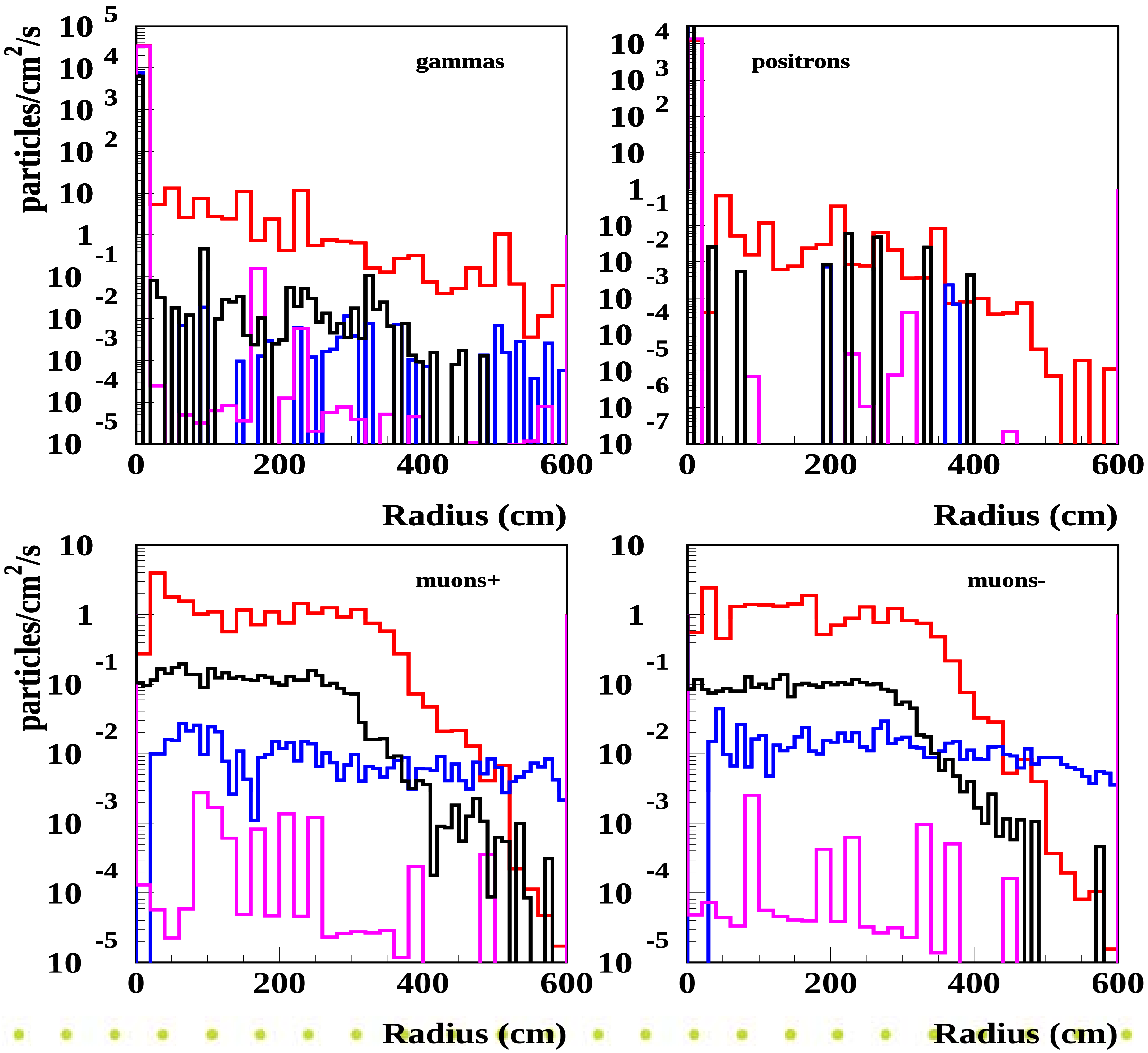
Hit rates in detector subsystems



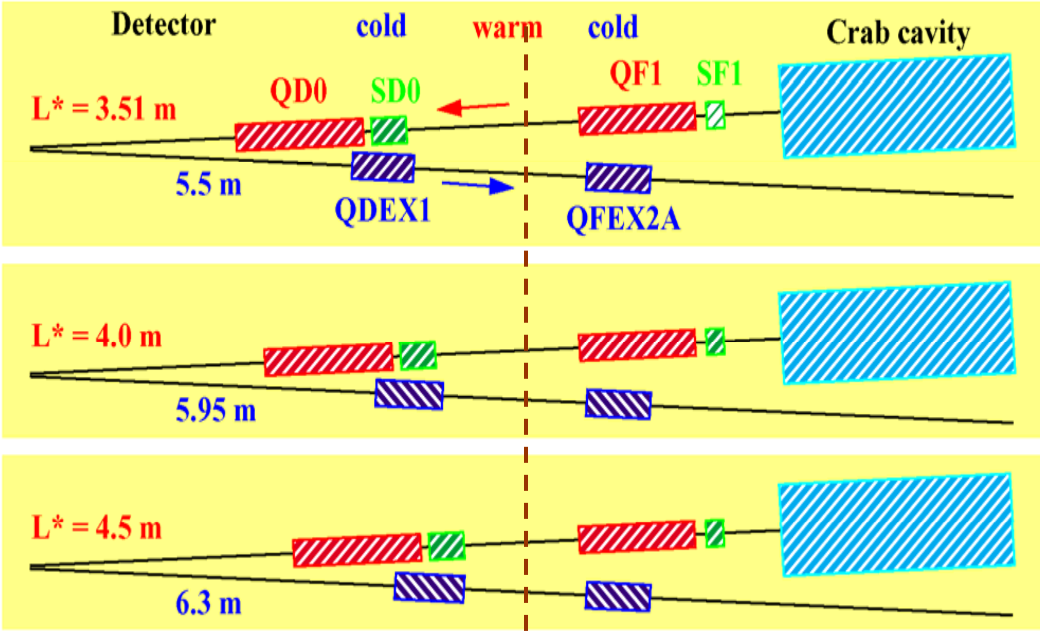
Particle Fluxes (cm^{-2}s^{-1}) at SiD from e^{+} BDS

Red lines: no shielding
Magenta: 9m + 18m walls
Blue: 5m wall
Black: Five 4-m doughnuts

