Emergency information

Fire

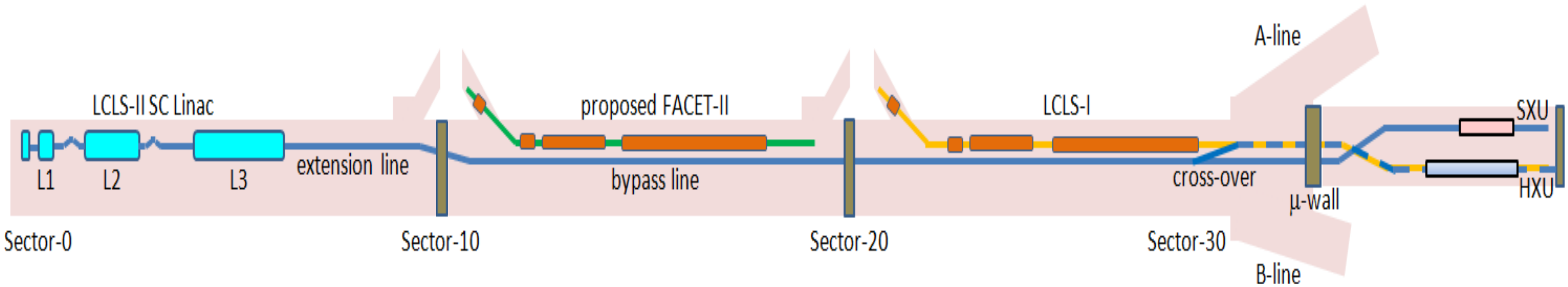
- Evacuate. Be aware of building exits.
- Follow building residents to the assembly area.
- Do not leave until you are accounted for, and have been instructed to.

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

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

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^+ PWFA

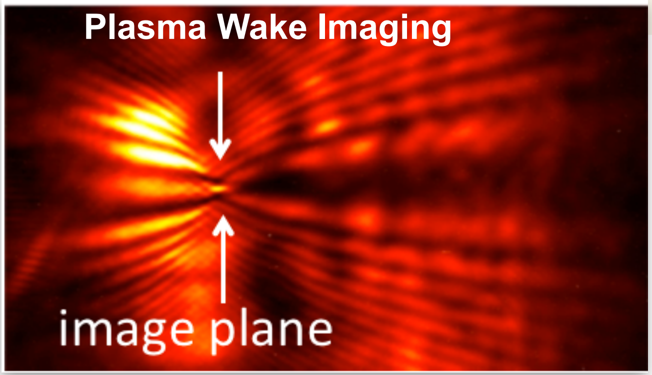
- Demonstrate required emittance, energy spread (FY16)

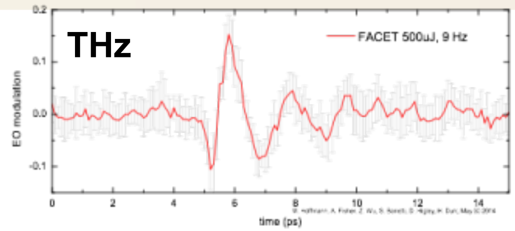
Premier R&D facility for PWFA: Only facility capable of e+ acceleration
Highest energy beams uniquely enable gradient > 1 GV/m

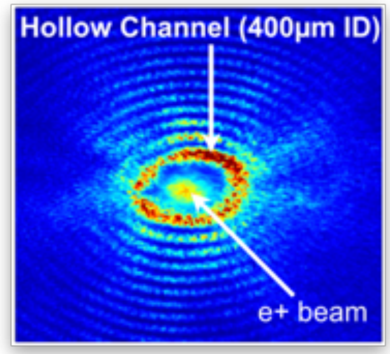
PWFA Staff Participates in Nearly Every FACET Experiment

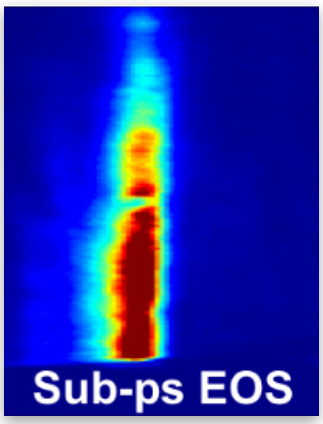
Proposal selection through peer reviewed proposal process like in any other user facility

