Detector at ILC

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TIFR, Mumbai,
Aug 2, 2019
Jet Energy Measurement (quark reconstruction):

- Charged particles
  - Use trackers
- Neutral particles
  - Use calorimeters
- Remove double-counting of charged showers
  - Requires high granularity

Jet energy resolution ~ ½ of LHC

<table>
<thead>
<tr>
<th></th>
<th>ECAL</th>
<th>HCAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILC (ILD)</td>
<td>100M</td>
<td>10M</td>
</tr>
<tr>
<td>LHC</td>
<td>76K(CMS)</td>
<td>10K(ATLAS)</td>
</tr>
</tbody>
</table>

Granularity:
X10^3 for ILC wrt LHC
Need new technologies!
(Si pads, GEM, RPC, etc.)
Two ILC Detector Concepts

Basic Strategies:

- **SiD**
  - High B field (5 T)
  - Small ECAL ID
  - Small calorimeter volume
    - Finer ECAL granularity
  - Silicon main tracker

- **ILD**
  - Medium B field (3.5 T baseline)
  - Large ECAL ID
    - Particle separation
  - TPC for main tracker

Both are based on PFA idea
Detector Hall and Push-Pull

‘Mountain site’ experimental hall Design
General Considerations (1)

- **Calorimeters inside solenoid**
  - For good jet reconstruction (track-cluster matching)

- **Low mass for tracking&vertexing**
  - Thin silicon sensors
    - e.g. ~50 µm for pixel vertex detectors
  - Light support structures
    - e.g. advanced endplate for TPC main tracker

- **High granularity esp. for calorimeters&vertexing (PFA)**
  - Fine-granularity calorimeter readout: new technologies
    - Technologies: Silicon pad, SiPM, RPC, GEM etc.
  - State-of-the-art pixel technologies for vertexing
    - Technologies: CMOS, FPCCD, DEPFET, SOI, 3D...
  - Front-end electronics embedded in/near the active area (cabling!)
General Considerations (2)

- As hermetic as possible
  - Forward calorimetry/tracking important

- Vertex detector as close as possible to beam
  - Limit: e+e- pair background

Density of pairs near IP
- High B field helps
- Worse for aggressive beam parameters
- Worse for high $E_{CM}$

- Low heat generation (cooling eats up material budget)
  - Low-power front-end electronics
  - Power pulsing
    - Turn off power during bunch train gap

<table>
<thead>
<tr>
<th>#bunch/train</th>
<th>train length</th>
<th>train gap</th>
<th>duty factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILC</td>
<td>1312</td>
<td>727µs</td>
<td>200ms</td>
</tr>
</tbody>
</table>
Anti-DID

Purpose:
make the solenoid field parallel to the outgoing beam so that pairs will proceed tightly around the beamline

Originally, DID was designed to make the field parallel to the incoming beams so that precession does not cause polarization loss. Not a big problem.

Anti-DID is a baseline: is it really needed? – more studies!
• **B**: 3.5 T baseline
• **Vertex pixel detectors**
  – 6 (3 pairs) or 5 layers
  – Technology open
• **Si-strip trackers**
  – 2 barrel + 7 fwd disks/side
    (2 of the disks are pixel)
  – Outer and endcap of TPC
• **TPC**
  – GEM or MicroMEGAS for amp.
  – Pad (or si-pixel) readout
• **ECAL**
  – Si-W or Scint-W (or hybrid)
• **HCAL**
  – Scint-tile or (semi)Digital-HCAL

All above inside solenoid
SiD Choices

• **B: 5T**

• Vertex pixel detectors
  – 5 barrel lyr +
    – (7 fwd disks)/side
  – Technology open (incl. 3D)

• **Si-strip-trackers**
  – 5 barrel lyr + 4 forward disks/side

• **EMCAL**
  – Si-W 30 lyr, pixel ~\((4\text{mm})^2\)

• **HCAL**
  – Digital HCAL with **RPC** or **GEM** with \((1\text{cm})^2\) cell
  – 40 lyr

All above inside solenoid
ILC Detector Performances

- **Vertexing**
  \((h \rightarrow b\bar{b}, c\bar{c}, \tau^+\tau^-)\)
  
  - \(\sim 1/3 \ r_{\text{beam}}\), \(1/50\sim1/1000\) pixel size, \(\sim 1/10\) resolution (wrt LHC)
  
  \[ \sigma_{IP} = 5 \oplus \frac{10}{p \sin^{3/2} \theta} (\mu m) \]

- **Tracking**
  \((e^+e^- \rightarrow Zh \rightarrow \ell^+\ell^- X; \text{ incl. } h \rightarrow \text{nothing})\)
  
