# Compton based Polarized Positrons Source for ILC

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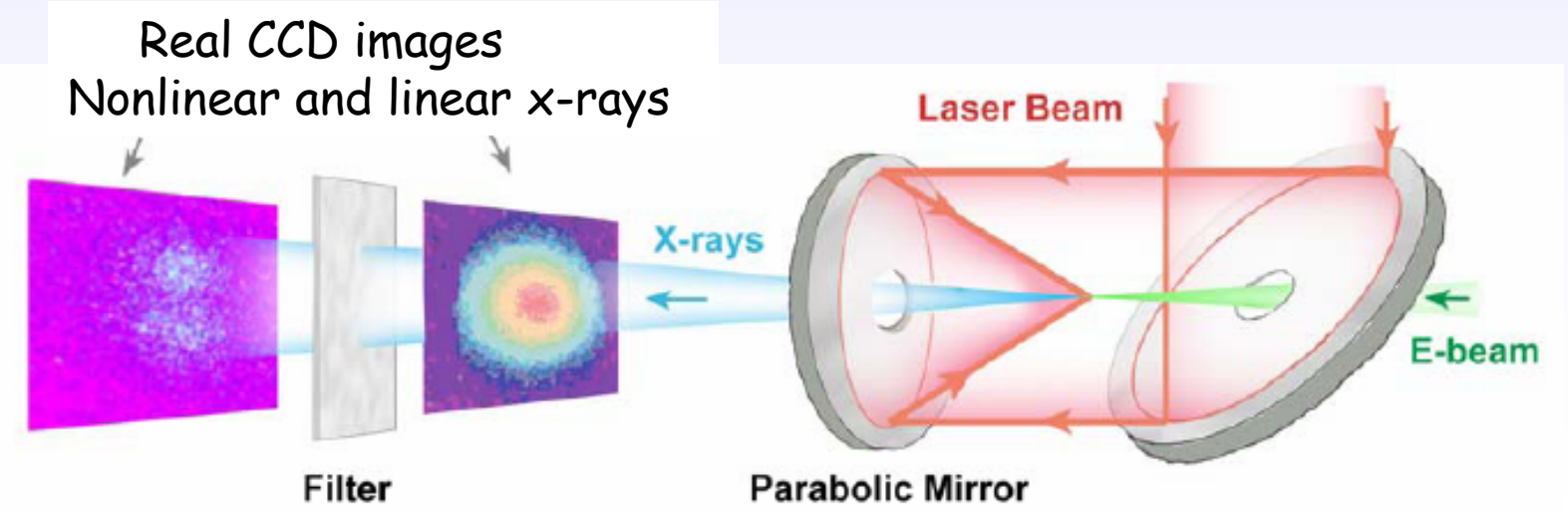
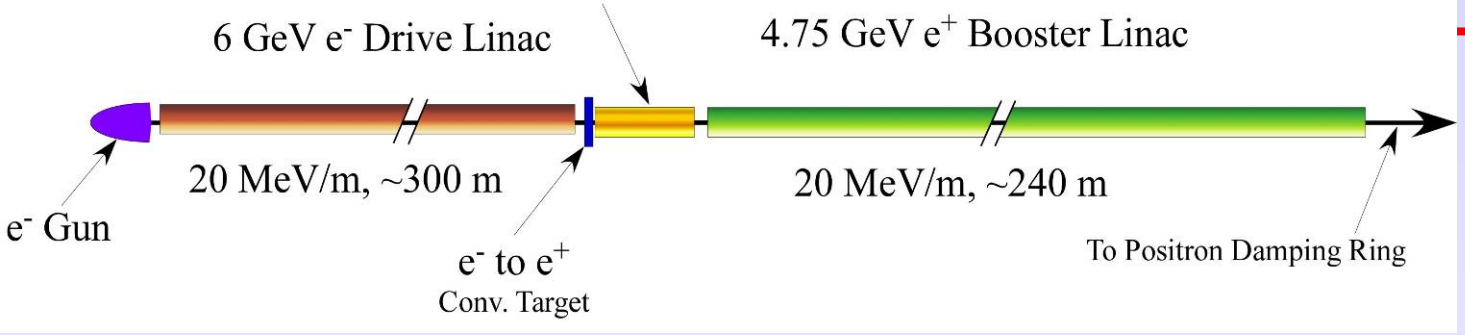
# Compton Experiment at Brookhaven ATF
## (record number of X-rays with 10 μm laser)

- More than $10^8$ of x-rays were generated 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. PRL 2005.



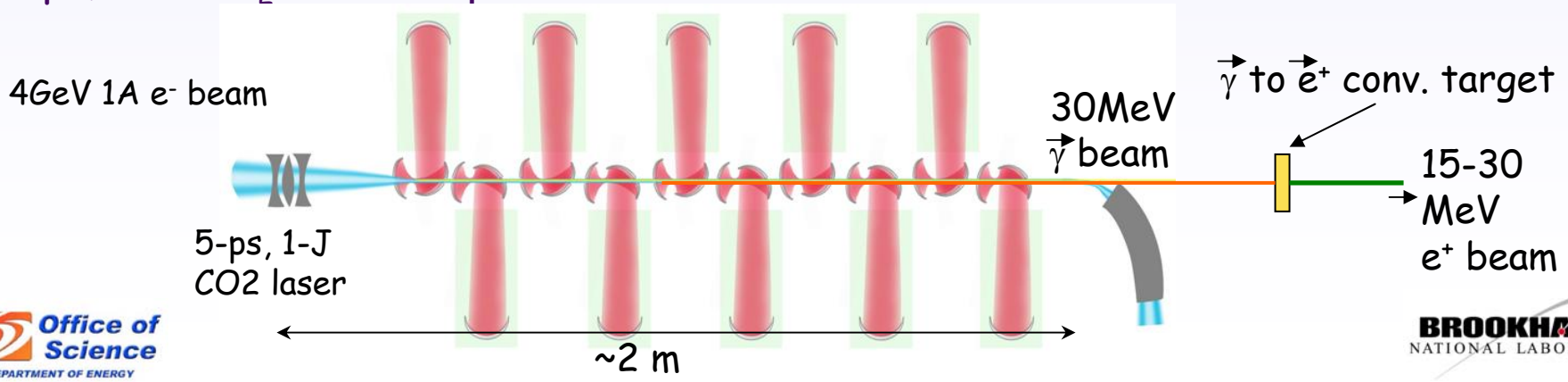
# Polarized Positrons Source (PPS for ILC)