SLAC

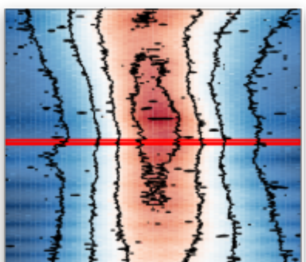




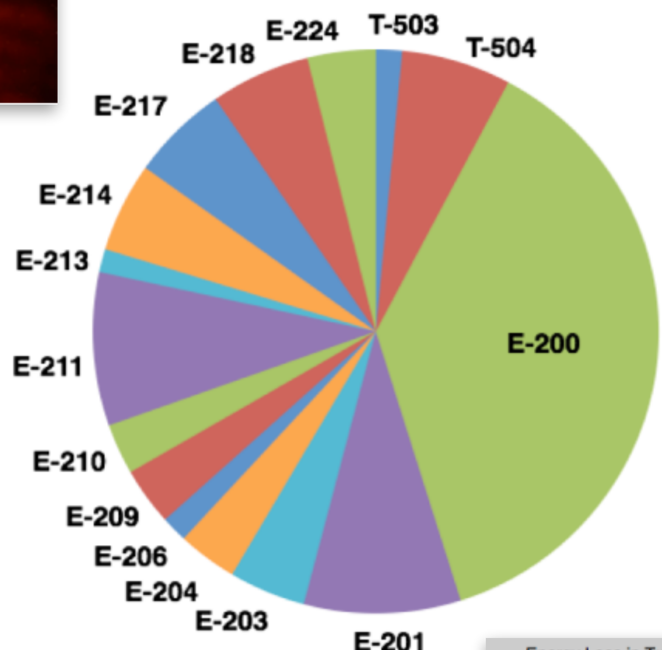


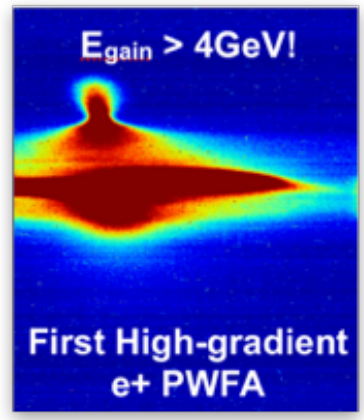


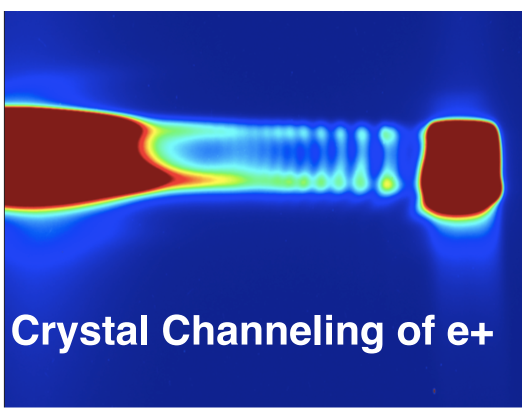
Ionization

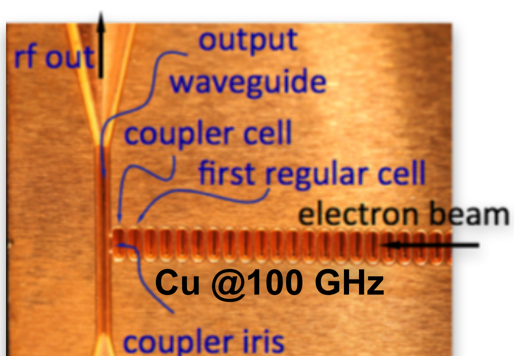


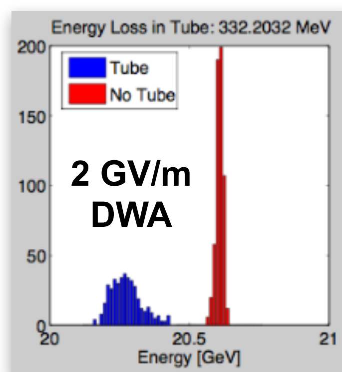
Injection

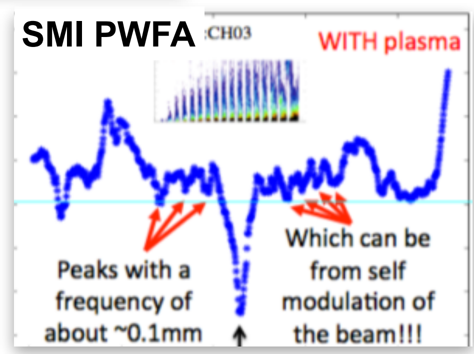






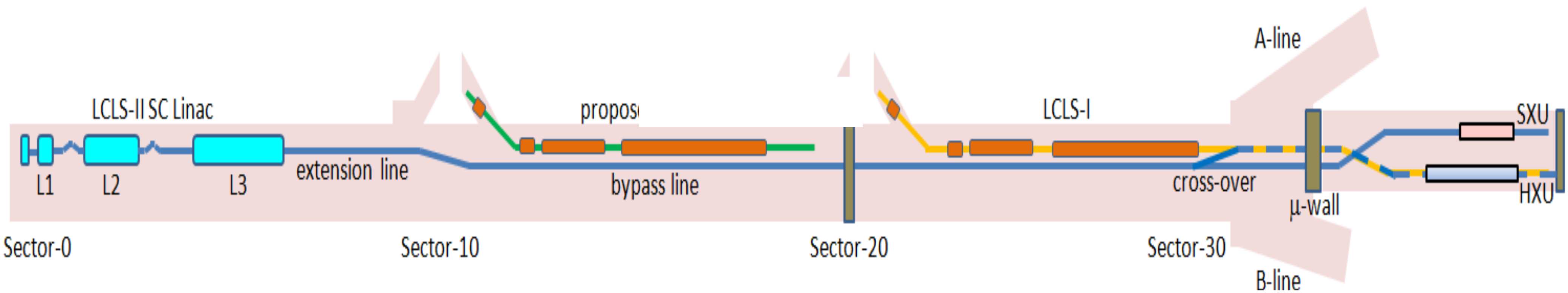






Planning for FACET-II

- 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-2/3A Aug. 2016
- CD-3B Dec. 2016
- CD-4 2022
- Experimental program (2019-2026)

Key R&D Milestones:

