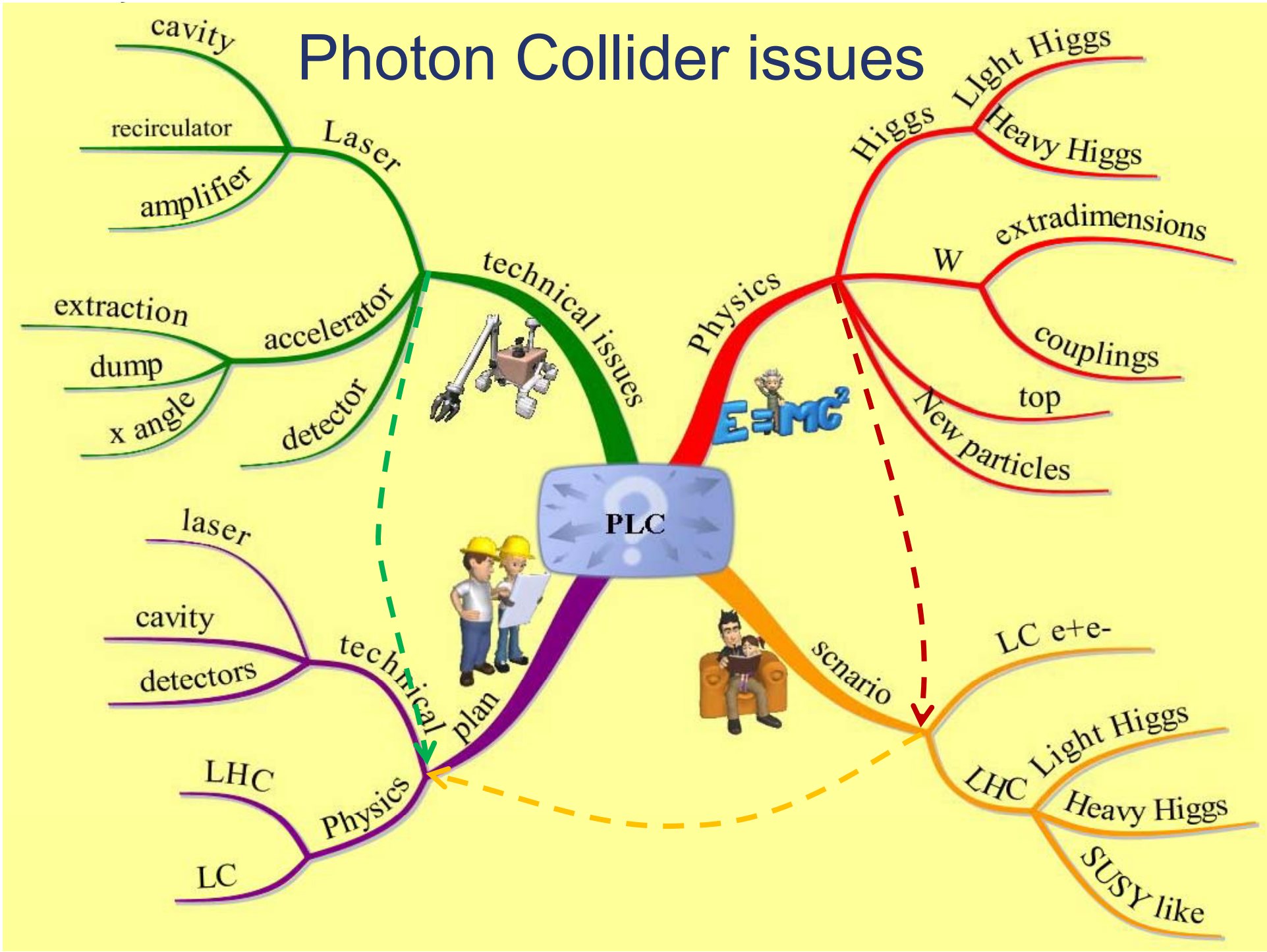
γγ state of the art and research plan, what system tests can be done at ATF2, ESA

T.Takahashi
Hiroshima Univ.