Conventional Non-Polarized Positrons:




**In the proposal**

- Polarized $\gamma$-ray beam is generated in Compton backscattering inside optical cavity of $CO_2$ laser beam and 6 GeV e-beam produced by linac.
- The required intensities of polarized positrons are obtained due to 10 times increase of the "drive" e-beam charge (compared to non polarized case) and 5 to 10 consecutive IPs.
- Laser system relies on commercially available lasers but need R&D on a new mode of operation.
- 5ps, 10J $CO_2$ laser is operated at BNL/ATF.

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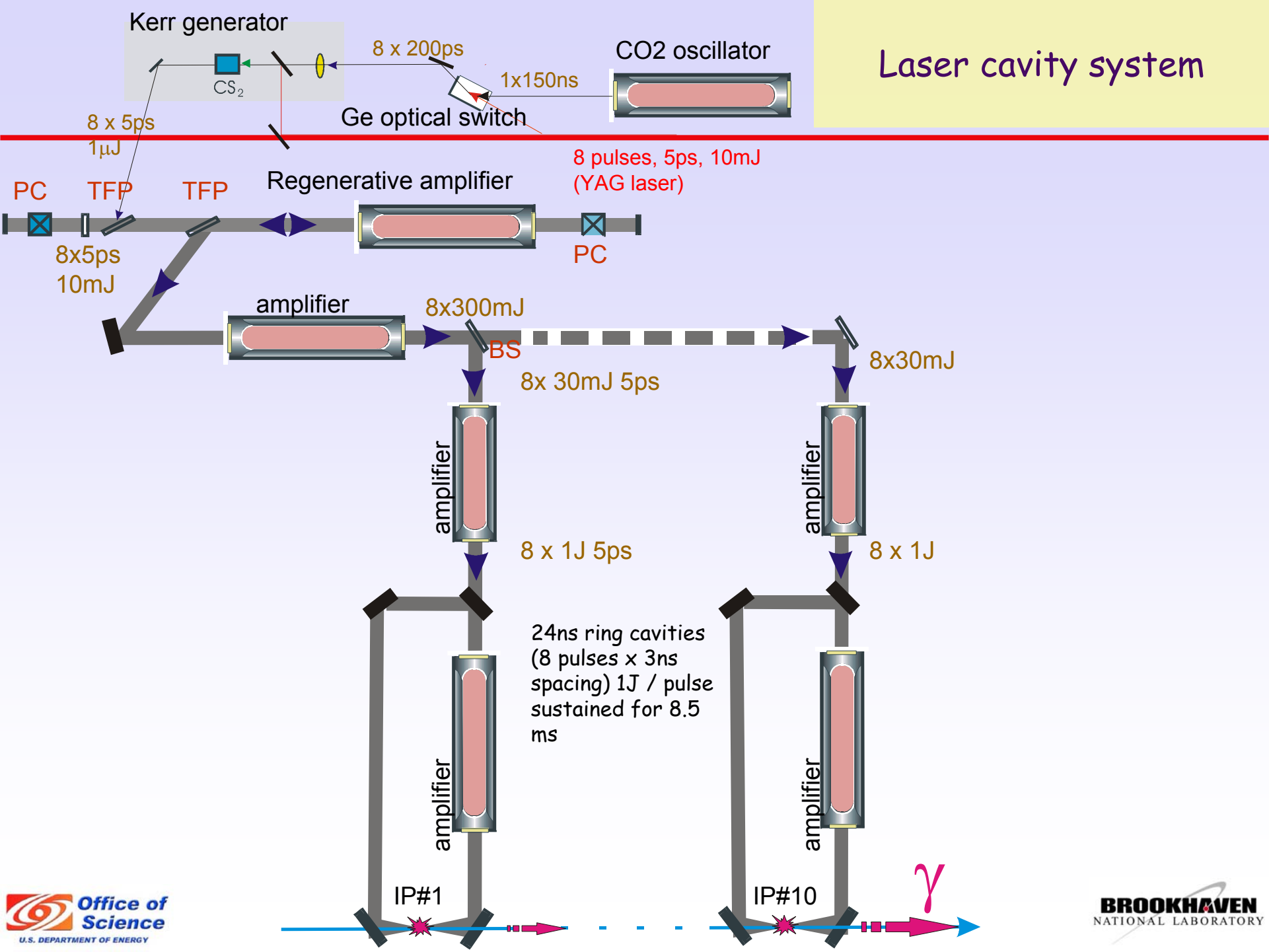
# Laser cavity system

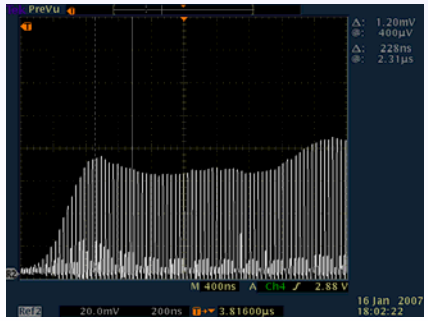


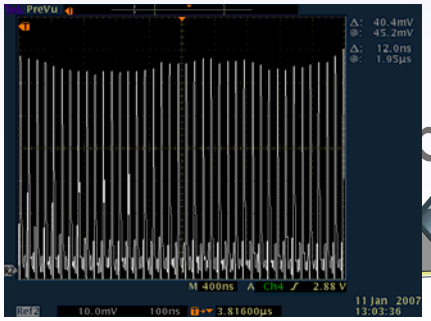
# LDRD – cavity tests

- Has a potential to increase average intra-cavity power ~100 times at 10.6 microns.