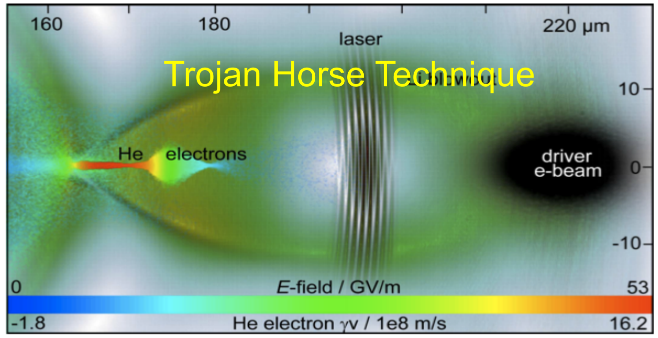
- Staging with witness injector
- High brightness beam generation, preservation, characterization
- e^+ acceleration in e^- driven wakes
- Generation of high flux THz and gamma radiation

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

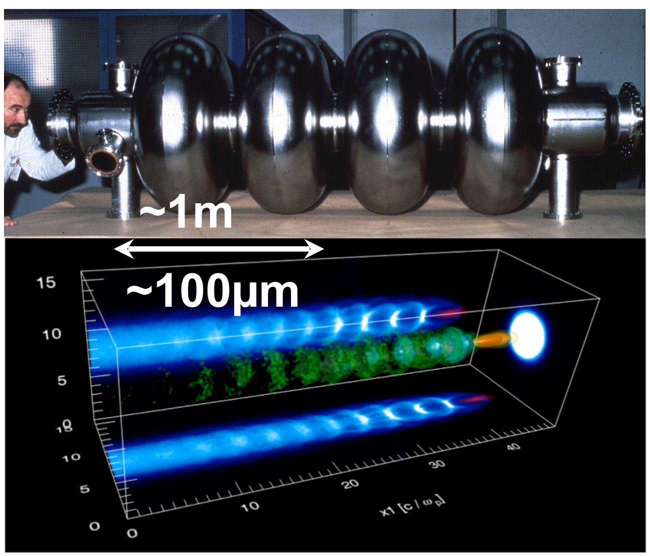
FACET-II will enable research for a broad user community
See talk by M.Hogan and Workshops: Oct.12-19 2015, SLAC

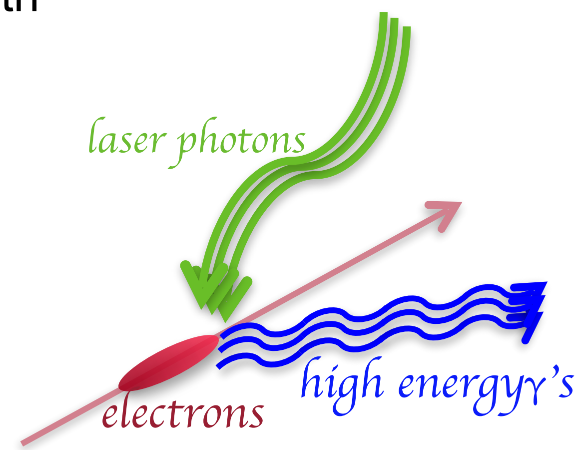
FACET II: High Gradient Acceleration – High Brightness Beams – Novel Radiation Techniques