OK with a safety margin



Extraction for Push-pull

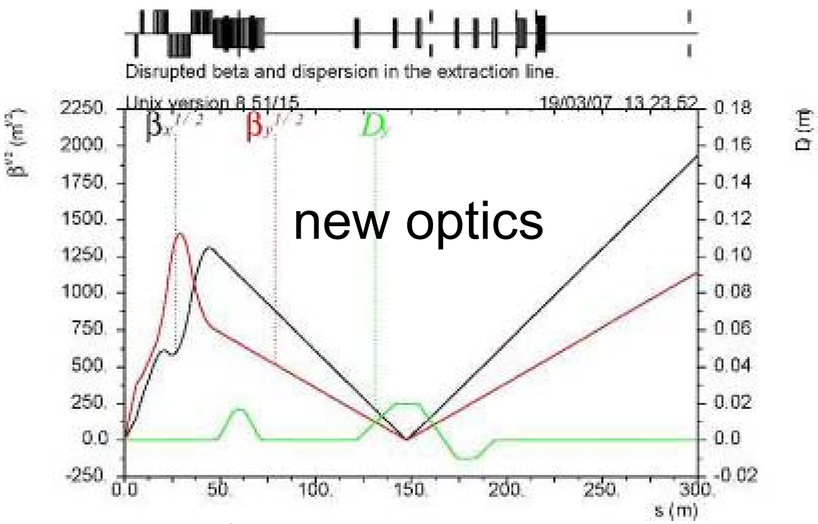


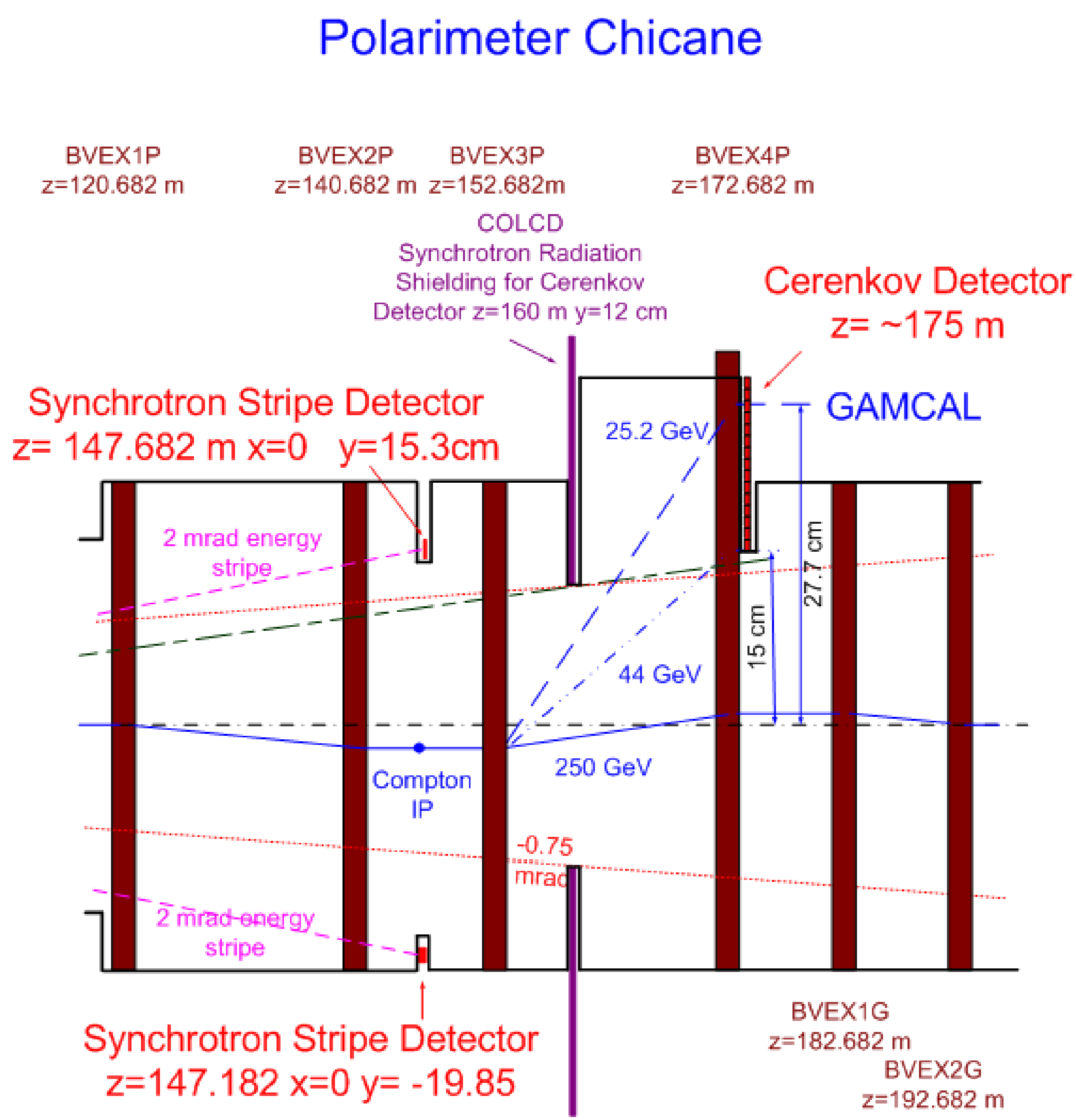
- Consequence to the design due to the need to break point for push pull, detector and QD0 cryostat design etc
  - e.g. is the present QD0-QF1 separation enough for detector opening?
- Consequence of different L* : Effect on FF and tuning after push-pull operation?