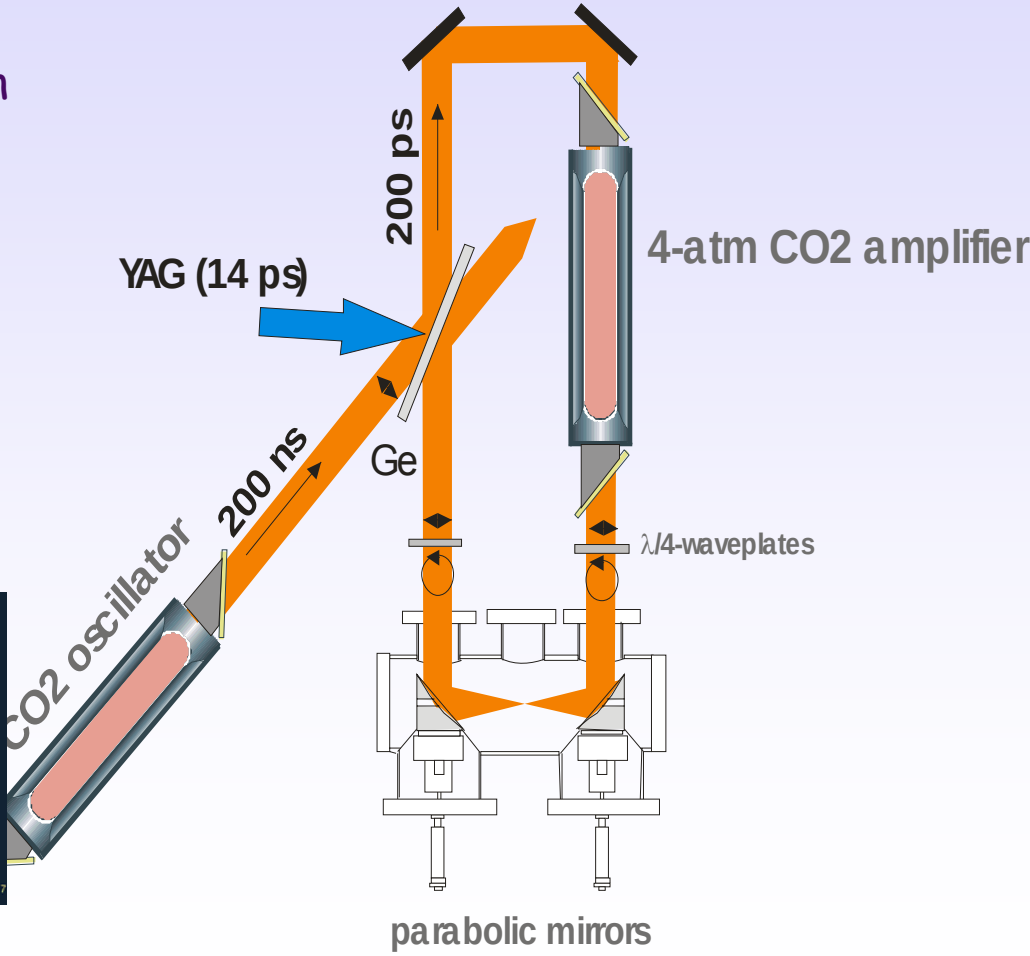
Purpose of the test:

- Demonstration of 100-pulse train inside regenerative amplifier that incorporates Compton interaction point.
- Demonstration of linear-to-circular polarization inversion inside the laser cavity.
- Test of the high power injection scheme