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

Compact high gradient plasma accelerator

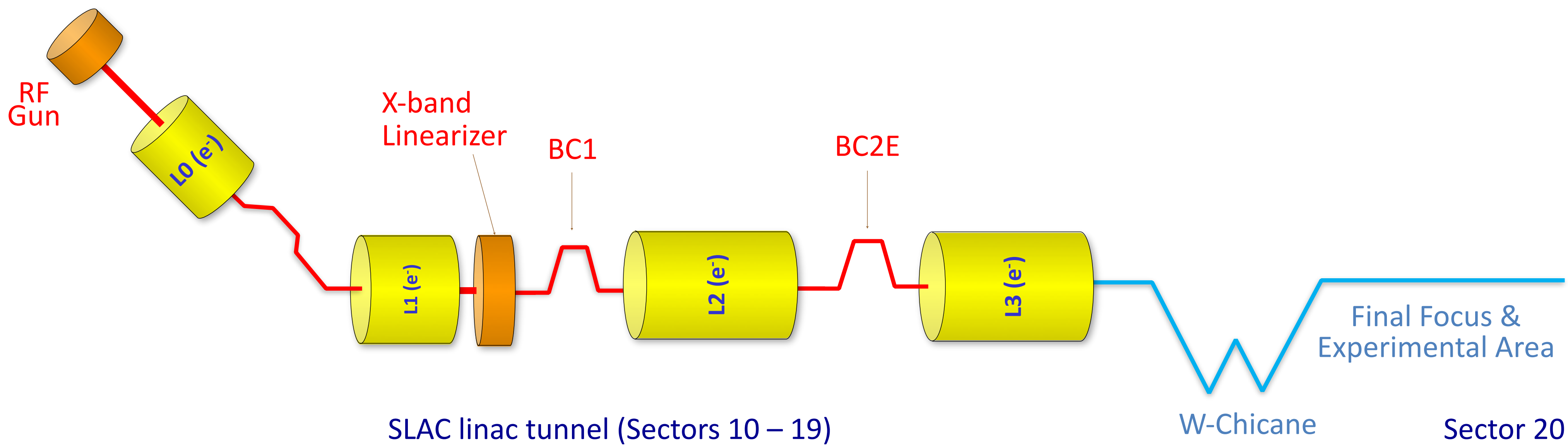


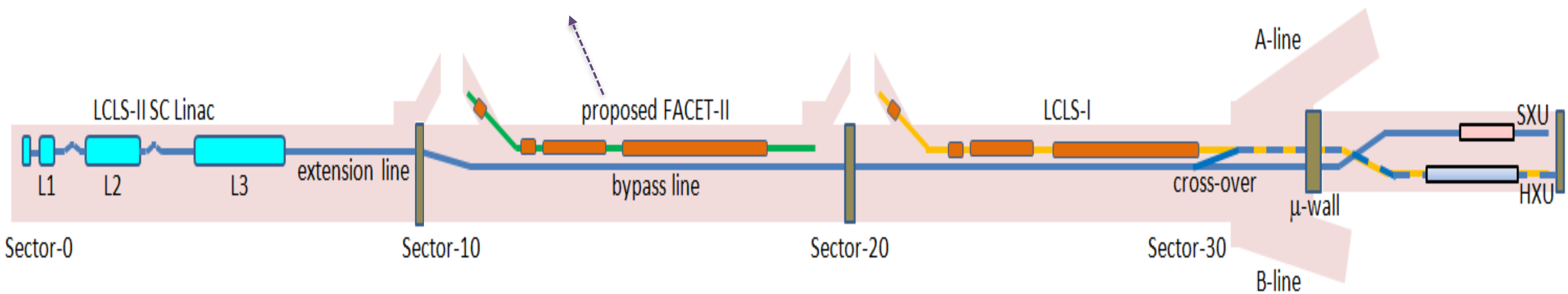


Polarized gamma beams
2 MeV - 4 GeV with high flux
10^{9}-10^{11} γ/sec for diverse research programs

