Thanks to all speakers

~20 people in session, 8 talks

All talks are available at https://indico.cern.ch/event/995633/timetable/

N3 session Monday 15.3 22:00-01.00 CET
Generalities

Approach: Provided a very loose guidance about ILC beams (injectors, DR, main linac) – mostly based presentation by Kaoru Yokoya at the LCWS 2019 (Sendai) (LINK)

- no reason to put too many limits now, in particular low energy beams can be envisaged which are not very constrained by ILC parameters

Three groups of ideas:
1. Use of low energy beams (~3 GeV) for accelerator R&D for many fields of science (including life medical sciences) but also laying the ground for ILC upgrades (improved “traditional” RF and/or plasma), testbeams and irradiation, huge training potential, can also envisage positrons production and use
2. Measurements one can do when combining a full energy ILC beam with a powerful laser, strong field QED and photon science
3. Two studies which point to new concepts, muon production studies, and an “energy recovery ILC” with very high luminosity

The two first I think should be explored in sessions in the fall workshop
The new ideas (muons, e-REC ILC) should be scrutinized by expert in the community
A generic R&D facility

CLEAR Layout & main installations

Additionally:
- Training/Schools
- Medical accelerators, VHEE and Flash RT

Wilfred Farabolini, CEA and CERN
Beams for plasma acceleration R&D

Patric Muggli, Max Planck Munich

Beamlines 50-70 m long, 1-3.5 GeV, followed by experimental area

Examples: EuPRAXIA@SPARC_Lab LNF/INFN and CERN study with compact 3.5 GeV linac (~70m)

D- and W-bunch parameters inferred from PWFA scaling to reach ~1 and ~10 GV/m accelerating fields

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{</td>
<td>H</td>
</tr>
<tr>
<td>Plasma</td>
<td>$1.2 \times 10^{24}$</td>
</tr>
<tr>
<td>Drive Bunch</td>
<td></td>
</tr>
<tr>
<td>$\gamma$</td>
<td>$&gt; 10^4$</td>
</tr>
<tr>
<td>$\sigma_x (\mu m)$</td>
<td>700</td>
</tr>
<tr>
<td>$\sigma_y (\mu m)$</td>
<td>700</td>
</tr>
<tr>
<td>$N$</td>
<td>$3 \times 10^{10}$</td>
</tr>
<tr>
<td>$Q (nC)$</td>
<td>5</td>
</tr>
<tr>
<td>Witness Bunch</td>
<td></td>
</tr>
<tr>
<td>$\gamma$</td>
<td>300</td>
</tr>
<tr>
<td>$\varepsilon_N$ (mm-mrad)</td>
<td>2</td>
</tr>
<tr>
<td>$\sigma_x (\mu m)$</td>
<td>9</td>
</tr>
<tr>
<td>$\beta_x (\mu m)$</td>
<td>12</td>
</tr>
<tr>
<td>$\sigma_y (\mu m)$</td>
<td>&lt;700</td>
</tr>
<tr>
<td>$Q (nC)$</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

Two facilities planned, opportunity to test PWFA stage for linear $e^+e^-$ collider
- eSPS injector, CERN
- SPARC_LAB linac LNF/INFN

Opportunities to address collider-related topics thanks to:
- >1 GeV D-beam energy
- Repetition rate
- Independent W-bunch ($e^-$)
- Bunch shaping
- $e^+W$-bunch
- $e^+D$-bunch + $e^+W$-bunch

D- and W-bunch parameters can be inferred from scaling
- Requires short, tight, high charge bunches

Self-consistent parameter set must be determined from numerical simulations
- Example for SLAC FACET II parameters
- Start-to-end simulations at LNF (FEL)

Bunch parameters challenging ...
- Decrease transverse size and length to lower $Q$?

Synergy with CERN/AWAKE plasma source development laboratory (eSPS)
Testbeam – Irradiation

**DESY II Test Beam Facility**

**Beam Generation & Beam lines**
- One of two user facilities offering multi-GeV test beams in Europe
  - The other one being the CERN PS&SPS
  - Worldwide: Fermilab & SLAC
- Beam Generation Carbon fiber targets in the electron beam generate bremsstrahlung photons
  - Conversion at thin metal plate target to e+e-
  - Momentum selection by dipole + collimator
  - Three individual beam lines
- Already meets many requirements
  - Energy 1-6 GeV (1-100 GeV)
  - Rate ~ 10 kHz (100 kHz)
  - Spread <5 % (a few %)
  - 1 e/ Bunch/mm² (few/bunch/mm²)
  - Independently operated
- Very reliable operation
  - Beam always available