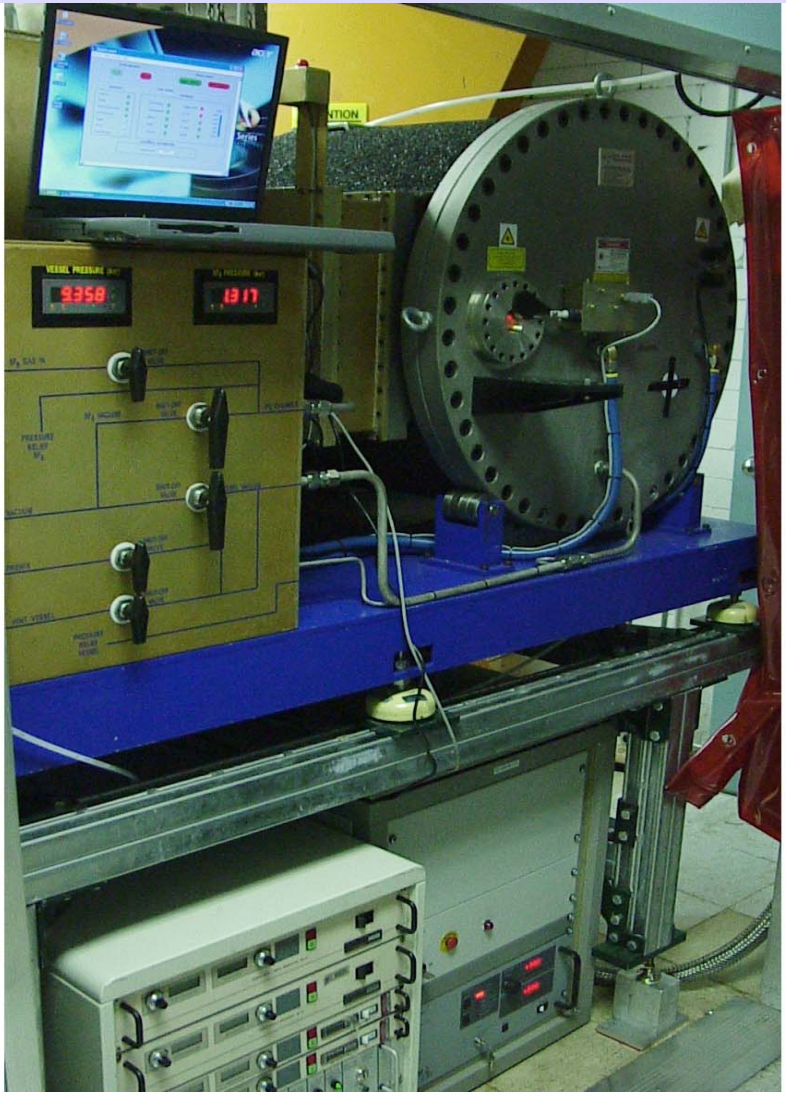
3% over 1 μs



# "~100 times increase of the average intra-cavity power at 10 μm"

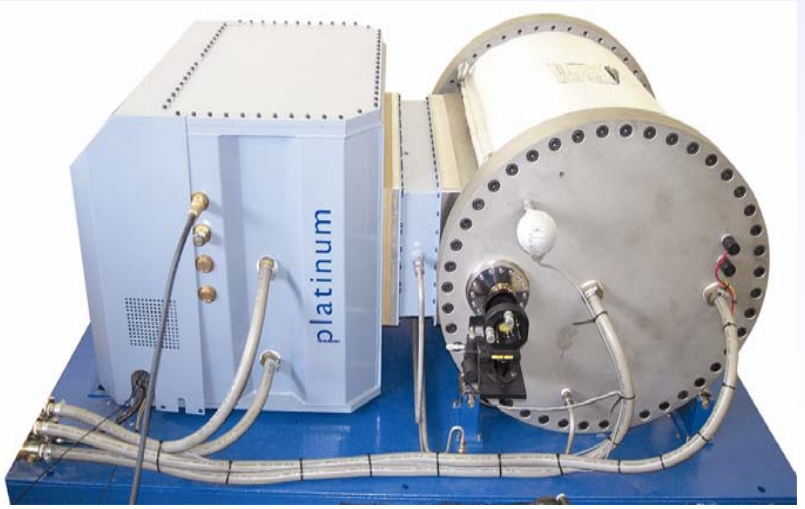
- The required laser train format / repetition rate /average acting power at each IP: 100 pulses x 150Hz x 1J = 15 kW.
- Efficient interaction with electron beam requires short (~5ps) and powerful (~1-2J) laser beam.
- Such high-pressure laser does not exist. Non-destructive feature of Compton scattering allows putting interaction point inside laser cavity.
- We can keep and repetitively utilize a circulating laser pulse inside a cavity until nominal laser power is spent into mirror/windows losses.
- Assuming available 0.5 kW CO2 laser and 3% round-trip loss, 1-J pulse is maintained over 15,000 round trips/interactions (100 pulses x 150 Hz). Thus, 0.5 kW laser effectively acts as a 15 kW laser.
- Equivalent solid state ( 1μm) laser producing the same number of gamma photons should be 150 kW average power with ~10J, 5ps beam.
- Applications:
  - Compact femtoseconds x-ray source
  - Gamma-ray source for RIA
  - Gamma collider laser
  - …

# Commercially Available High-Pressure $CO_2$ Lasers



SCIENTIFIC DEVELOPMENT & INTEGRATION (PTY) LTD

| | |
|---|---|
| Repetition Rate | 20 -500 Hz |
| Pulse Energy | 1.5 J |
| Beam Size | 13 x 13 $\mu m^2$ |
| Average Power | 750 W |