FACET-II Stage I FY17-19

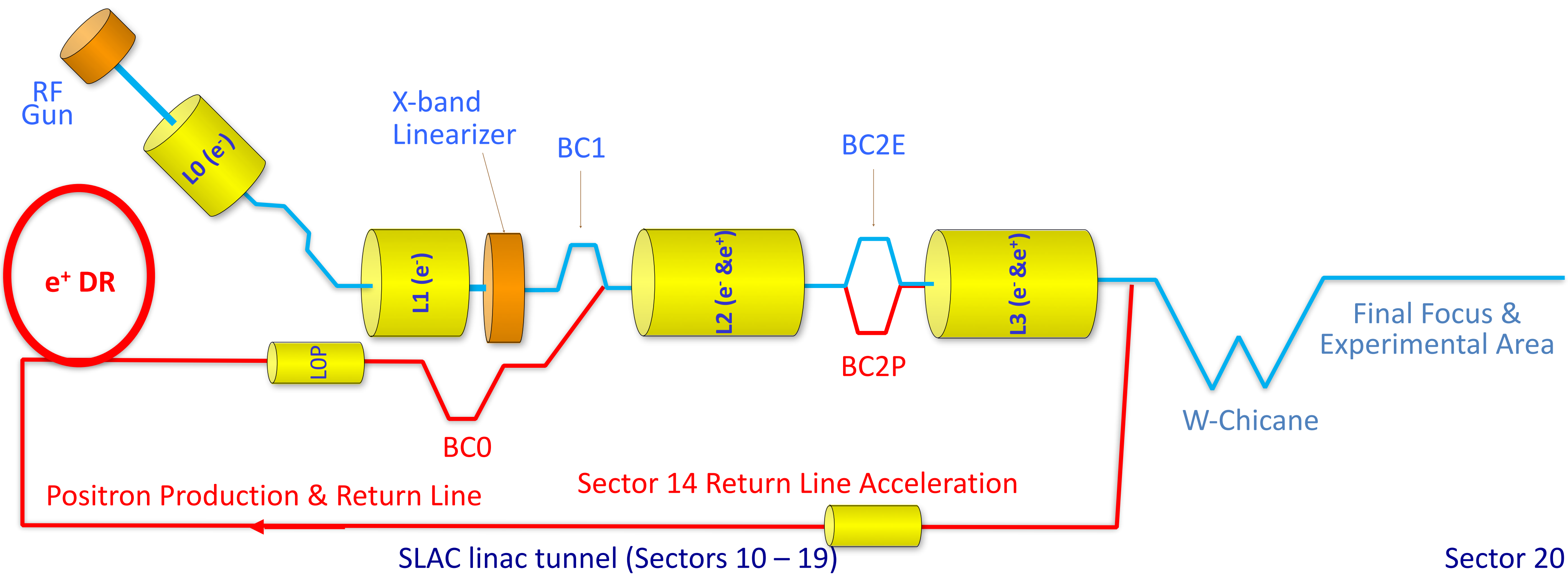
- **Goal:** deliver compressed electron beam to experiments in S20
- **Major upgrade:** Electron beam photoinjector in Sector 10
- **Scope:** Injector, Shielding wall in S10, X-band linearizer, Bunch Compressors in S11 (BC1) and S14 (BC2), beam diagnostics, upgrade to experimental area