  - \(\sim 1/6\) material, \(\sim 1/10\) resolution (wrt LHC)
  
  \[ \sigma(1/p) = 2 \times 10^{-5} (\text{GeV}^{-1}) \]

- **Jet energy** (quark reconstruction by PFA)
  
  - \(1000\times\) granularity, \(\sim 1/2\) resolution (wrt LHC)
  
  \[ \sigma_E / E = 0.3 / \sqrt{E (\text{GeV})} \quad \text{or } 3\sim4\% \text{ for } 50 - 250 \text{ GeV} \]

Above performances achieved in realistic simulations based on actual detector R&Ds.
Recoil mass resolution

- Momentum resolution far above current state-of-the-art is required.

\[ e^+ e^- \rightarrow ZH/ZZ \rightarrow l\bar{l} X \]

\( \sqrt{s} = 300 \text{ GeV} \)

\[ \int L \, dt = 500 \text{ fb}^{-1} \]

\[ \Delta E/E \sim 0.1\% \]

\[ \Delta P_T / P_T^2 = 5 \times 10^{-5} \]

\[ \Delta P_T / P_T^2 = 20 \times 10^{-5} \]

Higgs signal
Jet(quark) reconstruction

\[ e^+ e^- \rightarrow \nu \bar{\nu} WW, \nu \bar{\nu} ZZ \quad W/Z \rightarrow jj \]

\[ \sigma_E/E = 0.6/\sqrt{E} \text{ (GeV)} \quad \text{ILC} \]

\[ \sigma_E/E = 0.3/\sqrt{E} \text{ (GeV)} \quad \text{Current} \]

\[ \sigma_E/E = 0.3/\sqrt{E} \quad \text{is required for } Z/W \rightarrow jj \text{ to be separated} \]
Impact parameter resolution

- Belle
- ATLAS
- LHCb
- Alice

Graph showing the impact parameter resolution for different experiments (Belle, ATLAS, LHCb, Alice) as a function of $p_T$ (GeV). The graph includes data points and simulation results for each experiment.
Jet energy resolution

Jet Energy Resolution $\sigma / E_{\text{jet}}$ (%) versus Jet Energy (GeV)

- ILC goal
- ATLAS simulation
- H1 measured
- CDF measured
- ALEPH measured
- DREAM measured
- PFA simulation
ILD: Re-optimizing

- Large version (ILD-L): baseline
  - \( B = 3.5 \, \text{T} \)
  - \( R_{\text{TPC}} = 1.8 \, \text{m} \)
- Small version (ILD-S)
  - \( B = 4 \, \text{T} \)
  - \( R_{\text{TPC}} = 1.46 \, \text{m} \)

Summary of post TDR efforts
⇒ IDR (ILD Design Report) being finalized
<table>
<thead>
<tr>
<th>CMS</th>
<th>Inner Radius</th>
<th>SiD (DBD)</th>
<th>ILD_L (DBD)</th>
<th>CLICdp</th>
<th>ILD_S</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Vertex (mm)</td>
<td>14</td>
<td>16</td>
<td>31</td>
<td>16</td>
</tr>
<tr>
<td>1.3</td>
<td>ECAL (m)</td>
<td>1.3</td>
<td>1.8</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>3.0</td>
<td>Coil (m)</td>
<td>2.6</td>
<td>3.4</td>
<td>3.5</td>
<td>3.1</td>
</tr>
<tr>
<td>3.8</td>
<td>B-field (T)</td>
<td>5</td>
<td>3.5</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

For reference
- Compact design
- Expanded design
- Intermediate tracker size, deeper calo for up to 3 TeV
- Same B and tracker size as CLICdp, should allow comparison of TPC and Si tracker

**NB**: all 3 consortia now use the same software environment → should ease comparison of performances
Linear Collider Detector R&D Report

http://linearcollider.web.cern.ch/physics-detectors/working-group-detector-rd-liaison

- By LCC Physics and Detectors
- Summary of LC-related detector R&D efforts
- For each effort, it describes
  - Introduction
  - Institutions involved
  - Milestones achieved
  - Challenges
  - Future plans
- Continuously updated
Vertex Detectors
# Vertex detectors

## Categories of candidate technologies

<table>
<thead>
<tr>
<th>Monolythic pixel</th>
<th>(3D) Vertically integrated</th>
<th>Hybrid pixel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Examples</strong></td>
<td>DEPFET, FPCCD, MAPS, HV-CMOS</td>
<td>SOI, MIT-LL, Tezzaron, Ziptronix</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td>Often Specialised HEP processes where r/o and</td>
<td>Rapidly developing industry-driven: way of</td>
</tr>
</tbody>
</table>