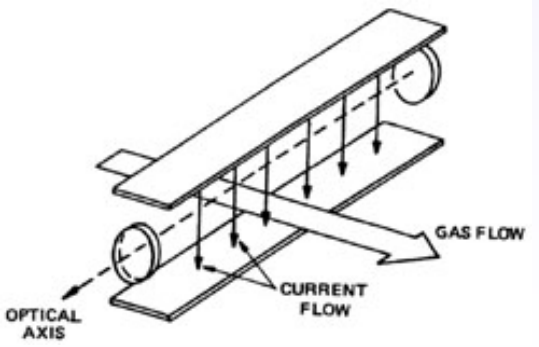
# Excimer laser convertible to $CO_2$

SOPRA

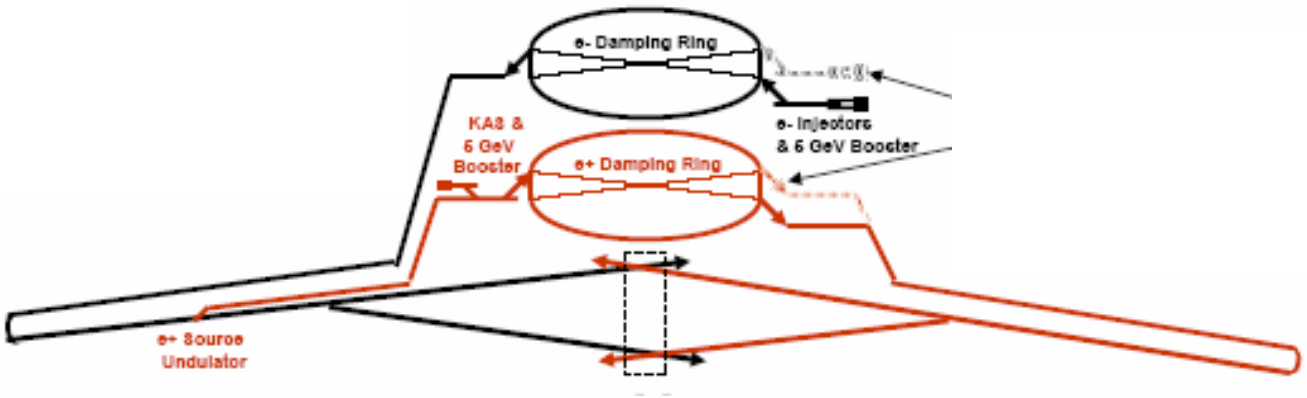
France

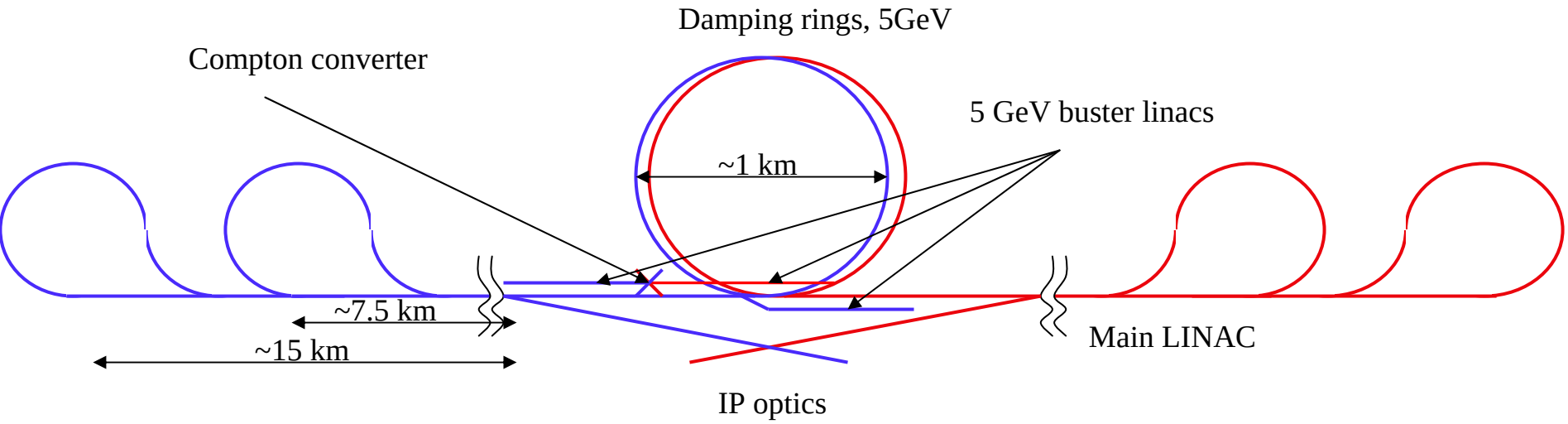
10 J per pulse,
100 Hz repetition rate,
1 kW average power

gas flow



# Upgradeable ILC Layout



# Benefits Of the Compton based source:

- Independent layout/operations of the electron and positron parts
  - ILC can start as 150x150GeV and upgraded in stages to higher energy. This is incompatibles with the "undulator positron source"
  - ILC can be build on conventional technology (~20 MV/m).
  - Future possibility of energy upgrade with advanced acceleration techniques (CLIC, Plasma Wakefield) can use conventional linac for the drive beam.
- High intensity polarized positron source for other applications:
  - SuperB factory
  - …
- High Intensity Gamma ray source for other applications:
  - RIA
  - …

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LETTERS

# Energy doubling of 42 GeV electrons in a metre-scale plasma wakefield accelerator

Ian Blumenfeld[1], Christopher E. Clayton[2], Franz-Josef Decker[1], Mark J. Hogan[1], Chengkun Huang[2], Rasmus Ischebeck[1], Richard Iverson[1], Chandrashekhar Joshi[2], Thomas Katsouleas[3], Neil Kirby[1], Wei Lu[2], Kenneth A. Marsh[2], Warren B. Mori[2], Patric Muggli[3], Erdem Oz[3], Robert H. Siemann[1], Dieter Walz[1] & Miaomiao Zhou[2]

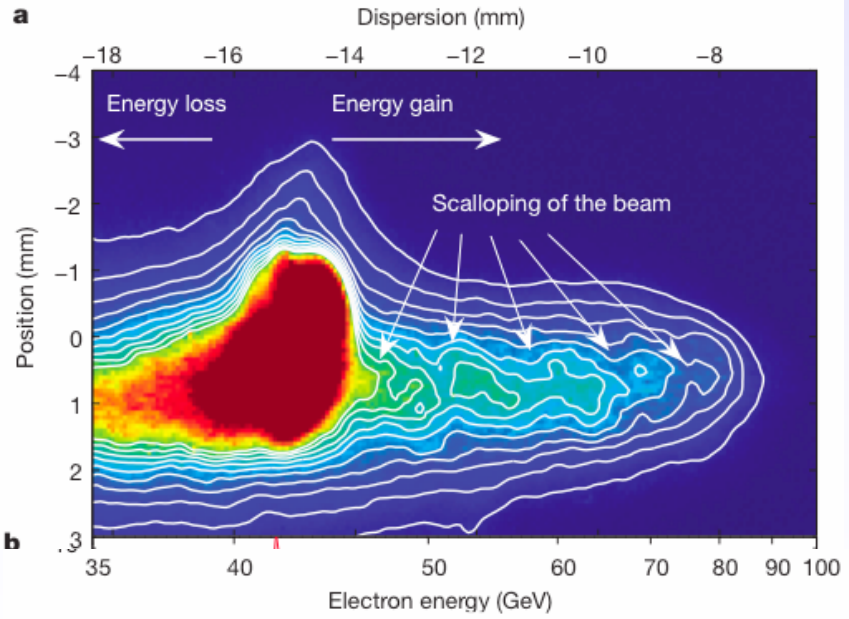


**Figure 2 | Energy spectrum of the electrons. a**, Energy spectrum of the electrons in the 35–100 GeV range as observed in plane 2. The dispersion