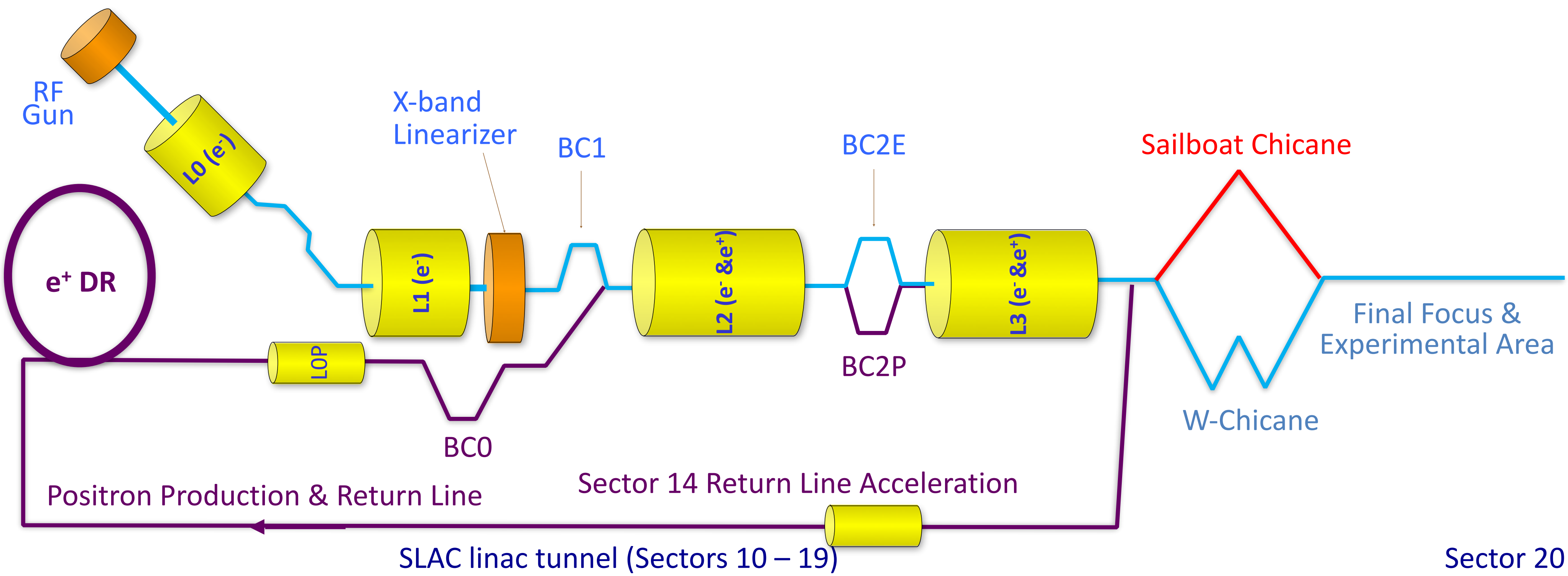
FACET-II Stage II FY18-20

- **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

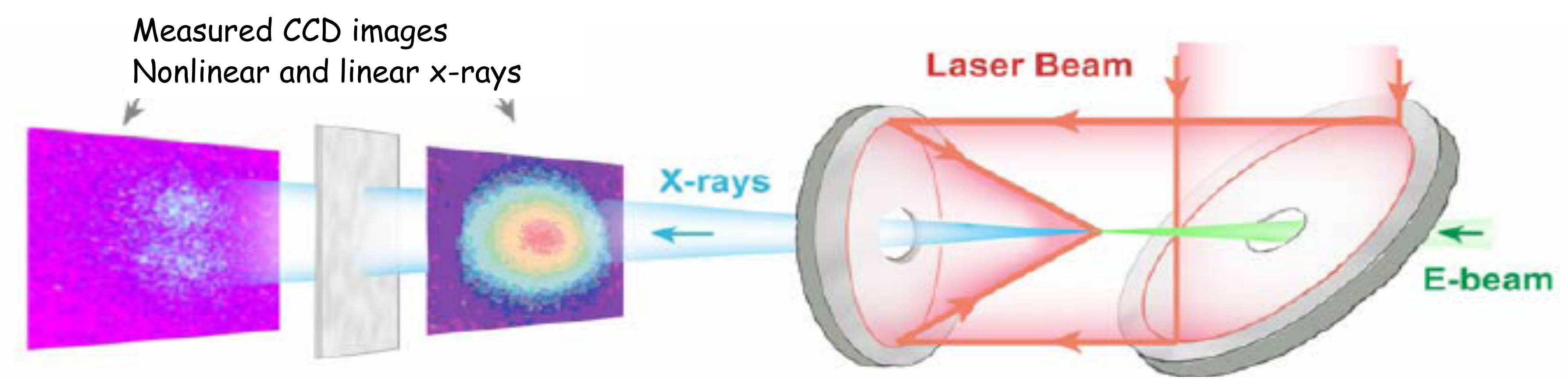
Description of Scope	*Units*	*Threshold KPP*	*Objective KPP*
Beam Energy	***[GeV]***	***9***	***10***
Bunch Charge (e-/e+)	***[nC]***	***0.1/0.1***	***2/1***
Final Normalized Emittance (e-/e+)	***[μm]***	***50/50***	***20/20***
Bunch Length (e-/e+)	***[μm]***	***100/100***	***20/20***

- 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

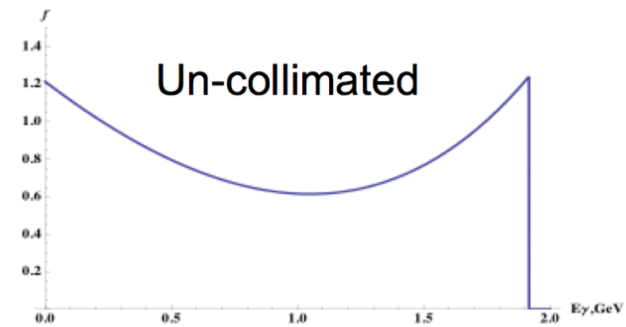
Layout of the ICS at BNL

- More than 10^8 of x-rays were regestered in the experiment N_X/N_{e-} ~0.35.
- 0.35 was limited by laser/electron beams diagnostics
- Interaction point with high power laser focus of ~30μm was tested.
- Nonlinear limit (more then one laser photon scattered from electron) was verified.

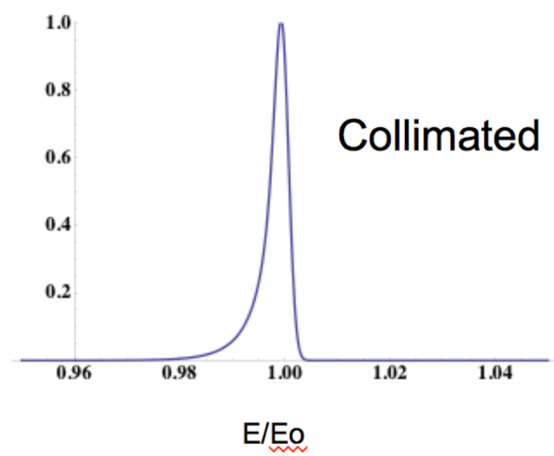


BIG: Beams of Intense Gamma-rays at FACET-II

- 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 p
  - White (un-collimated) and mono-energetic (collimated) gamma-rays
  - Linear, circular, elliptical polarization



$$E_\gamma = \frac{4\gamma^2 E_{ph}}{\left(1 + r + \gamma^2\theta^2\right)}; \quad r = \frac{4\gamma E_{ph}}{mc^2};$$