**Summary**
- Test beams and Irradiation facilities are essential infrastructures for detector R&D
- Both enhance the ILC Laboratory in the long term
  - Attract new users to the lab
  - Broaden usage beyond ILC community
  - Train next generation
- The ILC project view
  - As these facilities will come up in parallel with the ILC, they will come very late
- The ILC as a long-term infrastructure view
  - Shows the long-term future of the ILC laboratory
- Infrastructure
  - It’s not just the beam, the infrastructure for the Users is key for its success
- Operations
  - The amount for FTE required to run such a facility is small (5-10)
  - To be successful, it has to be long-term commitment

---

**Education and Outreach with a test beam**

**E.g. at the DESY II Test Beam Facility**

- **Summer Students**
  - Since several years very successful
  - Full life-cycle: setup → data taking → analysis

- **Teacher Education**
  - Nation-wide and going in its third year
  - Test Beam as one of the “lab experiments”

- **Beam Line for Schools (BL4S)**
  - Very successful project at CERN
  - Teams of high school students can propose experiments at a beam line
  - Two winning teams can perform their experiment supported by scientists

**EDIT 2020 School for Instrumentation**

---

Marcel Stanitzki, DESY
Important need, significant user community, any large lab needs such facilities, training/education aspects, timeline to be considered carefully for initial phase

My comment: if such a beamline is build independently as part of the ILClab then the timeline can be different (for all three purposes mentioned in the last three slides)
Exploring strong field QED with ILC beams

- The QED vacuum breaks down in the presence of an electrical background field $E \gtrsim E_{cr}$.
- This corresponds to a laser intensity of $I_{cr} = c\varepsilon_0E_{cr}^2 \sim 10^{29} \text{ W/cm}^2$.
- 100 PW optical laser, focused to 10 $\mu$m results in $10^{24} \text{ W/cm}^2$ → requires ultrarelativistic particles to reach the QED critical field in a boosted frame.

Sebastian Meuren, SLAC – linking also to:

Probing Strong-field QED in beam-laser interactions

E-320: combining the 13 GeV FACET-II beam with a 20 TW laser
New Research Opportunities with Ultrahigh Intensity Lasers at the ILC

James K. Koga\textsuperscript{1}, Masaki Kando\textsuperscript{1}, Timur Zh. Esirkepov\textsuperscript{1}, Sergei V. Bulanov\textsuperscript{1,2}, Stepan S. Bulanov\textsuperscript{3}, Joel Magnusson\textsuperscript{4}, Arkady Gonoskov\textsuperscript{5}, Tom G. Blackburn\textsuperscript{6}, Mattias Marklund\textsuperscript{5}

\textsuperscript{1) KPSI, QST, Japan
\textsuperscript{2) ELI Beamlines, Czech Republic
\textsuperscript{3) LBNL, USA
\textsuperscript{4) Chalmers Univ. of Tech., Sweden
\textsuperscript{5) University of Gothenburg, Sweden

New proposal

- Using a High Intensity Laser ahead of beam dump
1. X-FEL Facilities: SACLA, LCLS, EXFEL, ... → High Power Laser systems
2. The interaction of very high energy electrons with intense lasers is one of the active research fields in high-field science!
3. LCLS and LUXE experiments → electron-positron pair creation

Peak Laser Intensity (W/cm\textsuperscript{2})

- Vacuum Breakdown (Schwinger field)
- Pair creation (Multiple Colliding pulses)
- Strong Radiation Damping, QED effects

Summary

- It is expected to generate strong gamma-rays in future linear colliders. They can be used for photon science.

Delbrück scattering: non-linear effect of QED

- Photon vortex generation and detection: photon as the eigen state of angular momentum

Proposal of light vortices by non-linear inverse Compton scattering

Theoretical calculation of photon vortex generation in high-order harmonic radiations in synchrotron radiations.

Calculation of Compton scattering with photon vortex
Brilliant muon beam production at the ILC

Takayuki YAMAZAKI*, K. Shimomura, N. Kawamura (KEK IMSS), D. Nomura, S. Makimura (KEK IPNS), Y. Kawashima (RCNP)
*takayuki@post.kek.jp

Overview

• Conventional way to produce a muon beam from a proton beam

  - Target nucleus
  - $p (\sim - GeV)$
  - $\pi^\pm$,
  - $\mu^\pm$,
  - $T = O(1-10)\ MeV$
  - $I = O(10^8)\ \mu^+ / s$
  - $\epsilon = O(10^3)\ mm^*mrad$