SLAC Beam:
$E_0$=28.5 GeV
$\sigma_z \approx 20$ μm
$N=1.8\times10^{10}$ $e^-$
$n_e=2.7\times10^{17}$ $cm^{-3}$
L=90 cm

42 to 84 GeV in 90 cm
Energy Doubling

100% ΔE/E

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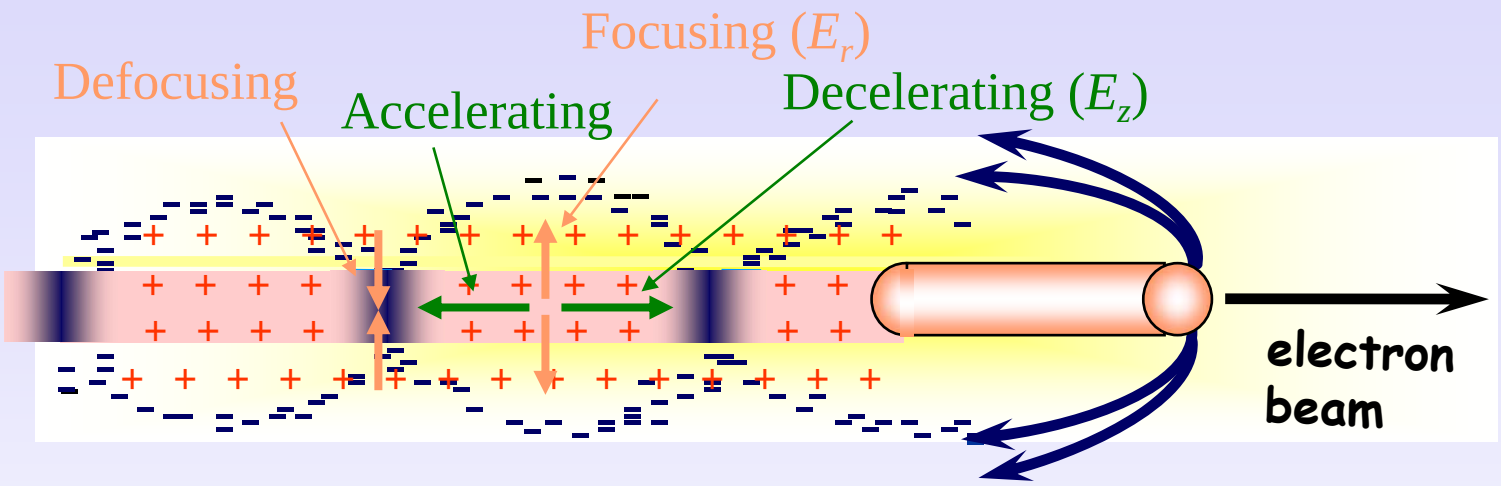
# e⁻-BEAM-DRIVEN PWFA




Plasma wave/wake excited by a relativistic particle bunch

Plasma e⁻ expelled by space charge forces => energy loss + focusing

Plasma e⁻ rush back on axis => energy gain

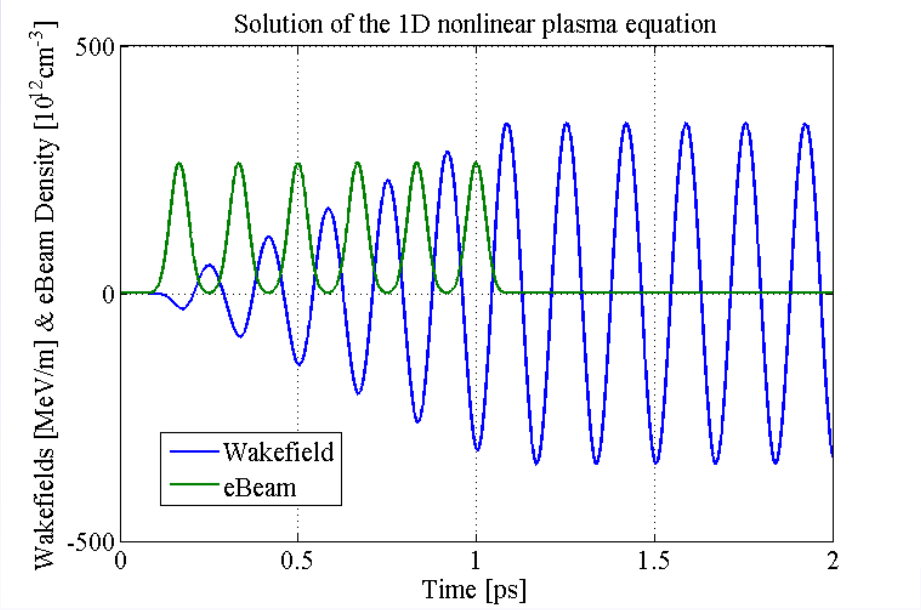
Plasma Wakefield Accelerator (PWFA) = Energy Transformer