- **Smaller pixels**: High level of pixel functionality
- **Thinner detectors**: Fast time-stamping
<table>
<thead>
<tr>
<th>Institutions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronopix</td>
<td>University of Oregon&lt;br&gt;Yale University&lt;br&gt;Sarnoff Corporation</td>
</tr>
<tr>
<td>CMOS MAPS</td>
<td>IPHC Strasbourg&lt;br&gt;DESY, Hamburg&lt;br&gt;University of Bristol&lt;br&gt;University of Frankfurt</td>
</tr>
</tbody>
</table>
### Vertex Technologies (2)

<table>
<thead>
<tr>
<th>Insitutions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPFET</td>
<td>The DEPFET technology integrates a p-MOS transistor in each pixel on the fully depleted, detector-grade bulk silicon. Additional n-implants near the transistor act as a trap for charge carriers created in the substrate (internal gate), so that they are collected beneath the transistor gate. (→ Belle II)</td>
</tr>
<tr>
<td>U of Barcelona, Spain</td>
<td></td>
</tr>
<tr>
<td>U of Bonn, Germany</td>
<td></td>
</tr>
<tr>
<td>Heidelberg U, Germany</td>
<td></td>
</tr>
<tr>
<td>Giessen U, Germany</td>
<td></td>
</tr>
<tr>
<td>U of Göttingen</td>
<td></td>
</tr>
<tr>
<td>KIT Karlsruhe, Germany etc. ..</td>
<td></td>
</tr>
<tr>
<td>FPCCD</td>
<td>Fine Pixel CCD sensors have pixel sizes of 5 μm and a fully depleted epitaxial layer with a thickness of 15 μm. Read out during train gaps.</td>
</tr>
<tr>
<td>KEK</td>
<td></td>
</tr>
<tr>
<td>Shinshu U</td>
<td></td>
</tr>
<tr>
<td>Tohoku U</td>
<td></td>
</tr>
<tr>
<td>JAXA</td>
<td></td>
</tr>
</tbody>
</table>
## Vertex Technologies (3)

<table>
<thead>
<tr>
<th>Insitutions</th>
<th>Description</th>
</tr>
</thead>
</table>
| **3D Pixels**                    | Brown U, Cornell U  
Fermilab, Northern Illinois U  
SLAC  
U of Illinois Chicago  
3D technology uses very fine pitch (4 μm) integration of sensors with multiple layers of electronics with interconnection of both the top and bottom of devices with vias. Provides techniques for low mass, thin devices. (way of the future?) |
| **SOI**                          | KEK  
U of Tsukuba  
Tohoku U  
Osaka U  
In the Silicon-On-Insulator (SOI) technology the sensing and processing functionalities are separated in different layers ('semi-3D'); the sensing is provided by a high-resistive substrate connected through an insulating layer with the processing layer. |
| **CLICPix**                      | Cambridge U, CERN  
U of Geneva, KIT  
U of Liverpool, SLAC  
ISS Bucharest,  
Spanish Network for Linear Colliders  
Hybrid pixel-detector technology comprising fast, low-power and small-pitch readout with timing capability. ASICs implemented in 65 nm CMOS technology (CLICpix) coupled to ultra-thin planar or active HV-CMOS sensors via low-mass interconnects. |
Tracking Detectors
Gaseous trackers: TPC (Time Projection Chamber)

Measure 2D location and time of hits → 3D reconstruction of track
GEM (Gas Electron Multiplier)

- Two copper foils on both sides of kapton layer of ~50µm thick
- Amplification at the holes
- Gain~$10^4$ for 500V
- Can be used multi-staged reduces ion/photon feed back

p~140µm  
D~60µm
MicroMEGAS
(MicroMEsh GAseous Structure)

- Micromesh with pitch ~ 50µm
- Pillar height ~ 50-100µm
- Amplification between mesh and pads/strips
- Most ions return to mesh.
## Main Trackers (1)

