FACET-II

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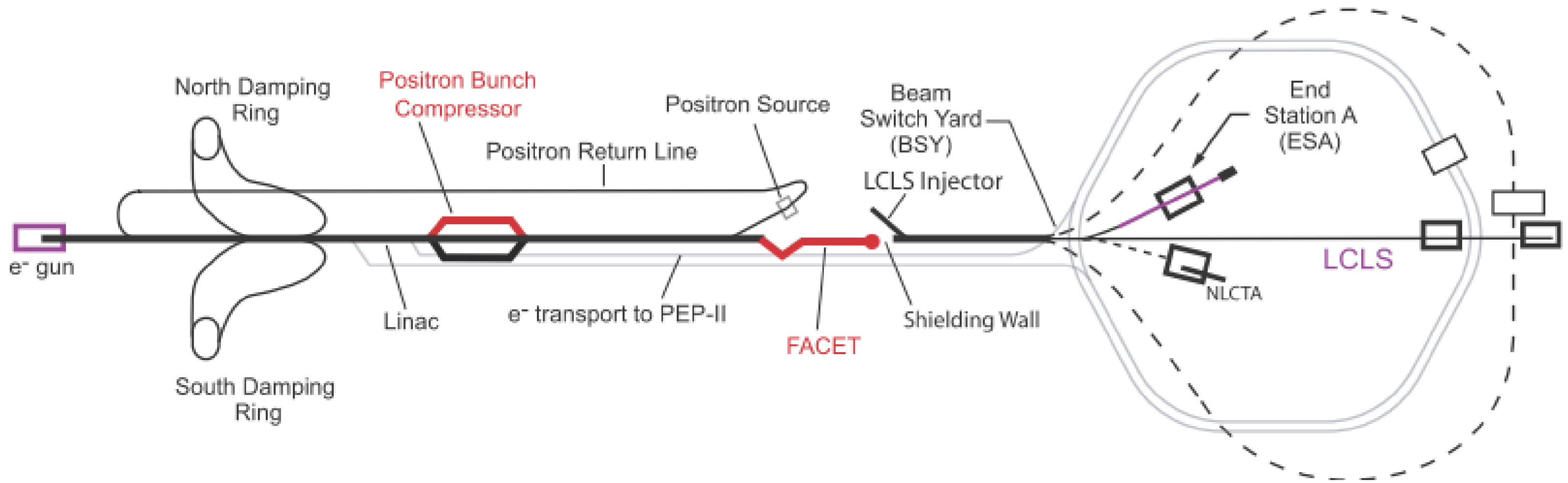
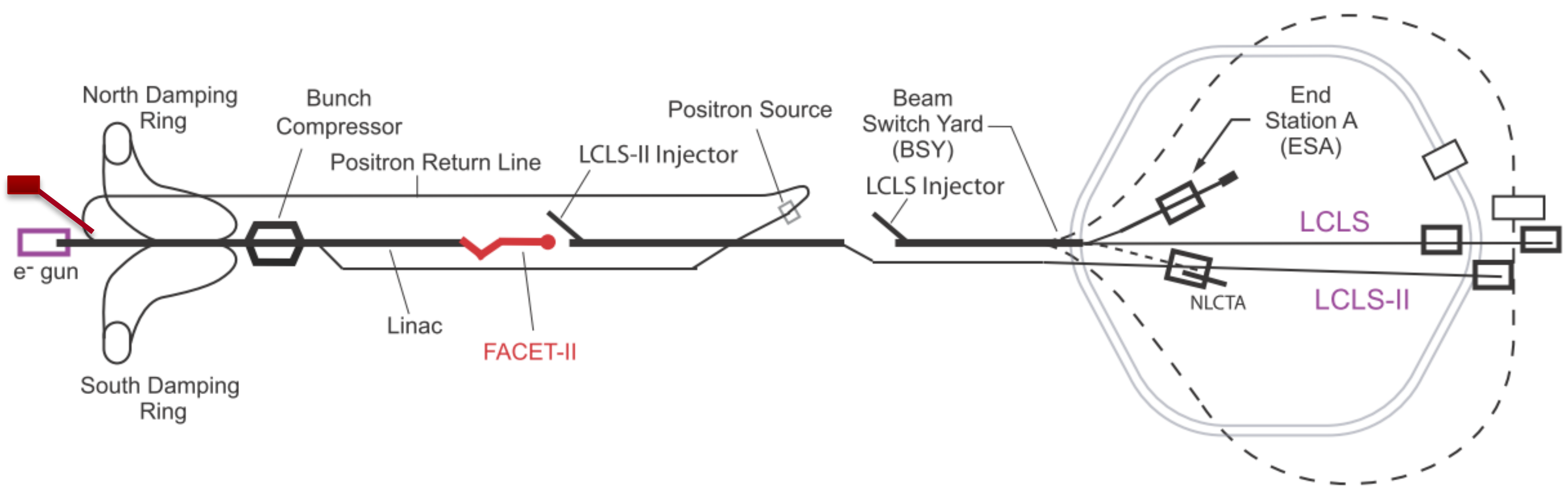
U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