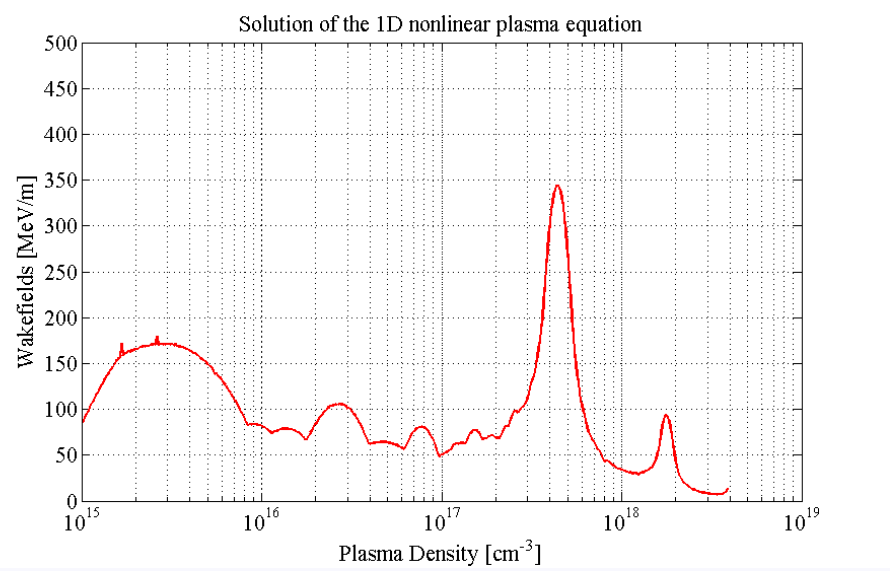
Booster for high energy accelerator?

# Model Prediction(1) for Multibunch PWFA Using Wire-Mesh

[1] Courtesy E. Kallos, USC

- Assume 6 microbunches, ≈30 μm long, separated by 50 μm, corresponding to resonant plasma of ≈4 × $10^{17}$ $cm^{-3}$

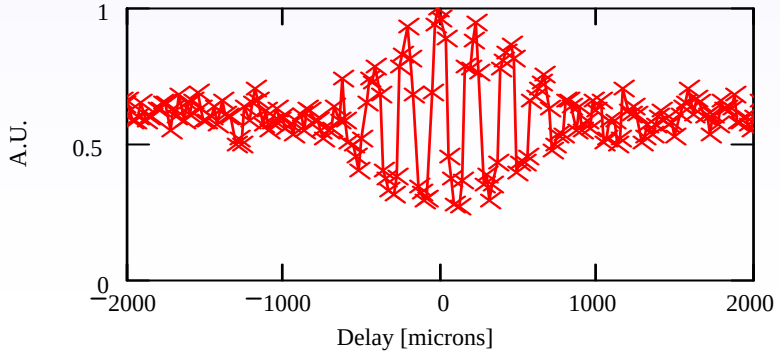


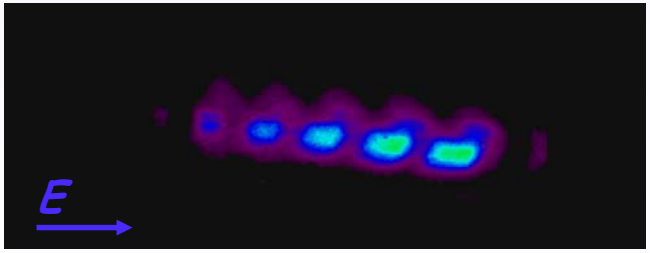




- 6 drive bunches can excite plasma wake to increase witness buch by 6 times. Optimal efficiency of the process simulated around 33%: Drive beam power needs to be 3 times the final witness beam power.

# Passive, Simple Technique Developed for Generating Tunable Microbunch Train

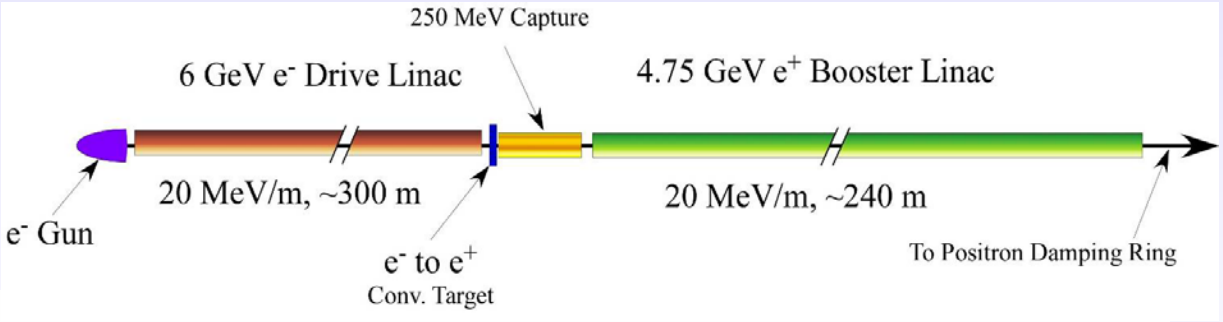
- Basic steps are:
  - -Generate *e*-beam with correlated energy chirp (time Vs. energy)
  - -Send through quadrupoles and dipole to create spot along beamline where transverse and longitudinal amplitudes are correlated
  - -Place an array of evenly-spaced thin wires ("wire-mesh") at spot (typical wire diameter 125 – 500 μm)
  - – Approximately half of the beam is scattered by wires the rest form microbunches
- Reverse transformation also demagnifies microbunch spacing relative to wire spacing
- Demagnifications of 10:1 to 5:1 demonstrated

