5th in a sequence of workshops co-organized by IHEP Beijing + Joint cons. Hong Kong with few days of specialised mini-workshops

2020 :

- 09-10/1  **Mini-workshop: theory, particle Phys, Astro-particle, Cosmology**
- 16-17/1  **Experiment / Detector - Software** with talks by Andre Sailer, Gerri Ganis / CERN
- 16-17/1  **Accelerator - Machine Detector Interface for Future colliders**, covered here
- 18/1    **Physics Potential Study for Future e+e- Higgs Factories**
- 20-22/1 **Conference**, including summary talks from mini workshops

giving my impressions, concentrating on the optics / background / simulation part
small workshop < 20 participants at any given time in the room, from FCC : M. Koratzinos + myself chaired by Toshiaki Tauchi / KEK ( giving summary at the conference ) + Mike

goal : bringing together the world experts in e+e- collider MDI

previous years had some other specialized mini workshops

last year  Polarisation, Tracking + Calorimetry
Venue

picture from jasprogram.ust.hk/hep/2020/venue.php
Opening Remarks, Jie Gao / IHEP 10’ followed by 30’ talks

Overview of Different Colliders, Jie Gao / IHEP

Background Status and Study at Belle II, SuperKEKB, Carsten Niebuhr / DESY, remote

Status of the Superconducting Final Focus Magnets at SuperKEKB, Norihito Ohuchi, remote

Stability of the Final Focus Magnets at SuperKEKB, Hiroshi Yamaoka, remote

Lessons Learned from LEP and Their Application to FCC/CEPC, H.B. / CERN

CEPC MDI Accelerator Issues, Sha Bai / IHEP

lunch break

CEPC MDI Physics Issues, Hongbo Zhu / IHEP

CEPC MDI SC Magnet System, Yingshun Zhu / IHEP

CEPC MDI Mechanics Issues, Haijing Wang /IHEP

CEPC MDI Detector Issues, Quan Ji / IHEP

CEPC Detector Overall Facilities and Hall Issues, Zian Zhu / IHEP
2nd day, Friday 17/1

BINP Super Taucharm Factory MDI Issues, Anton V. Bogomyagkov / BINP, remote

Overview of ILD MDI at ILC, Roman Poeschl / CNRS

ILD Background Studies at ILC, Daniel Jeans / KEK

SiD Background Studies at ILC, Marcel Stanitzki / DESY

Superconducting Final Focus Magnets at ILC and Future Colliders, Brett Parker, remote

Overview of MDI at CLIC, Philip Burrows / Oxford University, remote

IP Fast Feedback System (FONT) at CLIC and ILC, Philip Burrows / Oxford University, remote

Discussion  Moderators: Jie Gao / Hongbo ZHU and Michael Koratzinos

Closing Remarks :  Michael Koratzinos, CERN and Massachusetts Institute of Technology
Impressions

Bringing together and discussing plans and experience (rather limited these days) in the broad, not well defined subject of MDI from different projects and parts of the world has been interesting and useful.

As often, I find that what was most interesting and useful were the direct discussions (coffee, lunch, dinner) with the participants.

Generally good, pleasant open discussion atmosphere, well organised, strong interest, …

On a more critical note:
Unfortunately many of the non IHEP talks were given remote. Talks (in particular those from IHEP) often showing simulation results with figures and numbers without explanation of assumptions, uncertainties, programs used, trends, conclusions.

From my side, also in response to requests to provide our programs:
Stressing the importance of citing correctly and giving credit to efforts.
With www, GitHub, GitLab technically well possible to share code, development, maintenance.
Requires time and resources to be shared as part of collaborations, useful for all sides.
Bumpy Road to Design Luminosity

- Current machine issues to be solved
  - several major beam losses
    - QCS quenches
    - damage of collimators & PXD
    - unclear if caused by "dust" events
  - luminosity degradation due to vertical emittance blow-up
    - understand origin of X-Y coupling
    - develop crab-waist lattice
  - continuous injection
    - orbit stability of injected beams
  - bunch current stability (RF gun)

- Belle II beam background
  - LER beam gas (Coulomb)
    - maximum beam current limited by CDC and TOP background
  - injection spikes and damping time
    - mainly from LER
    - CDC trips, beam aborts
  - $\beta^*_{x,y}$ squeezing in HER
    - synchrotron radiation in PXD
    - adjustment of horizontal angle at IP affects horizontal dispersion

SuperKEKB Design

<table>
<thead>
<tr>
<th></th>
<th>LER</th>
<th>HER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy [GeV]</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Crossing angle [mrad]</td>
<td>2 x 41.5</td>
<td></td>
</tr>
<tr>
<td>$I$ [A]</td>
<td>3.6</td>
<td>2.6</td>
</tr>
<tr>
<td># of bunches</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>$I_{b^+}+I_{b^-}$ [mA²]</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>$\beta^*_{x,y}$ [mm]</td>
<td>0.27, 0.30</td>
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</tr>
<tr>
<td>$\xi_{yz}$ ~ $(\beta^<em>_y/e_y)^{1/2}/\sigma^</em>_x$</td>
<td>0.09, 0.09</td>
<td></td>
</tr>
<tr>
<td>$L_{\text{spec}}$ [10³¹ cm⁻²·s⁻¹]</td>
<td>21.4</td>
<td></td>
</tr>
<tr>
<td>$L_{\text{spec}}$ [10³¹ mA²·cm⁻²·s⁻¹]</td>
<td>21.4</td>
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</tbody>
</table>

