Emergency information

Fire

• Evacuate. Be aware of building exits.
• Follow building residents to the assembly area.
• Do not leave until you are accounted for, and have been instructed to.

Earthquake

• Remain in building: duck, cover, and hold position.
• When shaking stops: evacuate building via a safe route to the assembly area.
• Do not leave until you are accounted for, and have been instructed to do so.
Please remember...

- Vehicle-related accidents can and have happened here.

- We have uncommon hazards including construction projects, industrial vehicles, electric carts, and pedestrians any time of the day or night.

- Please obey the traffic rules, look out for bicyclists and pedestrians and exercise caution – especially when backing up.
BIG, a Future Gamma-Ray Source at FACET-II

FACET-II Science Opportunities Workshops
12-16 October, 2015
SLAC National Accelerator Laboratory
Menlo Park, CA

V. Yakimenko
FACET Project History

ARRA Funded Project $14.6M + $12M AIP

Primary Goal:
- Demonstrate a single-stage high-energy plasma accelerator for electrons

Timeline:
- CD-0 2008
- CD-4 2012, Commissioning (2011)
- Experimental program (2012-2016)

A National User Facility:
- Externally reviewed experimental program
- 150 Users, 25 experiments, 8 months/year operation

Key PWFA Milestones:
- Mono-energetic $e^-$ acceleration
- High efficiency $e^-$ acceleration
- First high-gradient $e^+\text{ PWFA}$
- Demonstrate required emittance, energy spread (FY16)

Premier R&D facility for PWFA: Only facility capable of $e^+$ acceleration
Highest energy beams uniquely enable gradient $> 1 \text{ GV/m}$
PWFA Staff Participates in Nearly Every FACET Experiment

Proposal selection through peer reviewed proposal process like in any other user facility

- Plasma Wake Imaging
- THz
- Hollow Channel (400μm ID)
- Sub-ps EOS
- Ionization
- Crystal Channeling of e+
- SMI PWFA
Planning for FACET-II

• FACET will stop running in April 2016
• Lab will then salvage needed equipment from first kilometer of linac
• Then will make it cold, dark and dry…and completely clean it out
• Over the next few years will build a new superconducting linac for LCLS-II
• At the same time we will upgrade middle kilometer for FACET-II

- electron beam photoinjector (e⁻ beam only) FY17-19
- positron damping ring (e⁺ or e⁻ beams) FY18-20
- “sailboat” chicane (e⁺ and e⁻ beams) FY20
FACET-II Plan

Timeline:
- Nov. 2013, FACET-II proposal, Comparative review
- CD-0 Aug. 2015
- CD-1 Oct. 2015
- CD-4 2022
- Experimental program (2019-2026)

Key R&D Milestones:
- Staging with witness injector
- High brightness beam generation, preservation, characterization
- e+ acceleration in e- driven wakes
- Generation of high flux THz and gamma radiation

Three stages:
- Photoinjector (e- beam only) FY17-19
- e+ damping ring (e+ or e- beams) FY18-20
- “sailboat” chicane (e+ and e- beams) FY19-20

FACET-II will enable research for a broad user community
See talk by M.Hogan and Workshops: Oct.12-19 2015, SLAC
FACET II: High Gradient Acceleration – High Brightness Beams – Novel Radiation Techniques

Plasma bubble act as ultra-high-brightness electron source with $\varepsilon \approx 10^{-9} \, \pi \text{mm mrad}$

Compact high gradient plasma accelerator

Polarized gamma beams
2 MeV - 4 GeV with high flux $10^9 - 10^{11} \, \gamma/\text{sec}$ for diverse research programs
**FACET-II Stage I**  
**FY17-19**

- **Goal:** deliver compressed electron beam to experiments in S20
- **Major upgrade:** Electron beam photoinjector in Sector 10
- **Scope:** Injector, Shielding wall in S10, X-band linearizer, Bunch Compressors in S11 (BC1) and S14 (BC2), beam diagnostics, upgrade to experimental area
FACET-II Stage II

**Goal:** deliver compressed positron beam to experiments in S20

**Major upgrade:** positron damping ring

**Scope:** damping ring, positron bunch compressor & return line
FACET-II Stage III (removed from scope)

- **Goal:** deliver electron and positron beams to experiments in S20
- **Major upgrade:** Sailboat chicane
- **Scope:** Sailboat chicane
### Proposed Key Performance Parameter Summary