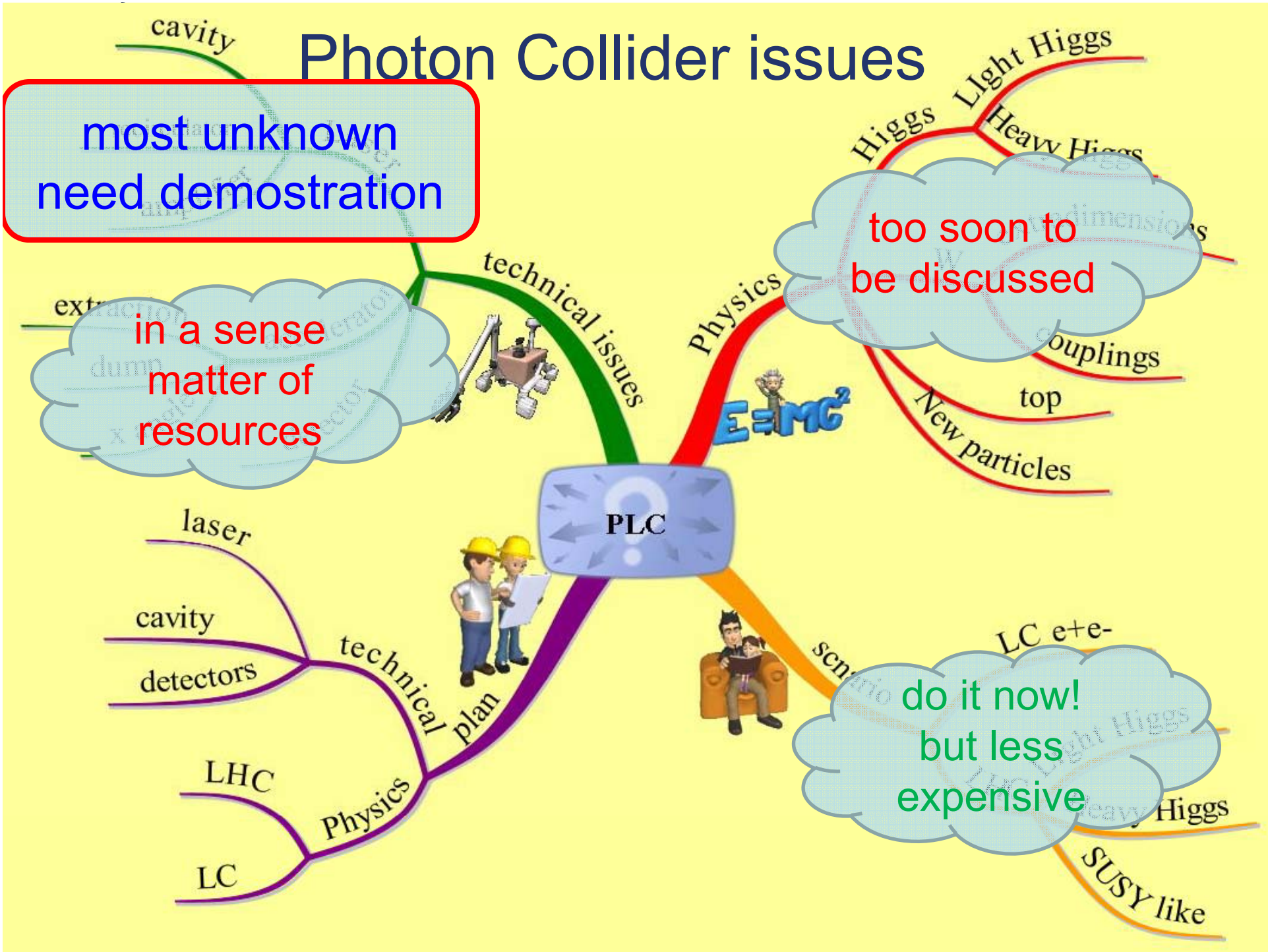
March 4 2008
GDE BDS/ACFA MDI
at Sendai

Photon Collider issues



Photon Collider issues

most unknown
need demostration



Laser for Photon Colliders at e-γ conversion point

- have to meet requirement of;
  - **5J~10J/pulse, 1-3ps pulse duration**
    - ~2TW pleak power
  - **337ns separation 3000bunches/train**

$$High\quad pumping\quad power = \frac{5J \times 3000}{1ms \times eff\ (0.3)} = 50MW$$

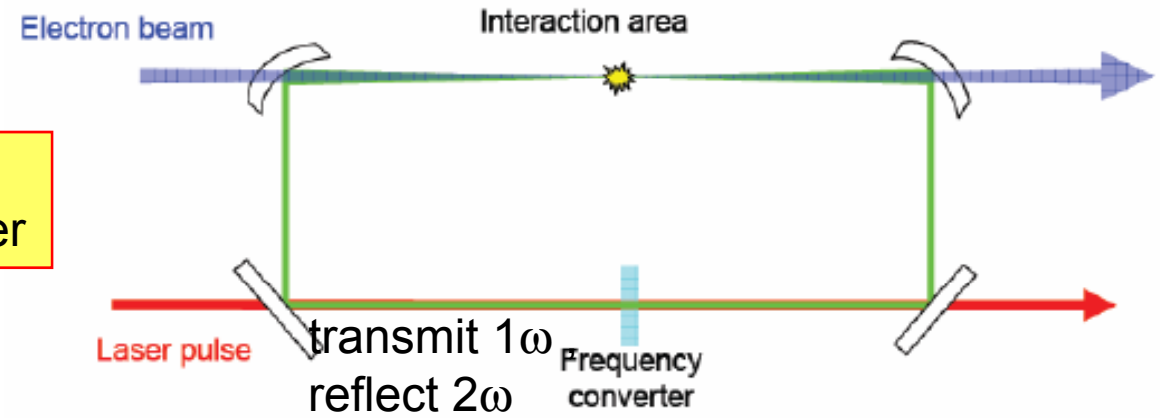
  - **5Hz**
    - ~70kW average power
  - **O(10μm) focusing**
  - **timing ~1ps**

- too costly to be built by single laser

Ideas to reduce laser power

- RING (Recirculation Injection by Nonlinear Gating) Cavity (Gronberg LEI2007)