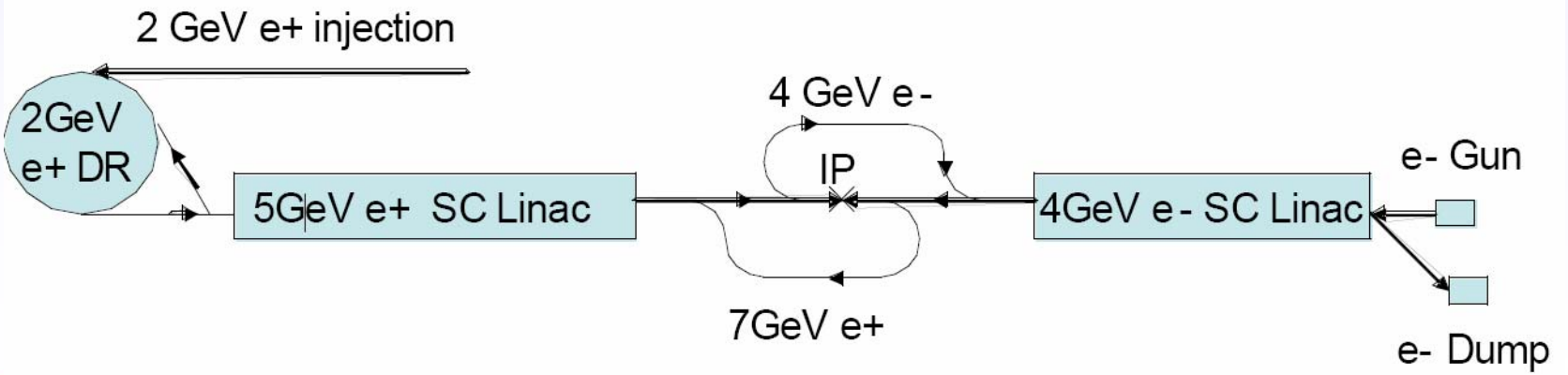



# SuperB Factory

- Combining linear and circular collider for B-Factory was discussed in the late 1980's and now considered for SuperB factory with luminosity of ~$10^{36}$ $cm^{-2}s^{-1}$
- Beam requirements are very similar to ILC
- Positron intensities are very challenging with conventional positron source:



# Potential for generating exotic beams of nuclei

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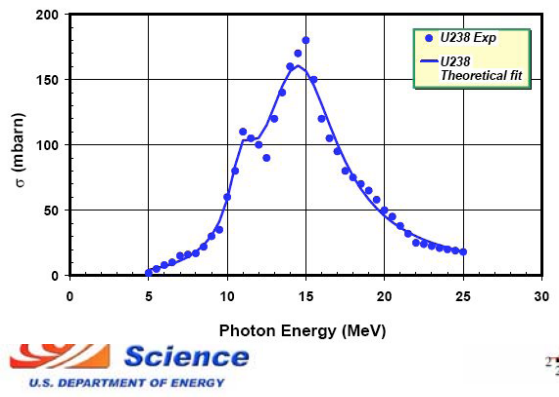
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS
LABORATOIRE COMMUN DSM/CEA-IN2P3/CNRS

Spiral2

- Idea came from SPIRAL II Project (electron option) to use 45 MeV electro beam to generated 10-20 MeV Bremmstrahlung γ-rays and use Giant Dipole Resonance (GDR) for photofission of $^{238}U$ into rare (neutron reach) nuclei http://ganinfo.in2p3.fr/research/developments/ spiral2/index.html
- Because of the hard-edge in the energy spectrum, Compton γ-ray beam with high average power average is a better choice for such source
- 3 GeV Linac in combination with four $CO_2$ lasers (2J/pulse, Rayleigh range of 0.2 cm, 500 Hz rep-rate x 500 reflections) will provide 90 kW (i.e. $4x10^{16}$/sec) of γ-rays within the 10-20 MeV range of GDR
- This γ-ray beam has very small divergence ~ 150 μrad, and can be used to for photofission of $^{238}U$ to generate ~$10^{16}$/sec nuclei, including exotic

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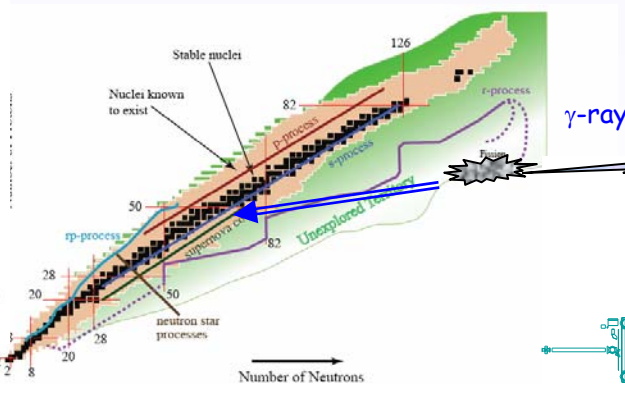


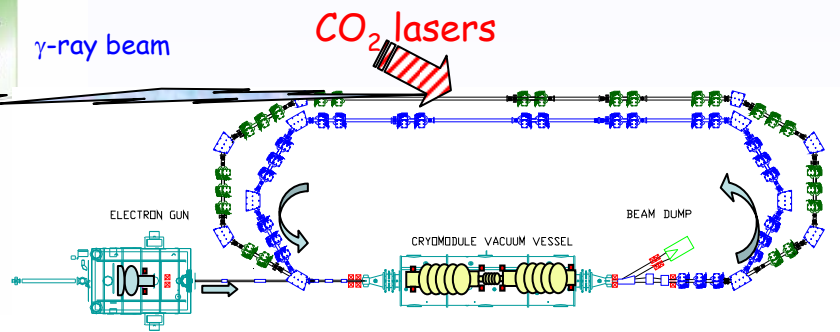

# Conclusion

- Compton based gamma ray source based on the $CO_2$ laser cavity offers unprecedented intensities useful for many applications.
- Polarized positron source can be realized without need for 150-200 GeV electron beam and therefore offers more flexibilities in the collider design.
- SuperB factory positron beam requirements can be satisfied with the same source.

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