Remark: $\beta^*_y = 1.0$ mm is under tuning

SuperKEKB, Carsten Niebuhr / DESY

IAS MDI workshop, Hongkong, 16.-17.01.20: Belle II Background
Methodology of Single-Beam Studies

Observable = \( B \cdot I pZ_{eff}^2 + T \cdot \frac{I^2}{n_b \sigma_y} \) ⇒ \( \frac{I pZ_{eff}^2}{Occupancy} = B + T \cdot \frac{I}{n_b \sigma_y PZ_{eff}^2} \)

Beam gas Touschek

Example of LER single-beam study in May

- Simplifying assumption: only Touschek + Beam-gas background
  - vary beam sizes and number of bunches (which should affect Touschek component only)
  - fit T and B coefficients and compare them against MC estimate
- Use observed data/MC ratio to scale background simulation results at future optics settings
Beam Background Situation in May

- Although conditions change somewhat from day to day the general observations are:
  - LER storage background $\approx 5 \times$ HER storage background
    - dominant background source from LER beam-gas
  - Data/MC ratio
    - $O(1)$ for LER Touschek, $O(10)$ for Beam-gas
    - $>10^3$ for HER Touschek due to (too) small MC estimate

<table>
<thead>
<tr>
<th>SVD L3 Occupancy (Recent condition)</th>
<th>data</th>
<th>MC</th>
<th>data/MC</th>
</tr>
</thead>
<tbody>
<tr>
<td>LER Beam-gas 11&lt;sup&gt;th&lt;/sup&gt;</td>
<td>0.26 %</td>
<td>0.020 %</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>14&lt;sup&gt;th&lt;/sup&gt;</td>
<td>0.14 %</td>
<td>0.012 %</td>
</tr>
<tr>
<td>LER Touschek 11&lt;sup&gt;th&lt;/sup&gt;</td>
<td>0.03 %</td>
<td>0.029 %</td>
<td>1.0</td>
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<tr>
<td></td>
<td>14&lt;sup&gt;th&lt;/sup&gt;</td>
<td>0.02 %</td>
<td>0.022 %</td>
</tr>
<tr>
<td>HER Beam-gas</td>
<td>0.03 %</td>
<td>0.0016 %</td>
<td>16</td>
</tr>
<tr>
<td>HER Touschek</td>
<td>0.02 %</td>
<td>1.6e-5 %</td>
<td>1600</td>
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</tbody>
</table>
SuperKEKB Collimators

- Tasks
  - protect QCS and Belle II against background bursts
  - mitigate Touschek/Beam-gas background
- Horizontal collimators effectively reduce Touschek BG
- Vertical collimators are essential for reducing Coulomb BG
  - aperture should be narrower than QC1 aperture
    \[ \frac{d}{\sqrt{\epsilon \beta}} < \frac{r_{QC1}}{\sqrt{\epsilon \beta_{QC1}}} \Rightarrow d_{\text{max}} \propto \beta^{1/2} \]
  - avoid Transverse Mode Coupling (TMC) instability
    \[ I_{\text{thresh}} \propto \frac{1}{k_\perp} \text{ and } k_\perp \propto d^{-2/3} \Rightarrow d_{\text{min}} \propto \beta^{2/3} \]
  - choose location where phase advance wrt QC1 is small
  - distribute loss rate budget over several collimators

New vertical collimator D06V1 installed in winter shutdown: reduce loss rate at D02V1 & IP

SuperKEKB, Carsten Niebuhr / DESY
Challenge of hard > 10 keV SR, with bb very dynamic particularly at lower (LEP1, Z) energy non-gaussian tails ~ 100 collimators + masks

Backgrounds
beam-gas, thermal $\gamma$, main challenge SR changing during fill and fill to fill performance limit $\beta^*, \xi_y$ increase horizontal emittance (wiggler LEP1),

Much of the work is on details, MDI - IR design particularly important, simulation, beam-dynamics, background — benchmarked with LEP and e+e− factories, stimulating and profiting from further hardware / technology developments
### MDI parameters