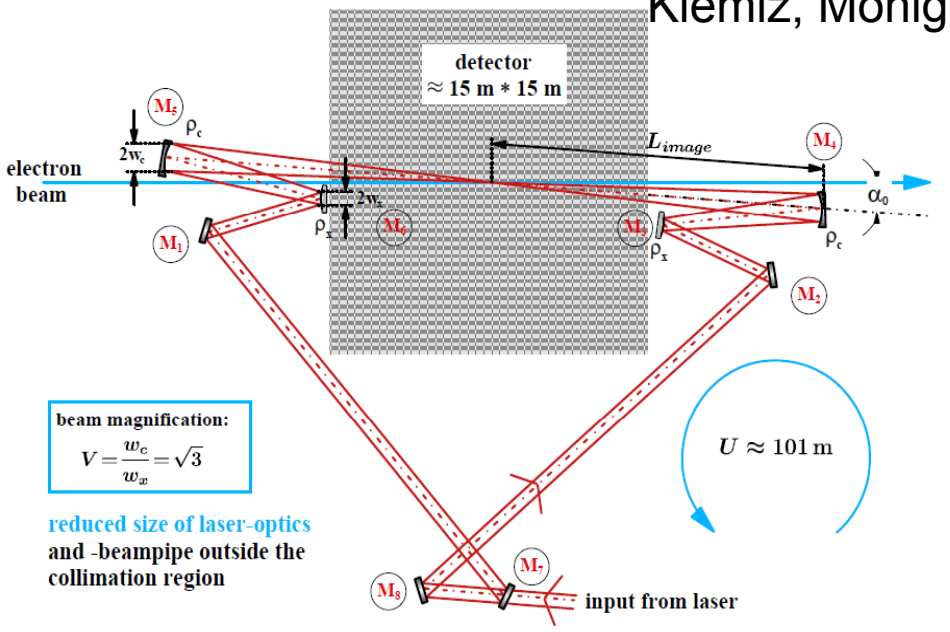
Recirculation of a laser pulse
to reduce average laser power