Modification of polarimeter chicane

new layout

- Some increase of cost, improved performance
- More suitable for GamCal
- Ratio of energy in Gammas/Pairs ~ Lumi signal





Further studies : extraction line

- Effects of magnet + beam errors on performance of downstream diagnostics
- Backgrounds causing due to beam halo (including machine & beam errors) in the extraction line and its effect on the polarisation and energy measurements
- The requirement of polarimetry measurements need knowledge of angle at the second focus within ±50μrad of IP angle.
  - Need measurement of two angles : angle at the IP and angle at the second focus.
- Worse case scenario and its implications to diagnostics measurements & beam losses
- Develop commissioning scenario to understand whether required number of BPMS (their resolutions!), steering etc fulfil the requirements of the diagnostics

Magnetic field requirements in the IR

•Magnetic field requirements in the IR

Magnetic field along the detector axis or along the beamline cause Y shift of the IP position and beam size growth via coupling and other terms

• The offset is to be compared with

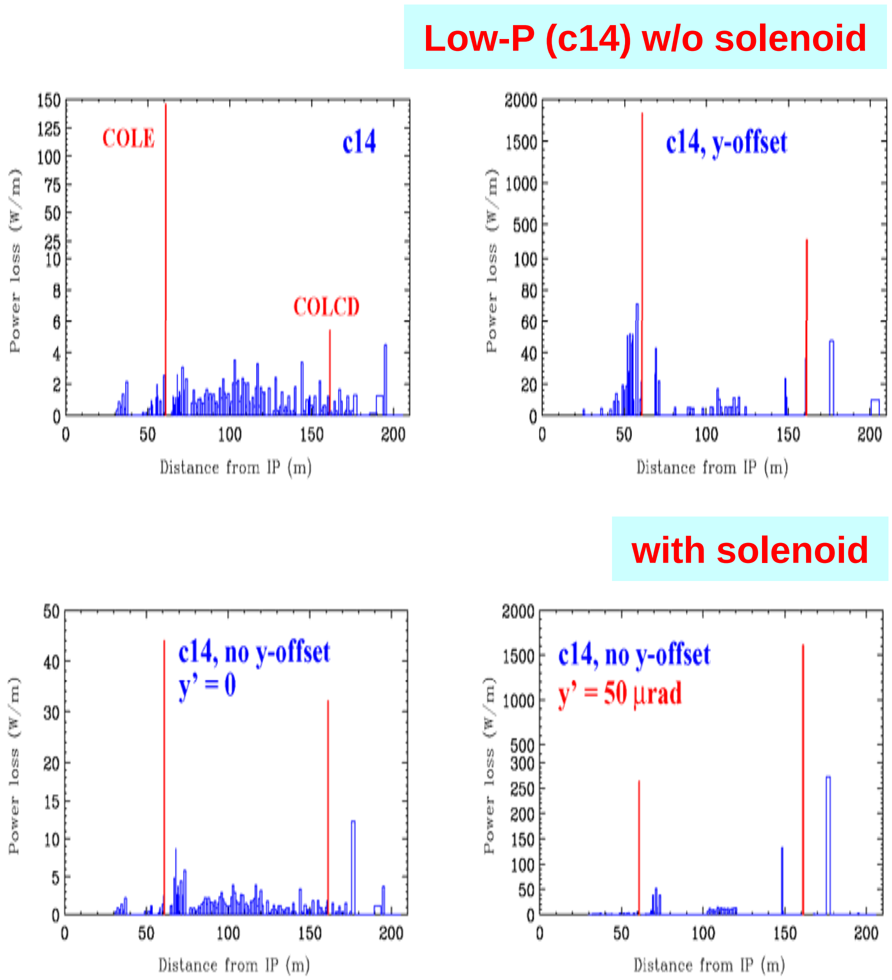
- $\frac{1}{4}$ sigma or 1nm of maximum tolerable bunch-to-bunch jitter in the train with 300ns between bunches
- roughly 100nm, which intratrain feedback can follow with time-constant of ~100 bunches (0.03ms).
- about 500nm of train-to-train offset, which intratrain feedback can comfortably capture (0.2s between trains)

•The coupling effect should be compared with desired tuning stability time, say 10 hours

What level of field "leakage" can we expect to have in the IR?
The limits can be set only on variation of the field in time, not on static value (which may need to be limited by safety or other consideration).
How much extra cost will it add onto the detector?