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

Name	ROKK	GRAAL	LEPS	HIγS	**BIG**
Location	Novosibirsk, Russia	Grenoble, France	Harima, Japan	Durham, US	**Menlo Park, US**
Accelerator	VEPP-4M	ESRF	SPRING-8	Duke SR	**SLAC**
e-beam, GeV	1.4 - 6	6	8	0.24 – 1.2	**1-10**
γ-beam, GeV	0.1-1.6	0.55-1.5	1.5-2.4	0.001-0.095	**0.001-2 (5)**
best γ–energy resolution, %	1-3	1.1	1.25	0.8-10	**0.1**
Maximum total flux, γ/sec	10^6	$3x10^6$	$5x10^6$	$3\ x10^9$, E<20 MeV $2\ x10^8$, E>20 MeV	**10^{11}** **(10^{10})**

BIG is a superior source:

- Few thousand-fold γ–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 ~ $3\ 10^{12} e^+/sec$
  - (working since 1980's)
- ILC needs ~ $4\ 10^{14} e^+/sec$
  - (close to solution?)
- LHeC => reduced performance < $4\ 10^{16} e^+/sec$
  - (ideas?)

- Facet-II will provide:
  - ~$4 \cdot 10^{11}$ γ/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

	N [$\mu^+\mu^-$ / *sec*]	$\varepsilon_{x,y}$ / ε_z
Neutrino factory	10^{13}-10^{14}	0.5mm/?? mm
Muon collider	2 x 10^{12}	25 µm/72 mm
Facet-II	10^6	150 µm/50 µm