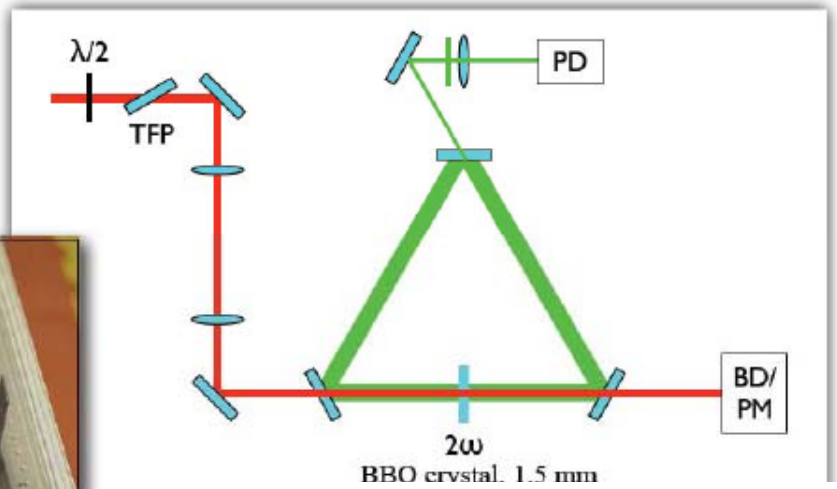
- Pulse Stacking Cavity

Stack laser pulses on phase
to reduce peak as well as average power

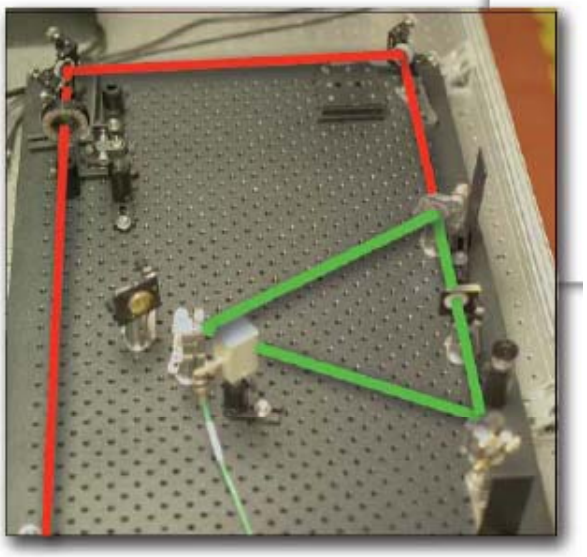
Klemiz, Monig



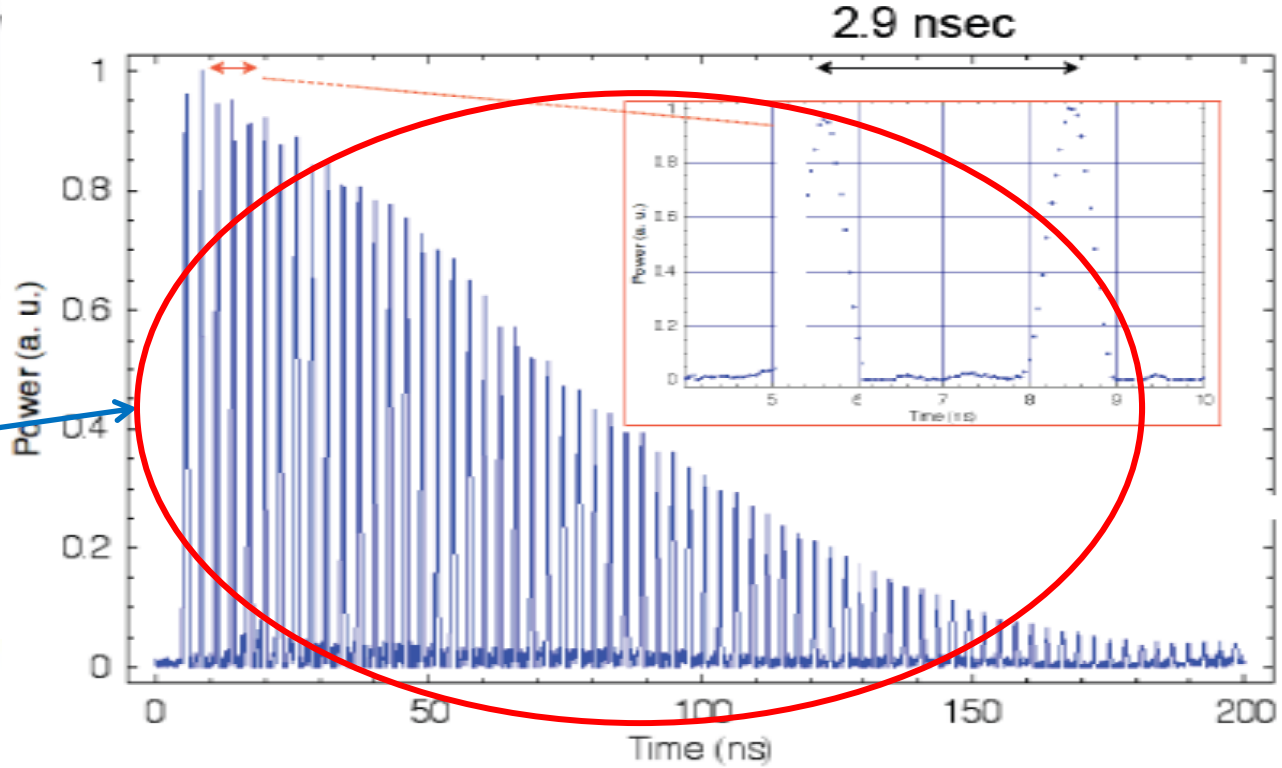
RING cavity at LLNL



I. Jovanovic,et.al



I. Jovanovic, LLNL



Integrated energy is 28.5 times that of a single pulse

The RING system has been demonstrated and published, joule-scale demo next year

Gronberg LEI2007

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High-power laser pulse recirculation for inverse Compton scattering-produced γ-rays

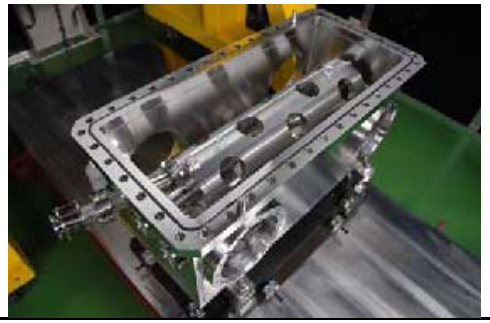
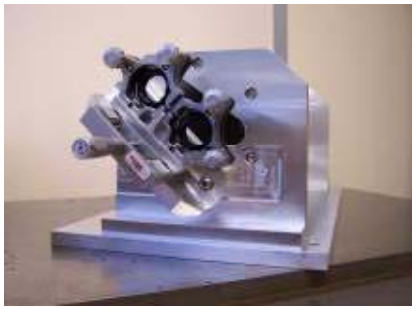
I. Jovanovic*, M. Shverdin, D. Gibson, C. Brown

Lawrence Livermore National Laboratory, Mail Code L-270, 7000 East Avenue, Livermore, CA 94550, USA

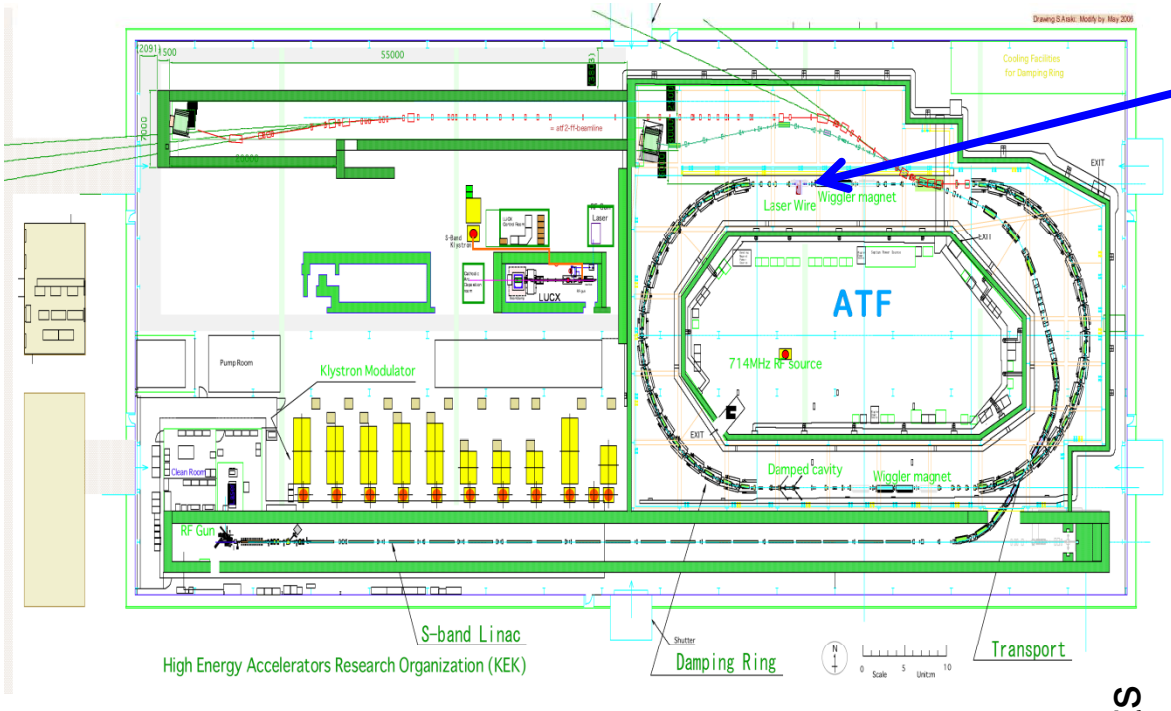
Received 24 April 2007; accepted 24 April 2007