<table>
<thead>
<tr>
<th>Description of Scope</th>
<th>Units</th>
<th>Threshold KPP</th>
<th>Objective KPP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beam Energy</strong></td>
<td>[GeV]</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td><strong>Bunch Charge (e-/e+)</strong></td>
<td>[nC]</td>
<td>0.1/0.1</td>
<td>2/1</td>
</tr>
<tr>
<td><strong>Final Normalized Emittance (e-/e+)</strong></td>
<td>[µm]</td>
<td>50/50</td>
<td>20/20</td>
</tr>
<tr>
<td><strong>Bunch Length (e-/e+)</strong></td>
<td>[µm]</td>
<td>100/100</td>
<td>20/20</td>
</tr>
</tbody>
</table>

- The threshold KPPs are the minimum parameters against which the project’s performance is measured when complete.
- The objective KPPs are the desired operating parameters that the project will design to with the intent that those may be achieved during steady operation.
- Taking performance from Threshold to Objective requires operations staff time to optimize accelerator performance, but does not require further capital investment.

Objective KPP will support the majority of the proposed science program. FACET-II flexibility allows other optimizations to meet User needs.
Layout of the ICS at BNL

- More than $10^8$ of x-rays were registered in the experiment $N_x/N_e \sim 0.35$.
- 0.35 was limited by laser/electron beams diagnostics.
- Interaction point with high power laser focus of $\sim 30\mu m$ was tested.
- Nonlinear limit (more than one laser photon scattered from electron) was verified.

Measured CCD images
Nonlinear and linear x-rays
BIG: Beams of Intense Gamma-rays at FACET-II

- Generating gamma beams at facet with Compton back scattering of 10µm, 800µm and 400µm laser beams
  - Energy range: 2 MeV - 4 GeV
  - Flux $10^9 - 10^{11}$ /sec;
  - Nearly 100% polarization
- Modes of operations:
  - High peak flux – single burst per pulse
  - High duty factor – trains of ~ 1,000 bunches
  - White (un-collimated) and mono-energetic (collimated) gamma-rays
  - Linear, circular, elliptical polarization

High-energy beam combined with state of the art laser systems deliver unprecedented combination of gamma-ray energy and flux
### Comparing BIG with other Compton Sources

<table>
<thead>
<tr>
<th>Name</th>
<th>ROKK</th>
<th>GRAAL</th>
<th>LEPS</th>
<th>HI$\gamma$S</th>
<th>BIG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Novosibirsk, Russia</td>
<td>Grenoble, France</td>
<td>Harima, Japan</td>
<td>Durham, US</td>
<td>Menlo Park, US</td>
</tr>
<tr>
<td>Accelerator</td>
<td>VEPP-4M</td>
<td>ESRF</td>
<td>SPRING-8</td>
<td>Duke SR</td>
<td>SLAC</td>
</tr>
<tr>
<td>e-beam, GeV</td>
<td>1.4 - 6</td>
<td>6</td>
<td>8</td>
<td>0.24 – 1.2</td>
<td>1-10</td>
</tr>
<tr>
<td>$\gamma$-beam, GeV</td>
<td>0.1-1.6</td>
<td>0.55-1.5</td>
<td>1.5-2.4</td>
<td>0.001-0.095</td>
<td>0.001-2 (5)</td>
</tr>
<tr>
<td>best $\gamma$–energy resolution, %</td>
<td>1-3</td>
<td>1.1</td>
<td>1.25</td>
<td>0.8-10</td>
<td>0.1</td>
</tr>
<tr>
<td>Maximum total flux, $\gamma$/sec</td>
<td>$10^6$</td>
<td>$3\times10^6$</td>
<td>$5\times10^6$</td>
<td>$3\times10^9$, E&lt;20 MeV</td>
<td>$10^{11}$ (10$^{10}$)</td>
</tr>
</tbody>
</table>

BIG is a superior source:

- Few thousand-fold $\gamma$–ray energy span from MeV to GeV
- About 10-fold better energy resolution
- Orders of magnitude larger flux
  - two – (at energies < 20 MeV)
  - four – (at energies > 20 MeV)

Unprecedented intensities and unique time structure open new opportunities in fundamental and applied research
Positron source studies

- SLC source  
  - (working since 1980’s)  
  \( \sim 3 \times 10^{12} e^+/sec \)