Gamma Gamma collider

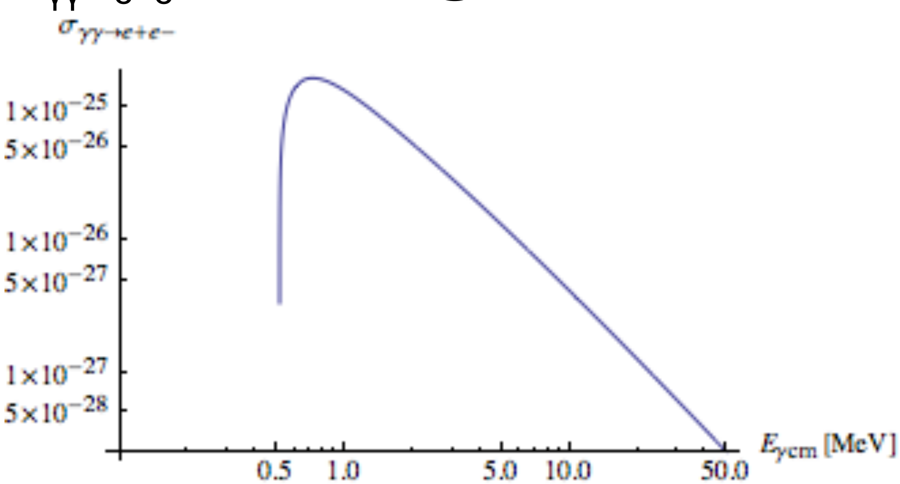
E_e = 4GeV

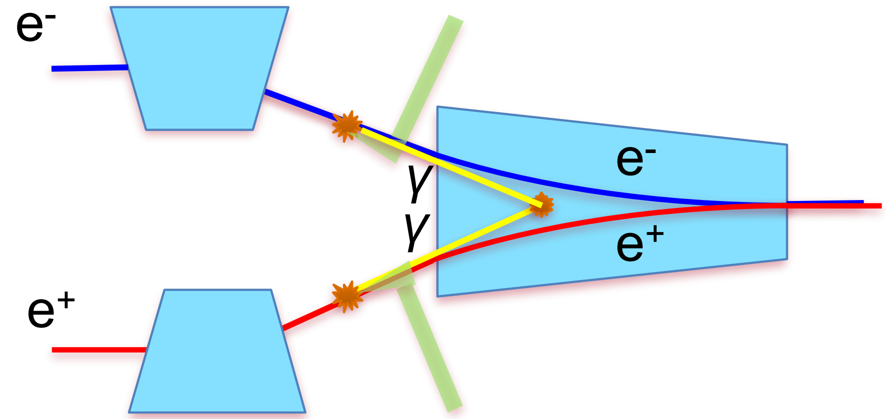
E_γ ~ 30 MeV, α ~ 0.05

$E_{\gamma cm}$ ~ 1.5 MeV

L ~ 5×10^{22} cm^{-2} sec^{-1}

$\sigma_{\gamma\gamma\to e+e-}$ ~$10^{-25}cm^2$ @ 1.5MeV





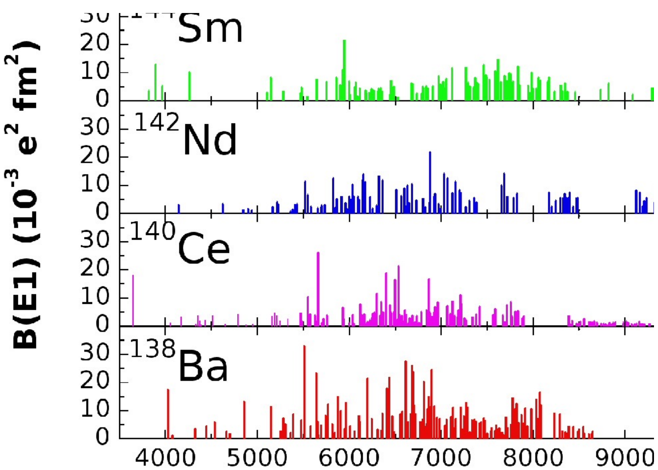
Will focus on technology research for gamma gamma collider.

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

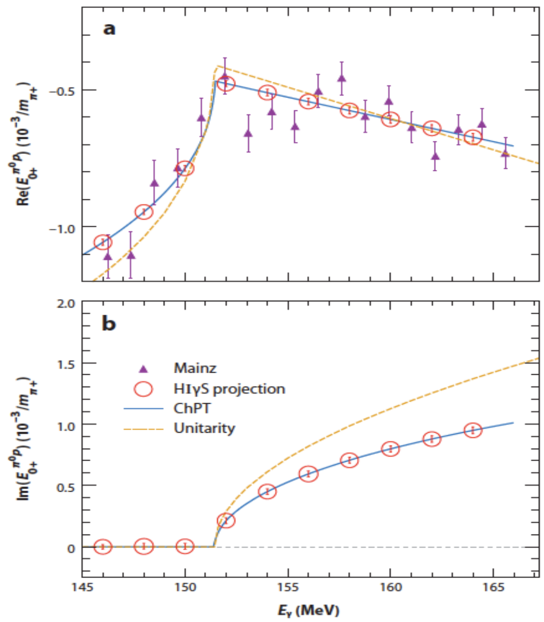
This would be the first pair creation test using real photons

Nuclear and higher energy physics: three main areas

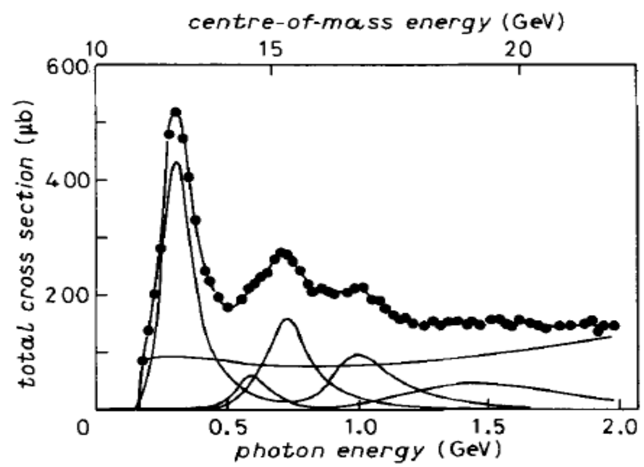
At low energies to study the resonant structure and states in rare nuclei. NRF & pigmy resonances. Astrophysics relevant processes (such as 12C(α, γ))



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

Beam	Energy [GeV]	ε_{NX} x ε_{NY} [μm x μm]	σ_X x σ_Y [μm x μm]	σ_Z x ΔE/E [μm x %]
5nC e^-	*10*	*5 x 5*	*10 x 10*	*20 x 0.3*
2nC e^+	*10*	*30 x 3*	*20 x 20*	*20 x 0.5*

Lasers	Energy / Power [Joule / TW]	Rep rate [Hz]	τ [fs]	λ [μm]
TI: Sapphire	*1 / 30*	*30 (120)*	*30*	*0.8*
CO_2 laser	*0.3 / 0.3*	*120*	*1000*	*10.2*

Gamma beams (Inverse Compton)	Energy [GeV]	Intensity	Rep rate [Hz]
TI: Sapphire	*1.8 GeV*	*10^{10}*	*30 (120)*
CO_2 laser	*150 MeV*	*10^{10}*	*30 (120)*