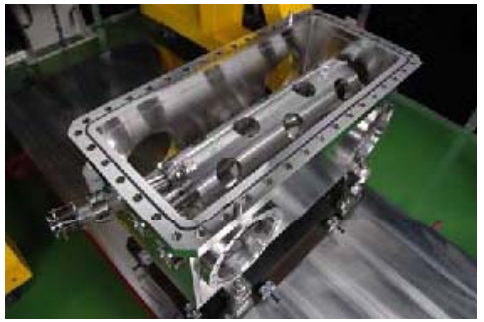
- RING cavity can increase the effective average power of the laser system by up to 100x
- RING cavity architecture is compatible with recirculation of high energy short laser pulses
- Compared to other "photon trapping" designs, RING cavity has 10x lower B-integral accumulation
- Compared to resonant enhancement schemes, RING cavity does not require interferometric stabilization
- Experimental work is underway to demonstrate recirculation of joule-scale pulses

Pulse Stacking Cavity R&D for Positron source
KEK-LAL-Hiroshima-Waseda-Kyoto-IHEP

	KEK	LAL
		
type	2 mirrors FP	4 mirrors ring
enhancement	1000	10000
Laser spot size	30μm	15μm
Feed back	Analog PID	digital
e-	at ATF, to get experiences with e-beam	stand alone (new w/ e- beam being designed. to be at ATF 2009)

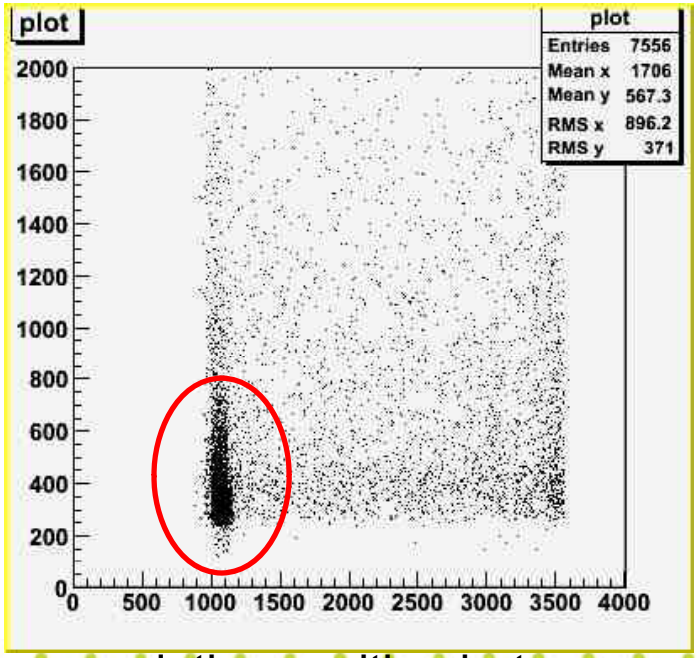
preliminary result from KEK-ATF





Enhansement of ~ 250 achived
(consistent w/ mirror reflectivity)

next step → to get stable high intensity γs



relative position between
e and laser pulse

Issues and Status

items	Pulse Stacking Cavity	RING Cavity
Performance	~300 enhancement of pulse energy	~recirculation of a pulse ~50 times
Laser requirements	•2820+300 pulses separated by 369ns •5 Joule / 300 = 0.016 J/pulse •5 Hz duty cycle	•2820 / 50 pulses separated by 369 * 50 ns •5J/ pulse •5 Hz duty cycle
Technical issues	•unprecedented for 100m long cavity •tight motion tolerances for interferometric stabilization •quiet environment •sophisticated feed back •adoptive optics ?	•unprecedented for 100m long cavity •No tight motion tolerances for interferometric stabilization •pulse deterioration during cirulation
R&D status	•PosiPol, x/γ sources •not for γγ system yet	•X ray source project at LLNL •not for γγ system yet

