International Workshop on Future Linear Colliders

LCWS13

11-15 November 2013, The University of Tokyo

Colored ILC

Atsuto Suzuki (KEK)

INTER-UNIVERSITY RESEARCH INSTITUTE CORPORATION

HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

1. Green ILC

2nd Workshop
Energy for Sustainable Science
at Research Infrastructures

CERN, GENEVA, SWITZERLAND, 23-25 OCTOBER 2013

Energy Management in Japan, Consequences for Research Infrastructures

Masakazu Yoshioka (KEK)

1. Electric power supply in Japan, before and after March 11, 2011 earthquake
   - High efficiency and "almost" environmental pollution-free electricity generators can save Japan, and contribute to reduce global CO_2 problem
2. KEK Electricity contract as an example of large-scale RIs
3. Accelerator design by considering optimization of luminosity/electricity demand
   - Example: Super-KEKB
   - ILC
4. Accelerator component design by considering high power-efficiency
   - Klystron
   - Availability based on MTBF and MTTR
5. Summary

Energy Management at KEK, Strategy on Energy Management, Efficiency, Sustainability

Atsuto Suzuki (KEK)

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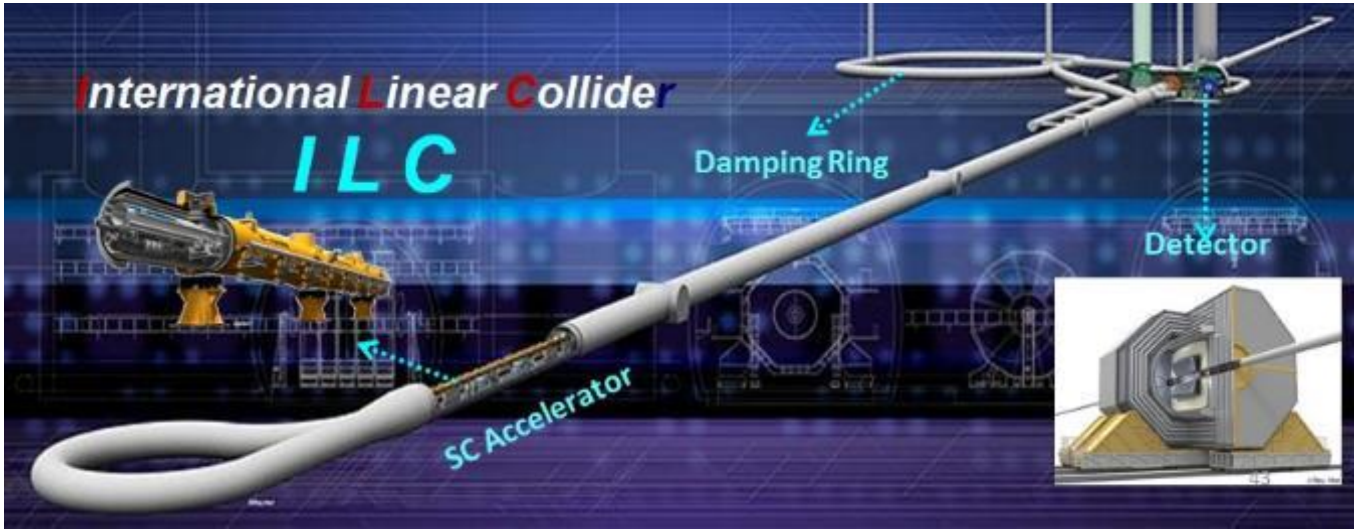
Improve Efficiency of Power Consumption in Accelerator Operation

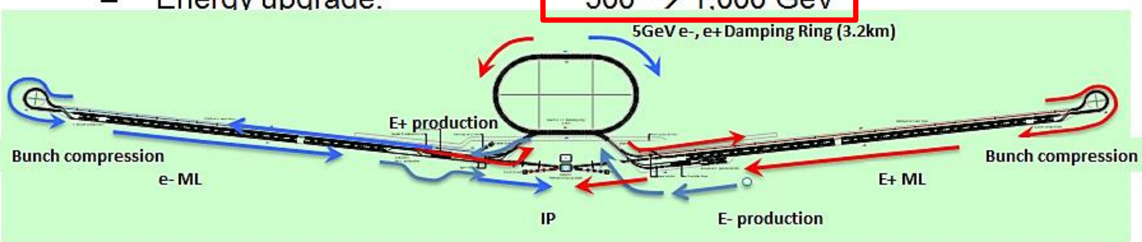
serious issue for ILC



Power Balance of Consumption and Loss in ILC

Requirements from Physics Exp.