- ILC needs  
  - (close to solution?)  
  \( \sim 4 \times 10^{14} e^+/sec \)

- LHeC => reduced performance  
  - (ideas?)  
  \(< 4 \times 10^{16} e^+/sec \)

- Facet-II will provide:  
  - \( \sim 4 \times 10^{11} \gamma/sec \), tunable 30-150MeV, low divergence

- Facet-II will study:  
  - New target ideas: crystal channeling, liquid metal jet…

Want GeV photons to maximize production cross-section and narrow energy spread to limit energy spread of produced positrons
# Muon source studies

<table>
<thead>
<tr>
<th></th>
<th>$N \ [\mu^+\mu^-/\text{sec}]$</th>
<th>$\varepsilon_{x,y} / \varepsilon_z$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutrino factory</td>
<td>$10^{13}-10^{14}$</td>
<td>0.5mm/?? mm</td>
</tr>
<tr>
<td>Muon collider</td>
<td>$2 \times 10^{12}$</td>
<td>25 µm/72 mm</td>
</tr>
<tr>
<td>Facet-II</td>
<td>$10^6$</td>
<td>150 µm/50 µm</td>
</tr>
</tbody>
</table>
Gamma Gamma collider

\[ E_e = 4\text{GeV} \]
\[ E_\gamma \sim 30 \text{ MeV}, \alpha \sim 0.05 \]
\[ E_{\gamma\text{cm}} \sim 1.5 \text{ MeV} \]
\[ L \sim 5 \times 10^{22} \text{ cm}^{-2} \text{ sec}^{-1} \]
\[ \sigma_{\gamma\gamma \rightarrow e^+e^-} \sim 10^{-25} \text{ cm}^2 @ 1.5 \text{MeV} \]

Will focus on technology research for gamma gamma collider.

Will test for the first time ability to generate \( e^+e^- \) pairs with real (not virtual) photons

This would be the first pair creation test using real photons
Nuclear and higher energy physics: three main areas

At low energies to study the resonant structure and states in rare nuclei. NRF & pigmy resonances. Astrophysics relevant processes (such as $^{12}\text{C}(\alpha, \gamma)$)

Intermediate energies to study spontaneous breaking of QCD’s chiral symmetry, GDH rule

High energies to study the resonant structure and spin structure in nucleons. Meson photo-production.

Broad energy range of polarized gammas opens up many areas of Nuclear Physics investigations
### Facet II beams

<table>
<thead>
<tr>
<th>Beam</th>
<th>Energy [GeV]</th>
<th>$\varepsilon_{NX} \times \varepsilon_{NY}$ $[\mu m \times \mu m]$</th>
<th>$\sigma_X \times \sigma_Y$ $[\mu m \times \mu m]$</th>
<th>$\sigma_Z \times \Delta E/E$ $[\mu m \times %]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5nC $e^{-}$</td>
<td>10</td>
<td>5 x 5</td>
<td>10 x 10</td>
<td>20 x 0.3</td>
</tr>
<tr>
<td>2nC $e^{+}$</td>
<td>10</td>
<td>30 x 3</td>
<td>20 x 20</td>
<td>20 x 0.5</td>
</tr>
</tbody>
</table>

### Lasers

<table>
<thead>
<tr>
<th>Lasers</th>
<th>Energy / Power [ Joule / TW ]</th>
<th>Rep rate [Hz]</th>
<th>$\tau$ [fs]</th>
<th>$\lambda$ [\mu m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti: Sapphire</td>
<td>1 / 30</td>
<td>30 (120)</td>
<td>30</td>
<td>0.8</td>
</tr>
<tr>
<td>CO$_2$ laser</td>
<td>0.3 / 0.3</td>
<td>120</td>
<td>1000</td>
<td>10.2</td>
</tr>
</tbody>
</table>

### Gamma beams (Inverse Compton)

<table>
<thead>
<tr>
<th>Lasers</th>
<th>Energy [GeV]</th>
<th>Intensity</th>
<th>Rep rate [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti: Sapphire</td>
<td>1.8 GeV</td>
<td>$10^{10}$</td>
<td>30 (120)</td>
</tr>
<tr>
<td>CO$_2$ laser</td>
<td>150 MeV</td>
<td>$10^{10}$</td>
<td>30 (120)</td>
</tr>
</tbody>
</table>