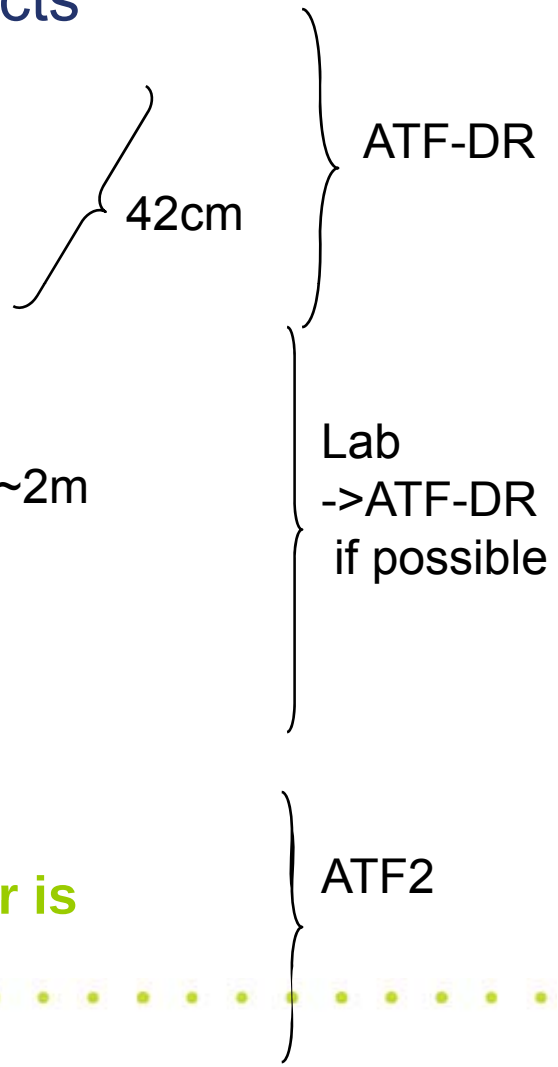
Possible plan at ATF

1. Cavities for Compton based pol. e+ projects
   - **Fabry-Perot type spherical mirror**
   - **Fabry-Perot type off-axis parabolic mirror**

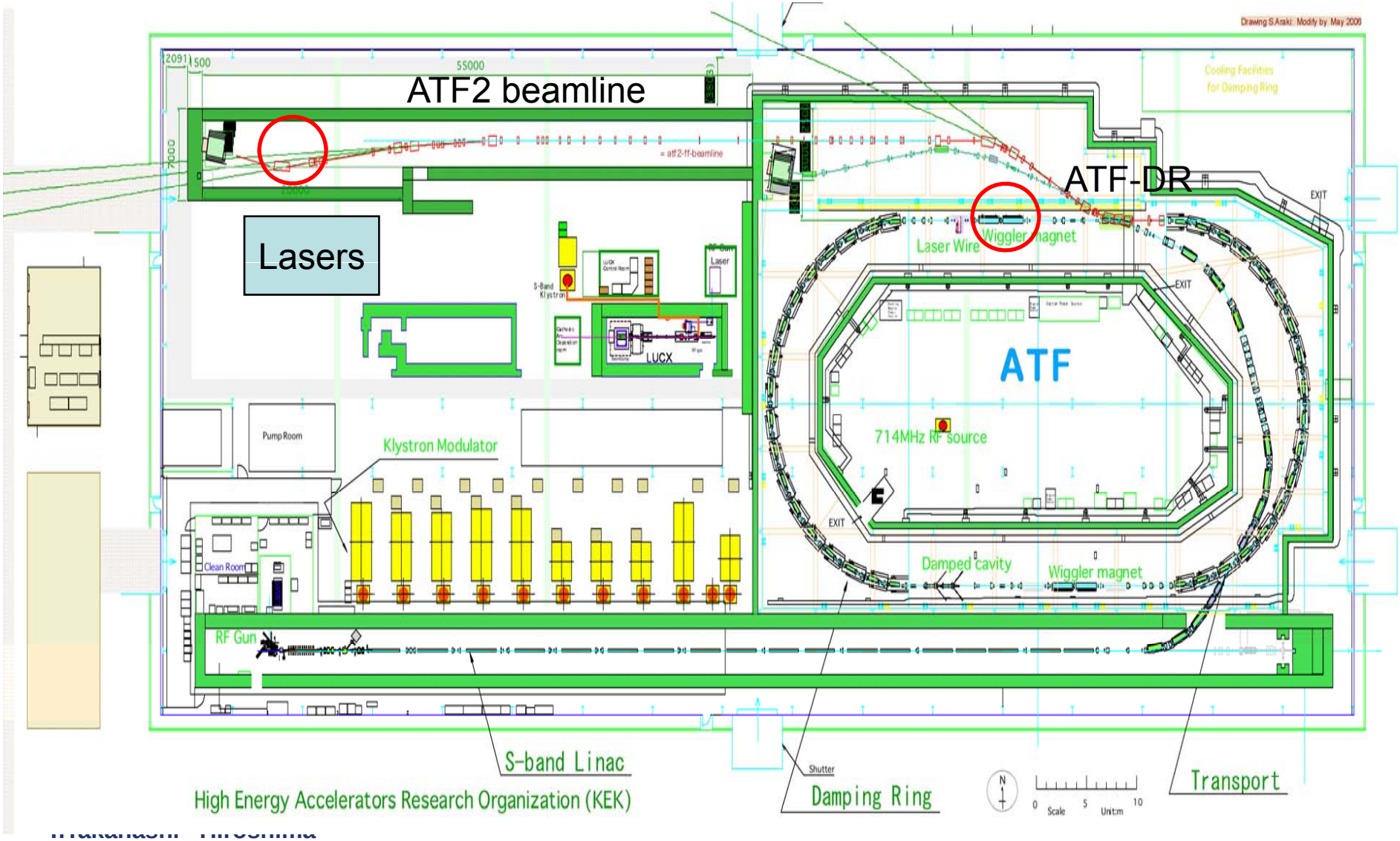
2. Going to large scale
   - **CW laser**
   - **independent mirror control**

3. 1-2m scale (with ATF bunch)
   - **pulse laser (low energy)**
   - **independent mirror control**