FACET II





In early 2016, LCLS-II, will begin commissioning using part of the tunnel occupied by FACET

List of Contributors

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51 researcher from 16 institutions supported by at least 9 different funding agencies

Three main themes at FACET II

- **High gradient acceleration techniques** that will reduce the cost of both a future high-energy collider and linac-based light sources
- **High brightness beam techniques** that improve the generation, preservation, and application of such beams
- **Novel radiation techniques** (spanning terahertz to gamma-rays) that can be generated by FACET's high brightness beams

High gradient acceleration

	multi GeV linac >5GeV	High Charge ~3 nC	High brightness	Sub-100 fs timing challenge	Positron beams
ILC relevant stage demonstration	X	X	X	X	
High transformer ratio challenge		X	X	X	
PWFA with positively charged particles	X	X	X	X	X
Ion motion in PWFA	X	X	X		
Generation of super high brightness beams	X	X	X	X	
Dielectric wake field acceleration		X	X	X	

ITF / FEL / General accelerator R&D

SLAC

	multi GeV linac >5GeV	High Charge ~3 nC	High brightness	Sub-100 fs timing challenge	Positron beams
Long linac tuning/emittance preservation	X	X	X	X	X*
Energy chirp compensation with short wakefield structures	X		X		
High energy bunch compression and CSR mitigation	X		X		
Attosecond electron bunch generation (attosecond FEL, single cycle optical/UV pulse)	X		X		
Plasma based coherent radiation generation (transverse gradient undulator, ion channel laser)			X		
High-brightness beam diagnostics: transverse profiles, ultrashort bunch measurements	X		X		
THz generation (with tapered undulator, corrugated pipe, grating compressors	X		X		
Beam manipulations techniques (Echo, emittance exchange)			X	X	

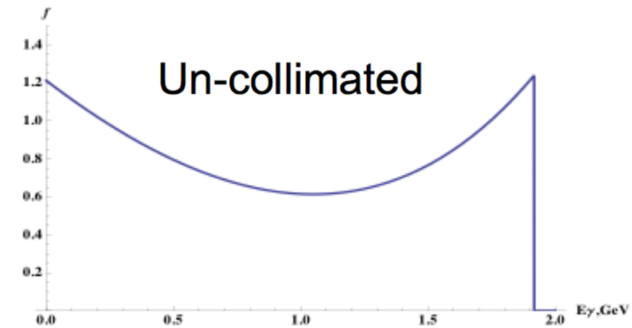
Gamma source

	multi GeV linac >5GeV	High Charge ~3 nC	High brightness	Sub-100 fs timing challenge	Positron beams
High intensity positron source for ILC, ...	X	X	X	X	
Studies for high brightness polarized muon source	X	X	X	X	
Low energy QCD		X	X	X	
Medium energy QCD	X	X	X	X	
High energy QCD	X	X	X	X	
Studies towards γγ collider	X	X	X	X	X

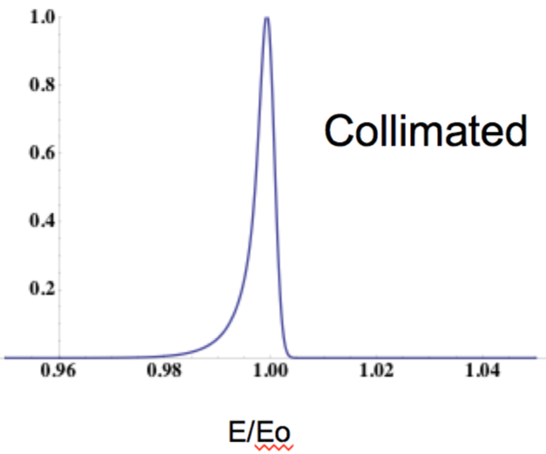
All three themes have uniform demand for the combination of high-energy and high-brightness beams

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 per pulse
  - 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	$3\text{x}10^6$	$5\text{x}10^6$	$3\text{ x}10^9$, E<20 MeV $2\text{ x}10^8$, 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:
  - $\sim 4 \cdot 10^{11}$ 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