Beam power losses in the extraction line

- No primary and photon loss on SC quads.
- Large y-offset and y-angle at IP increase load on collimators. These non-ideal conditions need to be efficiently corrected.
- Include magnet and other beam conditions to check that losses are tolerable



Y. Nosochkov

Alternative IR configurations

- Separate talks today morning on small crossing angle IR and extraction lines
  - Modified Head-on
  - 2 mrad scheme
- Magnet designs, beam losses and background studies
- Alternative ideas for downstream diagnostics

Vibration Tolerances

- Luminosity loss due to jitter of final doublet cryomodules (>5% @ ~200nm RMS).
  - Needs to be convolved with 'background' environment of GM and other jitter sources.
- Small effect due to kicker distance from SD0, becomes more pronounced in cases with larger RMS jitter.
- Simulations of BDS tuning show something like ~10% overhead in luminosity after initial tuning. All dynamic lumi-reducing effects should total less than this.
  - Remaining luminosity overhead dictates how long ILC can run before some (online) re-tuning required (~ 3 days with current assumptions).

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Settlement of Detector (IP)

- Effect of IP moving up or down by ~mm's per year? Assume settlement isolated to IP (+ QD0/SD0).
- If want to keep collision point at same physical location w.r.t. detector, need to periodically re-align BDS.
- How often? – What is tolerance of absolute collision position w.r.t. detectors from physics perspective?
- Can we do nothing? (Leave IP in a shifted location w.r.t. detectors)
- Would need to at least move QD0/SD0 cryomodules. Presumably get info on how far IP has shifted from detector vertex reconstruction?
- Beam offset w.r.t. detector solenoid a problem?

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Stability Issues

- Alignment, stability and audible noise requirements
  - Impact on detector designs
  - Design and location of facilities
    - Presence of service cavern
  - Effect on location and design of feedback hardware
- Required ranges of FD motion and corrected coils
- Effect on presence of interferometer path along the yoke of inside the detectors

Shallow site issues

- Stability requirements
  - Vibration
  - Slow settlement
- Radiation requirements
  - Depth? (Do we need to bend extraction lines (all 4 lines) down to reduce number of muons from the beam dumps on the surface?)

Options : e-e- & γ–γ

- Parameters for these options?
- 14 mrad in e-e-?
- Option for γ–γ
  - Layout generated by M. Woodley
  - Optics for these stretches
  - More stringent focussing requirements at the IP?
  - Beam dump
  - Detector constraints affecting the integration
  - Implications to CFS : hall size etc

Test facilities and their role in BDS optimisation

- Final focus tests at ATF2
  - Local chromaticity correction final focus optics
  - Beam diagnostics and skew correction
  - Stability of the beam at the IP
  - Tuning procedures
  - Instrumentation
  - Possibly beam damage?
- ESA
  - Collimation wake fields (the goal to agree ~10% with simulations)
  - Energy spectrometer
  - Bunch length?
  - Instrumentation?
- Prototype QD0 stability tests
- Crab system phase stability tests (ILCTA)

How do these tests feed back to the BDS design?