4. Cavity w/ high power laser at ATF2-IP
   - **not possible at ATF-DR as high power laser is destructive target**

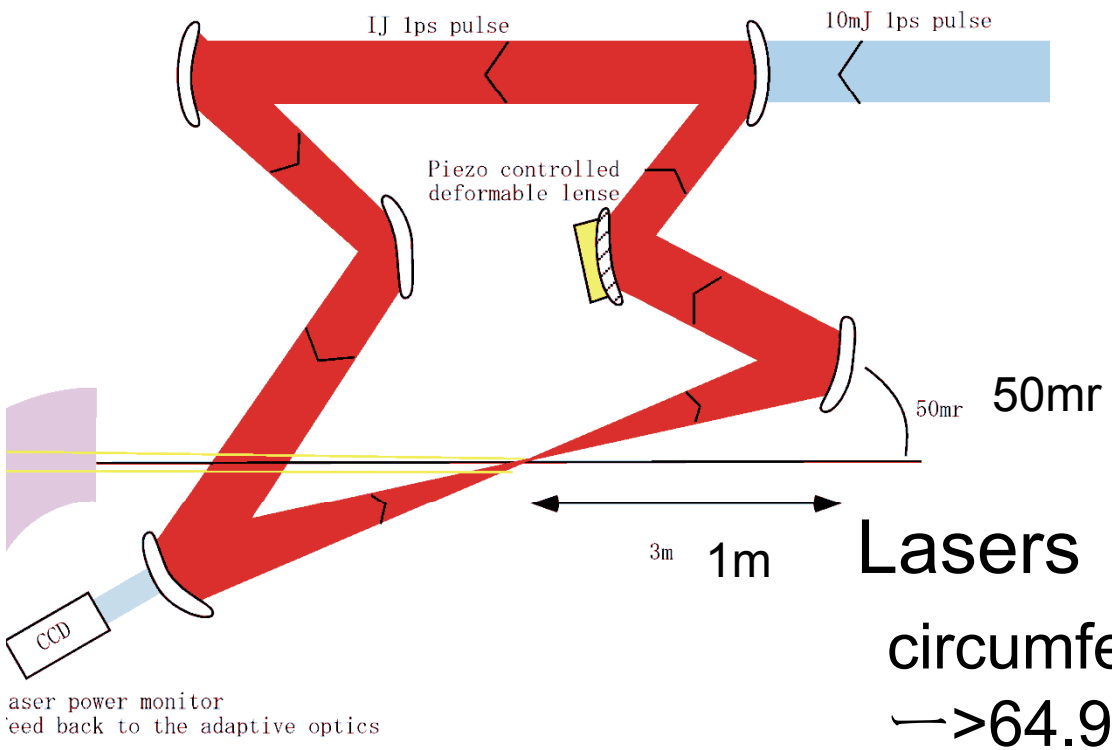


ATF-Layout


ATF2 beamline
ATF-DR
Lasers
Laser Wire
Wiggler magnet
ATF
714MHz RF source
Damped cavity
Wiggler magnet
Klystron Modulator
Pump Room
Clean Room
RF Gun
LUCX
S-band Linac
Damping Ring
Transport
Shutter
EXIT
Cooling Facilities for Damping Ring
High Energy Accelerators Research Organization (KEK)

Ring cavity at ATF-DR

-after we learn a lot from PosiPol cavities-



For 154ns spacing:
1/10 scale (15.4ns)

A laser pulse hits once in
10 turns

Lasers

circumference 4.62m (15.4ns)
—>64.9MHz

very similar to
PosiPol experiment

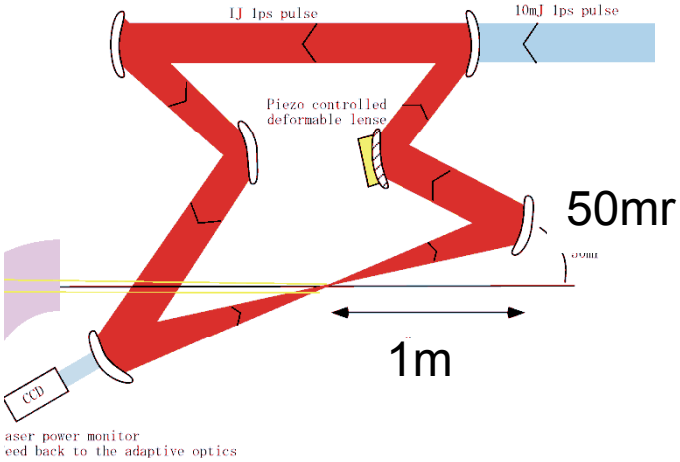
10W mode locked,,,154nJ/pulse
->15.4μJ/pulse w/ 100 pulse stacking

2400γ/xing

Ring cavity+High power at ATF2-IP

Cavity can be the same as ATF-DR but the laser is not

we want 50mJ/pulse for the laser (5J/pulse in cavity)



⇒ 64.9MHz ×50mJ=3.245kW

Continuous pumping (64.9MHz)of the cavity is not wise:
just for 20 bunches (for a train)