- Basic requirements :
  - Luminosity : $\int Ldt$ = 500 fb^{-1} in 4 years
  - E_{cm} : 200 – 500 GeV and the ability to scan
  - E stability and precision: < 0.1%
  - Electron polarization: > 80%
- Extension capability :
  - Energy upgrade: 500 → 1,000 GeV



ILC 500 GeV Total Power : ～200 MW

Improve efficiency

	loss rate
Infrastructure : 50 MW	50 % : 25 MW
RF System : 70 MW	50 % : 35 MW
Cryogenics : 70 MW	90 % : 60 MW
Beam Dump : 10 MW	100 % : 10 MW
200 MW	～ 130 MW

Obligation to Us

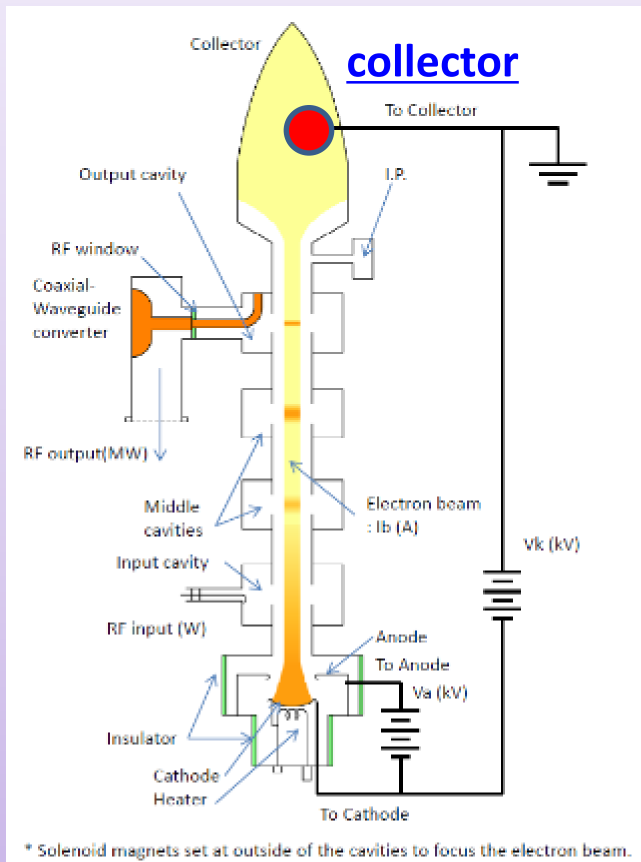
Increase recovery

How to Improve RF Efficiency

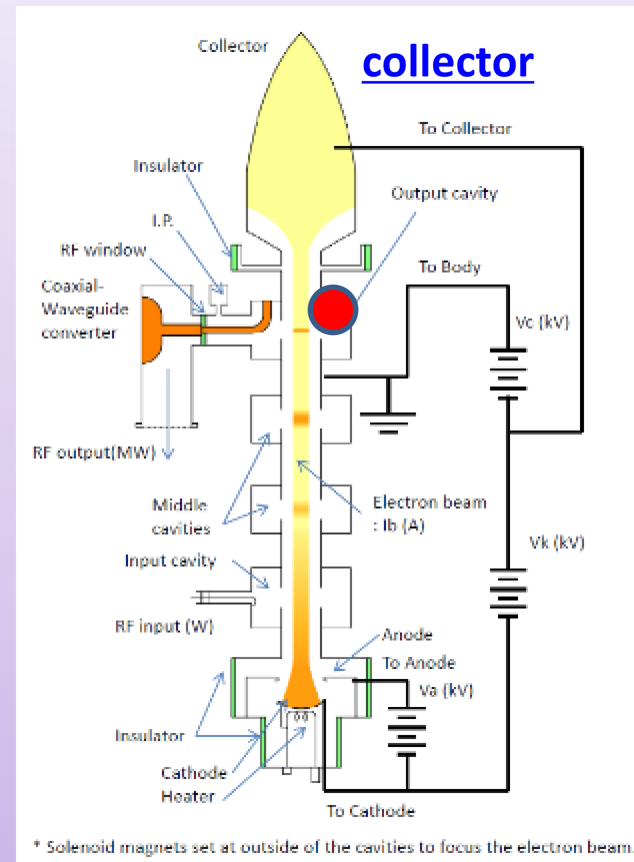
R&D of CPD (Collector Potential Depression) Klystron

CPD is an energy-saving scheme that recovers the kinetic energy of the spent electrons after generating rf power.