<table>
<thead>
<tr>
<th>parameter</th>
<th>range</th>
<th>Peak filed in coil</th>
<th>Central filed gradient</th>
<th>Bending angle</th>
<th>length</th>
<th>Beam stay clear region</th>
<th>Minimal distance between two aperture</th>
<th>Inner diameter</th>
<th>Outer diameter</th>
<th>Critical energy (Horizontal)</th>
<th>Critical energy (Vertical)</th>
<th>SR power (Horizontal)</th>
<th>SR power (Vertical)</th>
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<tbody>
<tr>
<td>$L^*$</td>
<td>0~2.2m</td>
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<tr>
<td>Crossing angle</td>
<td>33mrad</td>
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<tr>
<td>MDI length</td>
<td>±7m</td>
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<tr>
<td>Detector requirement of accelerator components in opening angle</td>
<td>13.6°</td>
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<tr>
<td>QDa/QDb</td>
<td>2.4T</td>
<td>77.5T/m</td>
<td>1.5m</td>
<td>19.2/22.0mm</td>
<td>72.61/124.75mm</td>
<td>48mm</td>
<td>59mm</td>
<td>458.7/657.9 keV</td>
<td>271.6/36 1.5keV</td>
<td>80.9/242.3 W</td>
<td>40.3/65.5W</td>
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<tr>
<td>QF1</td>
<td>63.4T/m</td>
<td></td>
<td></td>
<td>2m</td>
<td>30.9mm</td>
<td>181.85mm</td>
<td>56mm</td>
<td>69mm</td>
<td>428.3keV</td>
<td>613.5keV</td>
<td>245.9W</td>
<td>187.5W</td>
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<tr>
<td>Lumical</td>
<td>0.95~1.11m</td>
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<tr>
<td>Anti-solenoid before QD0</td>
<td>7.26T</td>
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<tr>
<td>Anti-solenoid QD0</td>
<td>2.8T</td>
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<tr>
<td>Anti-solenoid QF1</td>
<td>1.8T</td>
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<tr>
<td>Beryllium pipe</td>
<td>±118mm</td>
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<tr>
<td>Last B upstream</td>
<td>83.69~198.7m</td>
<td></td>
<td></td>
<td>0.76mrad</td>
<td>115.01m</td>
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<tr>
<td>First B downstream</td>
<td>57.04~132.09m</td>
<td></td>
<td></td>
<td>0.72mrad</td>
<td>75.05m</td>
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<tr>
<td>Beampipe within QDa/QDb</td>
<td>1.5m</td>
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<tr>
<td>Beampipe within QF1</td>
<td>2m</td>
<td></td>
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<tr>
<td>Beampipe between QD0/QF1</td>
<td>0.23m</td>
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</table>

Sha Bai, CEPC MDI accelerator
**SYNCHROTRON RADIATION**

- Beam particles bent by magnets (last bending dipole, focusing quadrupoles) can emit synchrotron radiation photons → critical at circular machines

- **BDSim** to transport beam (core + halo) from the last dipole to the interaction region and record the particles hitting the central beryllium beam pipe

I checked with Laurie Nevay yesterday: he was not aware BDSIM build on Geant4 is used for CEPC talk here also referred to BBBrem without link nor citation

Most of them scattered by the beampipe between [1,2 m] into the central region
Hongbo Zhu

The number of collimators is shown at around 2-4. Taking into account the necessary freedom required for tuning, the number of the collimators is extremely insufficient. According to experience in other colliders such as LEP, KEKB, PEP-II, SuperKEKB, 10-20 of them may be needed per IP.

SUMMARY & OUTLOOK

• Radiation backgrounds calculated for different sources
  • Pair production, synchrotron radiation, off-energy beam particles (with collimators)

• Validate (partly) the simulation codes with background data from BEPC II, LEP II and SuperKEKB
  • Participate in the background studies for SuperKEKB/Belle II Phase III commissioning, postponed to May ...

• To include machine related backgrounds and provide updates as the machine design evolves ...

16-17 January 2020 CEPC Radiation Backgrounds, H. Zhu
Detector field compensation: elliptical

Smaller field components, emittance

<table>
<thead>
<tr>
<th>Energy, GeV</th>
<th>1</th>
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<tbody>
<tr>
<td>Qx</td>
<td>27.548</td>
</tr>
<tr>
<td>Qy</td>
<td>22.571</td>
</tr>
<tr>
<td>$\varepsilon_x$, nm*rad</td>
<td>1.20</td>
</tr>
<tr>
<td>$\varepsilon_y$, nm*rad</td>
<td>0.0005</td>
</tr>
<tr>
<td>$\varepsilon_y/\varepsilon_x$</td>
<td>0.0004</td>
</tr>
<tr>
<td>$\beta_x^*$, m</td>
<td>0.050</td>
</tr>
<tr>
<td>$\beta_y^*$, mm</td>
<td>0.50</td>
</tr>
<tr>
<td>$D_x^*$, m</td>
<td>4.9E-06</td>
</tr>
<tr>
<td>$D_y^*$, m</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Brett Parker, remote: final focus magnet for various future colliders; eIon collider goes to BNL

ILC, MDI ILC, SiD detector side: doubts if push/pull realistic, better 2xBDS?
showing (the familiar) e+e- pair Beamstrahlung, high solenoid field to keep at small radius
using (good old) Lew Keller et al MuCarlo and proposing optional magnetised shield

CLIC, Phil Burrows:
single detector just to focus studies
push-pull remains option
L* increased from 3.5 m to 6 m
also increases length of BDS