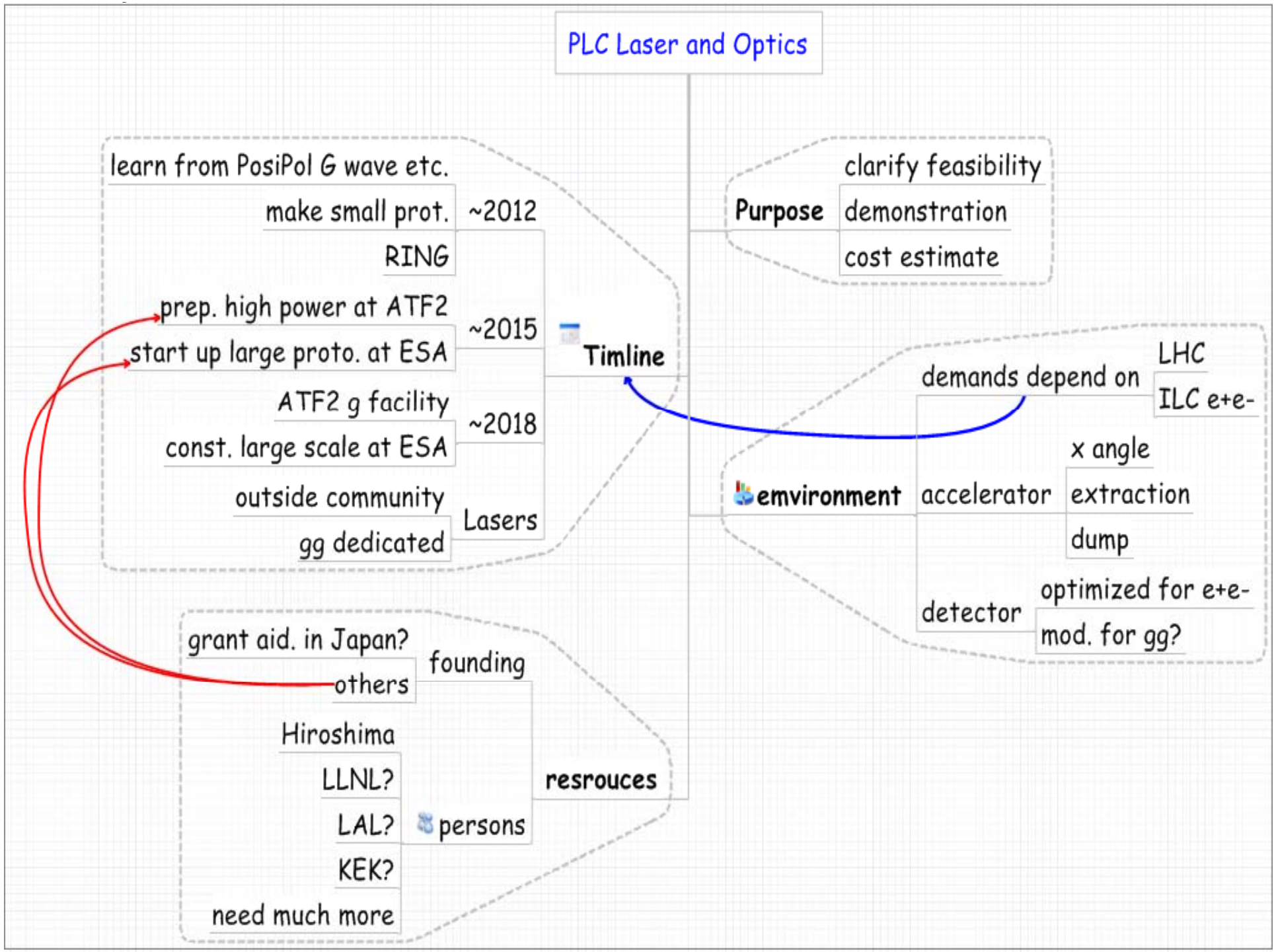
Average power = 50mJ×20×repetition = as low as 1W (or less)

$$\text{Peak laser pumping power} = \frac{50mJ \times 20}{1ms \times eff\ (0.3)} = 3.3kW$$

need mini-Mercury amplifier?

What we can do at ESA?

	ESA	**ATF/ATF2**
e beam	up to 50 GeV	1.3 GeV
	up to 12Hz single bunch	A few Hz 154 ns x 30 bunches
	jitters?	very stable sub ps
γ s	10 GeV	10MeV
falicity	large enough for 100 sale cavity?	No enoun space for large cavity regulation for the radiation safe
comment	10GeV γ facility attractive?	10MeV γ facility for pol e+ etc? physics w/ intense field


PLC Laser and Optics
Purpose
clarify feasibility
demonstration
cost estimate
Timline
learn from PosiPol G wave etc.
make small prot.
~2012
RING
prep. high power at ATF2
~2015
start up large proto. at ESA
ATF2 g facility
~2018
const. large scale at ESA
outside community
Lasers
gg dedicated
emvironment
demands depend on
LHC
ILC e+e-
accelerator
x angle
extraction
dump
detector
optimized for e+e-
mod. for gg?
resrouces
founding
grant aid. in Japan?
others
persons
Hiroshima
LLNL?
LAL?
KEK?
need much more

Summary

- **Two Ideas of cavities to reduce laser power**
  - **RING**
    - technically easier but moderate power reduction
    - R&D at LLNL for x ray sources
  - **Pulse Stacking**
    - reduce both peak and average power ~(100) but very challenging
    - R&D for PosiPol at KEK-ATF
- **Laser technology continues to improve without our involvement but need an effort to meet design for cavities**
    - *still high power*
    - *mode locked laser for stacking cavity?*
- **γ ray faclity at ATF2 and/or ESA possible?**

•Still much to learn from other field but 100m long cavity is completely different world
•need to setup dedicated R&D toward the large scale cavity and γ ray generation