**Gaseous trackers (TPC)**

Much of R&Ds by LCTPC collaboration

<table>
<thead>
<tr>
<th>Insitutions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Asian GEM</strong></td>
<td>Saga, KEK, Hiroshima, Kindai, Kogakuin, Iwate, Nagasaki IAS, Tsinghua Design of an endcap readout module with a stack of two thicker laser etched polymer-based GEMs and pads.</td>
</tr>
<tr>
<td><strong>GEM</strong></td>
<td>CEA Saclay Carleton Design of an endcap readout module with a stack of three standard CERN GEMs and pads.</td>
</tr>
<tr>
<td><strong>Micromegas</strong></td>
<td>CEA Saclay Carleton Design of an endcap readout module with a Micromegas gas amplification stage, a resistive layer for charge dispersion and integrated readout. Construction of 11 modules.</td>
</tr>
<tr>
<td><strong>GridPix (Si pixel)</strong></td>
<td>Bonn, NIKHEF, CEA Saclay Bonn, Siegen Design of an endcap readout module with a highly pixelized 1s pixel readout with GridPixes. Micromegas mesh built by postprocessing technology on a pixel ASIC (Alternatively a GEM-stack).</td>
</tr>
<tr>
<td>Institutions</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Long-Ladder</td>
<td>UC Santa Cruz</td>
</tr>
<tr>
<td>Micro-strips</td>
<td>CSIC, Spain</td>
</tr>
<tr>
<td>KPiX</td>
<td>LAC</td>
</tr>
<tr>
<td></td>
<td>UC Irvine</td>
</tr>
<tr>
<td></td>
<td>U Oregon</td>
</tr>
</tbody>
</table>
Calorimeters
Most of the R&Ds in the framework of the CALICE collaboration
## Calorimeters (1)

<table>
<thead>
<tr>
<th>Scintillator ECAL</th>
<th>Institutions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nihon Dental U, Shinshu U, Tokyo U, Tsukuba U</td>
<td>ECAL with scintillator strips (or combination of pads and strips) read out by MPPC(SiPM).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Silicon ECAL</th>
<th>Institutions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U of Birmingham, U of Bristol, Imperial College London, Queen Mary, U of London, RAL</td>
<td>High granularity ECAL ($\approx 4000$ channels/dm³ read out by square matrix of about $5 \times 5$ mm² PIN diode pixels produced from one hi-res Si wafer. 4 sensors are glued to PCB holding fully integrated readout electronics and passive cooling. Absorber: self-supporting modular tungsten in carbon-fiber structure. (inspired CMS HGCAL)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AHCAL (analog HCAL)</th>
<th>Institutions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DESY, Heidelberg, MPI Munich, Wuppertal, Mainz, Omega, CERN, ITEP, MEPHI, Dubna, Prague, NIU, Tokyo U, Bergen, Shinshu</td>
<td>The analog hadron calorimeter is based on small plastic scintillator tiles read out with SiPM. It uses fully integrated electronics with power pulsing, auto-trigger and time-stamping capability.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DECAL (digital ECAL)</th>
<th>Institutions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bonn, NIKHEF, CEA Saclay, Bonn, Siegen</td>
<td>Monolithic active pixel sensors (MAPS) for the readout of the silicon-tungsten ECAL. The pixels are small enough to count the number of secondary particles of the particle shower, hence the digital calorimeter.</td>
</tr>
<tr>
<td>Institutions</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>SDHCAL (micromegas)</td>
<td>Micromegas signal is proportional to the energy deposit in the gas. To avoid discharge upon very large energy deposits, it now incorporates resistive elements on the readout electrodes.</td>
<td></td>
</tr>
<tr>
<td>GEM DHCAL</td>
<td>U Texas Arlington</td>
<td></td>
</tr>
<tr>
<td>Dual Readout (RD5)</td>
<td>Texas Tech, Iowa State INFN (Pavia, Pisa, Cagliari, Rome, Cosenza, Lecce) LIP Lisbon, CERN, Tufts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measure scintillation and Cerenkov light independently in optical fibers and measure neutron content event-by-event. Current small modules are dominated by lateral leakage. (→ CEPC)</td>
<td></td>
</tr>
</tbody>
</table>
## Calorimeters (2)

<table>
<thead>
<tr>
<th>Institutions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEM DHCAL</td>
<td>U Texas Arlington</td>
</tr>
<tr>
<td>Dual Readout (RD5)</td>
<td>Texas Tech, Iowa State INFN (Pavia, Pisa,Cagliari, Rome, Cosenza, Lecce) LIP Lisbon, CERN, Tufts</td>
</tr>
</tbody>
</table>

Other important R&Ds: Forward calorimetry, Muon system, software
Summary

• Unprecedented resolutions required for ILC Detectors
• PFA is an effective guiding principle for design
  Low-mass and high granularity are the keys
• To realize the goals, new technologies are needed
  Already many applications other than ILC
• Since the TDR in 2012, many progresses have been made
• Still there are many holes in the R&Ds
  (Silicon trackers, muon system, and many others)
• Now is the good time to plug in to ILC detector R&Ds
  (joining too late makes it difficult to take on attractive technologies)
Backups
TPC => Si pixel readout