  - @J-PARC MLF
    - Graphite, t=2mm
    - Rotating target

• From a positron/electron beam, a low emittance and high energy muon beam can be produced.
  1. 45GeV positron beam on a fixed target
    - $e^+ (>45 GeV)$
    - EM shower
    - $\mu^+$
  2. $\gamma A \rightarrow \mu^+ \mu^\prime A$, $\gamma$ is generated via Laser Compton Scattering (LCS)

Summary

• We considered two methods to generate a muon beam from a $e^+$ beam.
  ✓ 45GeV positron on fixed target ($e^++e^-\rightarrow\mu^+ + \mu^-$)
    - $E=22.5\ GeV$, $F=3\times10^7\ \mu^+ \mu^- / s$, $\epsilon \sim 2\times10^{-4}\ mm^*mrad$
  ✓ LCS $\gamma$ from $e^-$ and laser on fixed target ($\gamma+A \rightarrow \mu^+ + \mu^- + A$)
    - $E=0\sim85\ GeV$, $F=5\times10^8\ \mu^+ \mu^- / s$, $\epsilon \sim 0.3\ mm^*mrad$

• These beams have much higher energy and much lower emittance compared to the conventional muon beams generated from proton beams. Applications like radiography and large structure analysis are promising.

Comparison

<table>
<thead>
<tr>
<th></th>
<th>~1GeV $p$</th>
<th>45GeV $e^+$</th>
<th>LCS $\gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinetic energy (GeV)</td>
<td>$10^{-3}$</td>
<td>22.5</td>
<td>0~85GeV</td>
</tr>
<tr>
<td>Energy width (%)</td>
<td>10</td>
<td>20</td>
<td>broad</td>
</tr>
<tr>
<td>Emittance (mm*mrad)</td>
<td>$O(10^3)$</td>
<td>$O(10^6)$</td>
<td>$O(0.1)$</td>
</tr>
<tr>
<td>Flux (/s)</td>
<td>$10^8$</td>
<td>$3 \times 10^7$</td>
<td>$5 \times 10^8$</td>
</tr>
<tr>
<td>Others</td>
<td>$\mu^+ \mu^-$</td>
<td>$\mu^+ \mu^-$</td>
<td>$\mu^+ \mu^-$</td>
</tr>
</tbody>
</table>

• Conventional method is suitable for material sciences like $\mu$SR or element analysis using muonic X rays which needs muons to stop in a sample.

• A low emittance and high energy muon beam is suitable for radiography of large structure, which is currently conducted using cosmic ray muons. And input to muon collider?

• $e^+ & fixed target$ is best to generate a low emittance beam, but "LCS method” is better in intensity.
The proposed LC scheme

1) LC consists of two parallel SC linac connected with each other with rf-couplers, so that the fields are equal at any time. One line is for acceleration, the other for deceleration.

2) Damping is provided by wigglers (no damping rings) at the “return” energy about E~5 GeV. The energy loss per turn dE/E~1/100. Damping is needed to reduce the energy spread arising from collision of beams.

3) In the presence of a return path, e+ and e- are always correctly focused by their own FF.

4) The duration of one cycle (several seconds) is determined by the refrigeration system (rise of temperature on ~0.1 K at 1.8 K).

Total power

For N=2 \times 10^{10}, d=3 m, DC=1/3, 2E=250 GeV.

\[ L = 10^{36} \text{ cm}^{-2} \text{s}^{-1} \]

The number of circulating bunches \( n_b = 2 \times (30 \text{ km}/3 \text{ m}) = 2 \times 10^4 \) (both beams). If bunches are prepared once per >3 s, the average power for beam generation (with ε=10%) will be less than 10 MW.

Radiation in wigglers \( P_{SR} \sim 6 \text{ MW} \) (with ε~50%).

Refrigeration power \( P_{ref} \sim 110 \text{ MW} \)

The total wall plug power ~130 MW

Unclear questions:

• minimum distance between bunches (wakefields, high harmonics)
• RF-coupling between linacs
Three groups of ideas:

1. Use of low energy beams (~3 GeV) for accelerator R&D for many fields of science (including life medical sciences) but also laying the ground for ILC upgrades (improved “traditional” RF and/or plasma), testbeams and irradiation, huge training potential, can also envisage positrons production and use

2. Measurements one can do when combining a full energy ILC beam with a powerful laser, strong field QED and photon science

3. Two studies which point to new concepts, muon production studies, and an “energy recovery ILC” with a very high luminosity

The two first could be explored in sessions in the fall workshop (needs to be prepared)

The new ideas (muons, e-REC ILC) should be scrutinized by expert in the community