Timeline

BDS vacuum design

RDR vacuum requirements

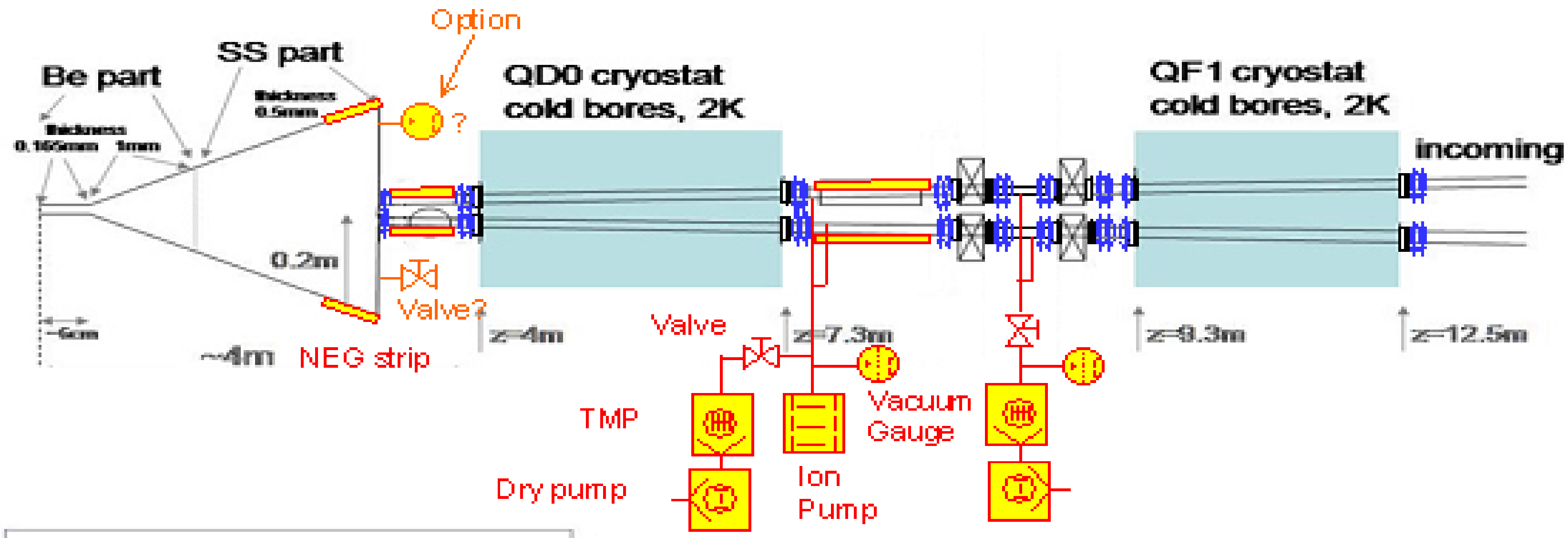
1 nTorr near IP(for 200m), 50 nTorr in rest of the line.

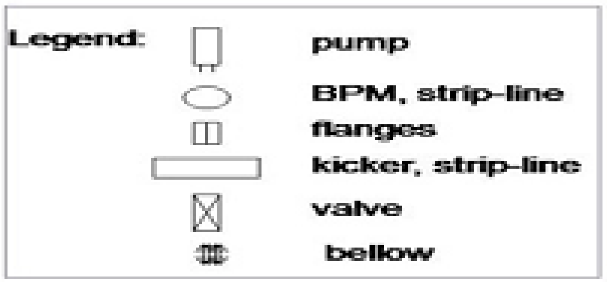
Latest studies [***ILC-NOTE-2007-016 (Keller, Maruyama, Markiewicz)*** indicate

- 1 nT from 0-200m from the IP is conservative.
- 10 nTorr from 200-800 m
- Beyond 800m, the pressure could be an order of magnitude higher than 10 nT (need to check Beam Gas Beamsstrahlung background in downstream diagnostics)
- Need feedback from the detector groups on the effect of different hit rates (described in the above note) on their detectors.

IR vacuum design

- Required pressures
  - **For z < L* : 1 ~ 10 x 10^{-7} Pa (= 1 ~ 10 nTorr)**
  - **Up to 200 m from IP: ≤1x10^{-7} Pa (= 1 nTorr)**





Apertures typically r=1cm in incoming beamline, and r=1.2cm+0.08cm*Z(m) in the outgoing beamline

Be-SS connection is permanent

IRENG07
Y.Suetsugu
O.Malyshev

To investigate in more details

- Standardisation of magnets to reduce number of types
- Magnets on strings
  - Additional correctors/PSs
  - How will it affect the tuning + beam based alignment
  - How will it affect the performance after push-pull
- Operable energy range : 45, 350, 500 GeV,1 TeV
- Temperature requirements in the tunnel
- Stability requirements for push-pull
- Angle feedback and integration of other feedbacks?
- Effect of wakes from pumping ports, vacuum chamber misalignments, resistive wall, IR wakes, HOM heating, wake fields from crab, spoilers, other transitions….
- Commissioning scenarios : Do we need extra QD0/SD0? What about shielding?