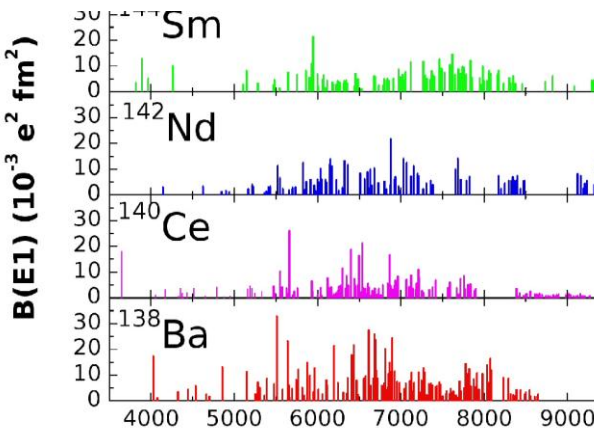
Facet-II will study photo production of muons:

- New target ideas: crystal channeling, nano-tubes targets, liquid metal jet…
- Study process with 10's Watt photon beams; scale up by many orders of magnitude
- Small phase space reduces the need for difficult and complicated cooling schemes

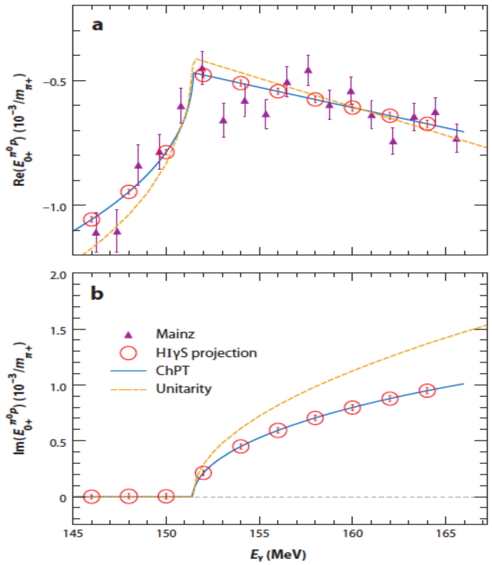
Photo-production is the only known way to produce polarized muons

Nuclear and higher energy physics: three main areas

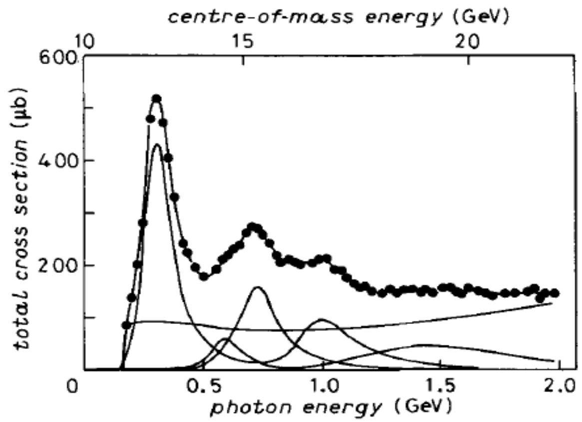
At low energies to study the resonant structure and states in rare nuclei. NRF & pigmy resonances. Astrophysics relevant processes (such as 12C(α, γ))