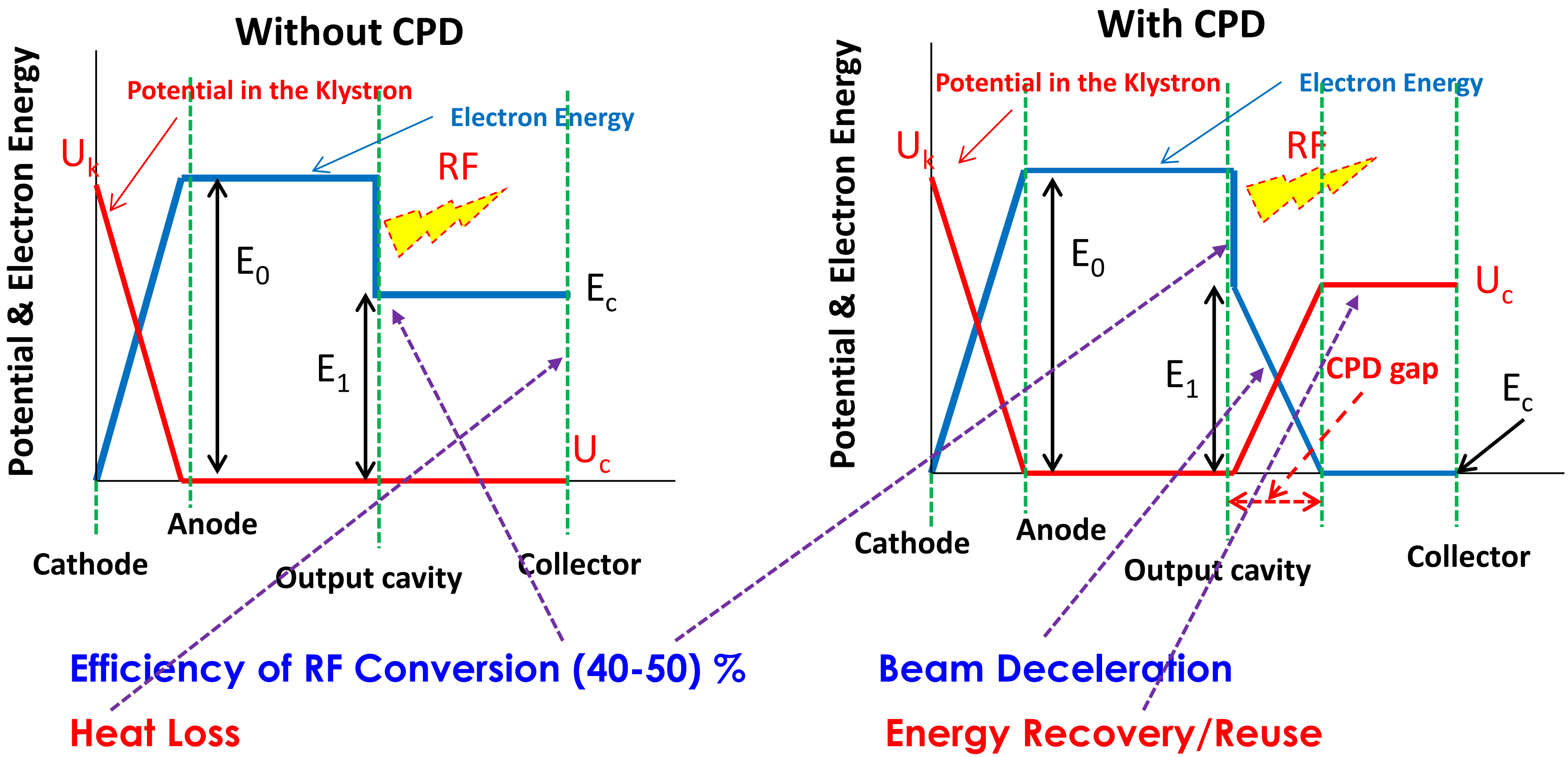
Conventional



Schematic diagram of CPD



Simplified Schematic Concept

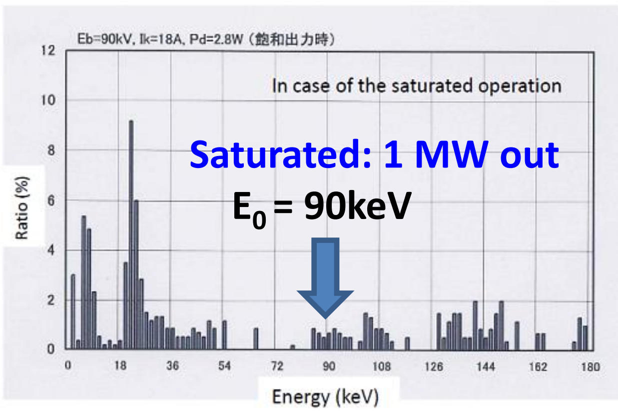


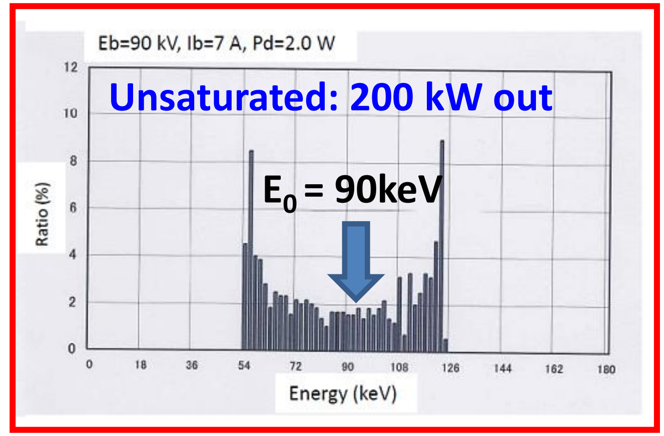
Potential denotes the electron potential energy, eV. For simplicity, input and intermediate cavities are omitted here and the anode potential is set to zero.

Issues must be addressed for CPD Klystron

(I) Energy spread

The spent electron beam has large energy spread through electromagnetic interaction in the cavities. Therefore, the collector potential cannot be increased beyond the lower limit of energy distribution of the spent electron beam, otherwise backward electrons hit the cavities or the gun, and then deteriorate the klystron performance.





(II) Pulse-to-DC conversion

The spent electron beam is longitudinally bunched, so that pulsed voltage is induced on the collector. An adequate pulse-to-DC converter has to be implemented.

(III) RF Leakage

CPD klystron has to be equipped with an insulator between the collector and the body column in order to apply CPD voltage to the collector. Thus, it would be possible for the CPD klystron to leak rf power out more or less from the insulator.

Present Status of R&D

Target

proof-of-principle of CPD in the unsaturated region (a maximum rf power of 500 kW) using a KEKB 1.2MW-klystron

R&D Schedule

2013.3: Modification of an existing klystron to CPD klystron (already done)