- Ultra high granularity (~50 µm)
- Prototype INGRID production (at IZM)
- New reconstruction software needed

Source illumination near centre of the chip
### ILC 250 Higgs Factory

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Unit</th>
<th>Initial</th>
<th>$\mathcal{L}$ Upgrade</th>
<th>TDR</th>
<th>Upgrades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre of mass energy</td>
<td>$\sqrt{s}$</td>
<td>GeV</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>500</td>
</tr>
<tr>
<td>Luminosity</td>
<td>$\mathcal{L}$</td>
<td>$10^{34}$ cm$^{-2}$s$^{-1}$</td>
<td>1.35</td>
<td>2.7</td>
<td>0.82</td>
<td>1.8/3.6</td>
</tr>
<tr>
<td>Polarisation for $e^-$($e^+$)</td>
<td>$P_-$($P_+$)</td>
<td>80% (30%)</td>
<td>80% (30%)</td>
<td>80% (30%)</td>
<td>80% (30%)</td>
<td>80% (20%)</td>
</tr>
<tr>
<td>Repetition frequency</td>
<td>$f_{\text{rep}}$</td>
<td>Hz</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Bunches per pulse</td>
<td>$n_{\text{bunch}}$</td>
<td>1</td>
<td>1312</td>
<td>2625</td>
<td>1312</td>
<td>1312/2625</td>
</tr>
<tr>
<td>Bunch population</td>
<td>$N_e$</td>
<td>$10^{10}$</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Linac bunch interval</td>
<td>$\Delta t_b$</td>
<td>ns</td>
<td>554</td>
<td>366</td>
<td>554</td>
<td>554/366</td>
</tr>
<tr>
<td>Beam current in pulse</td>
<td>$I_{\text{pulse}}$</td>
<td>mA</td>
<td>5.8</td>
<td>5.8</td>
<td>8.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Beam pulse duration</td>
<td>$t_{\text{pulse}}$</td>
<td>$\mu$s</td>
<td>727</td>
<td>961</td>
<td>727</td>
<td>727/961</td>
</tr>
<tr>
<td>Average beam power</td>
<td>$P_{\text{ave}}$</td>
<td>MW</td>
<td>5.3</td>
<td>10.5</td>
<td>10.5</td>
<td>10.5/21</td>
</tr>
<tr>
<td>Norm. hor. emitt. at IP</td>
<td>$\gamma \epsilon_x$</td>
<td>$\mu$m</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Norm. vert. emitt. at IP</td>
<td>$\gamma \epsilon_y$</td>
<td>nm</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>RMS hor. beam size at IP</td>
<td>$\sigma_x$</td>
<td>nm</td>
<td>516</td>
<td>516</td>
<td>729</td>
<td>474</td>
</tr>
<tr>
<td>RMS vert. beam size at IP</td>
<td>$\sigma_y$</td>
<td>nm</td>
<td>7.7</td>
<td>7.7</td>
<td>7.7</td>
<td>5.9</td>
</tr>
<tr>
<td>Luminosity in top 1%</td>
<td>$\mathcal{L}_{0.01}/\mathcal{L}$</td>
<td></td>
<td>73%</td>
<td>73%</td>
<td>87.1%</td>
<td>58.3%</td>
</tr>
<tr>
<td>Energy loss from beamstrahlung</td>
<td>$\delta_{\text{BS}}$</td>
<td></td>
<td>2.6%</td>
<td>2.6%</td>
<td>0.97%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Site AC power</td>
<td>$P_{\text{site}}$</td>
<td>MW</td>
<td>129</td>
<td>122</td>
<td>163</td>
<td>163</td>
</tr>
<tr>
<td>Site length</td>
<td>$L_{\text{site}}$</td>
<td>km</td>
<td>20.5</td>
<td>20.5</td>
<td>31</td>
<td>31</td>
</tr>
</tbody>
</table>

**TABLE I:** Summary table of the ILC accelerator parameters in the initial 250 GeV staged configuration (with TDR parameters at 250 GeV given for comparison) and possible upgrades. A 500 GeV machine could also be operated at 250 GeV with 10 Hz repetition rate, bringing the maximum luminosity to $5.4 \cdot 10^{34}$ cm$^{-2}$s$^{-1}$ [10].
Luminosity vs Energy

- FCCee/CEPC points are for 1 IP (their CDR have 2 IPs)
- LC Higgs Factory numbers do not include effective $x \sim 2.5$ by polarization
- ILC 10 Hz collision requires $\sim$ILC500