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

Gamma Gamma collider

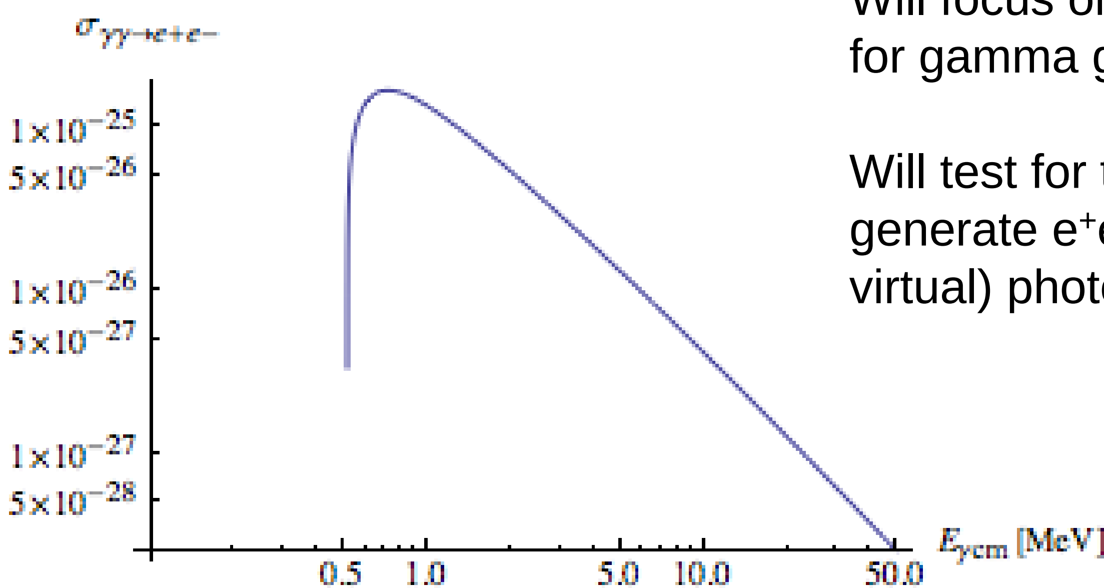
$E_e = 4\text{GeV}$

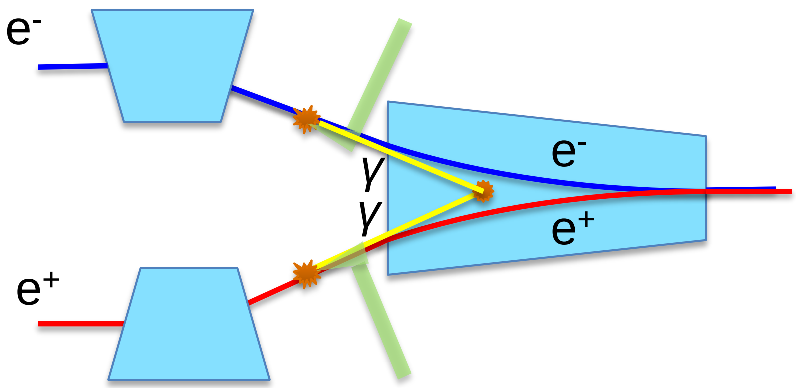
$E_\gamma \sim 30$ MeV, $\alpha \sim 0.05$

$E_{\gamma cm} \sim 1.5$ MeV

$L \sim 5\times10^{24}\ \text{cm}^{-2}\ \text{sec}^{-1}$

$\sigma_{\gamma\gamma\text{->e+e-}} \sim 10^{-25}\text{cm}^2$ @ 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

Conclusion

C. Joshi: “PWFA program needs FACET II, it can not be done anywhere else.”

….

Breadth of the potential research program makes FACET II truly unique. It will synergistically pursue accelerator science that is vital to the future of both advanced acceleration techniques for High Energy Physics, ultra-high brightness beams for Basic Energy Science, and novel radiation sources for a wide variety of applications.

No other test facility has such broad interest across so many branches of the Office of Science.

Facet-II beams

Injectors	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 %]
Thermionic	3nC e^-	10	30 x 3	20 x 20	40 x 1
	1.5nC e^+	10	30 x 3	20 x 20	40 x 1
Photoinjector	20pC e^-	10	0.1 x 0.1	1 x 1	2 x 1
	1nC e^-	10	1 x 1	3 x 3	5 x 1
	6nC e^-	10	5 x 5	10 x 10	20 x 1
	3nC e^+	10	30 x 3	20 x 20	40 x 1
Witness photoinjector	0.1nC e^-	0.1	1 x 1	50 x 50	20 x 0.1

Lasers	Energy / Power [Joule / TW]	Rep rate [Hz]	τ [fs]	λ [μm]
TI: Sapphire	1 / 30	120	30	0.8
CO_2 laser	0.1 / 0.1	120	1000	10.2

Gamma beams (Inverse Compton)	Energy [GeV]	Intensity	Rep rate [Hz]	σ_X x σ_Y [μm x μm]	σ_Z [μm]
TI: Sapphire	1.8 GeV	10^{10}	120	5 x 5	10
CO_2 laser	150 MeV	10^{10}	120	5 x 5	10

FACET II cost $M (40% overhead rate)

FACET Decommissioning		4.9
Minimal Facility		35
- Wall, PPS, S4 Chicane, dog. leg/FF, spectrometer, dump, exp. area, ionization laser, access		
Positron operations		22
- Kickers/transport to target	7	
- Experimental area chicanes	15	
Witness e- injector (reuse XTA)		5
ITF (PPA/FEL)		38 / 31
- Injector-L0	25 / 5	
- BC1-L1	13 / 5	
- BC2-L2-L3 (exp. Area)	0 / 21	
Lasers (BIG)		9-36
- S10 Laser infrastructure	2	
- 10-120 Hz Ti Sapphire	3-30	
- 120Hz CO_2	4	
Totals (PPA/FEL)		109-136 / 31