2014.3: until then, preparation and commissioning of the test station

~2014: Verification of klystron operation without CPD

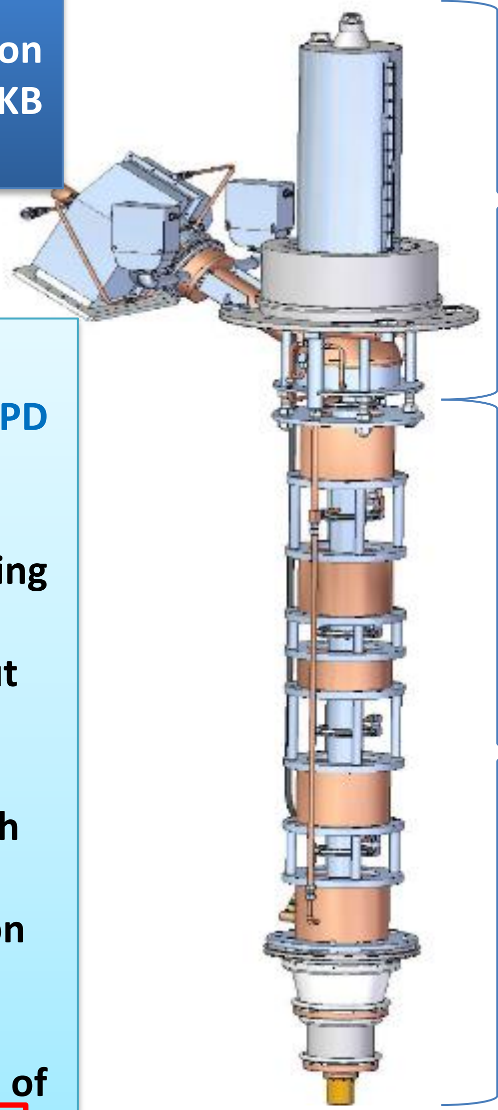
~2015: Measurement of rf leakage from the gap between the body column and the collector (with no CPD voltage applied)

Measurement of induced pulse voltage on the collector with CPD

~2017: Test of rectification by Marx circuit

Integration test of the proof-of-principle of CPD operation

80 % efficiency



Newly fabricated components

- collector
- ceramic insulator
- output cavity
- output coupler

Recycled components

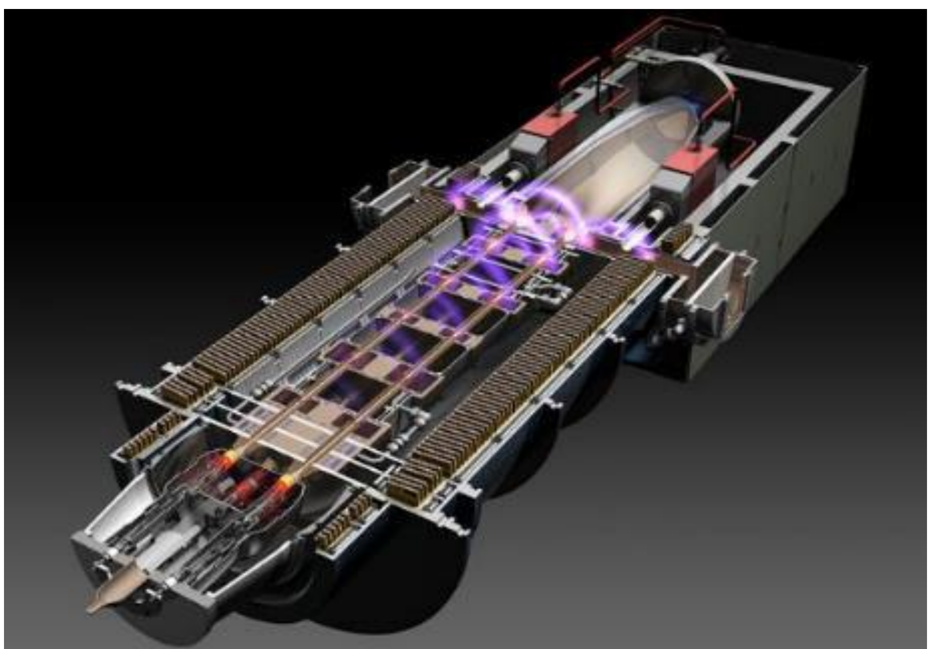
- electron gun
- input cavity
- intemediate cavities

Multi(6) – Beam Klystron (MBK) for 26 Cavities for ILC

DEVELOPMENT OF TOSHIBA L-BAND MULTI-BEAM KLYSTRON FOR EUROPEAN XFEL PROJECT

Y. H. Chin, KEK, Tsukuba, Japan,
A.Yano, S. Miyake, TOSHIBA ELCTRON TUBES & DEVICES Co., Ltd., Ohtawa-shi, Japan,
S. Choroba, DESY, Hamburg, Germany

- **The design goal is to achieve 10 MW peak power with 65 % efficiency at 1.5 ms pulse length at 10 Hz repetition rates.**
- **MBK has 6 low-perveance beams operated at low voltage of 115 kV for 10 MW to enable a higher efficiency than a single-beam klystron.**



e 2: Electron Gun of the E3736.

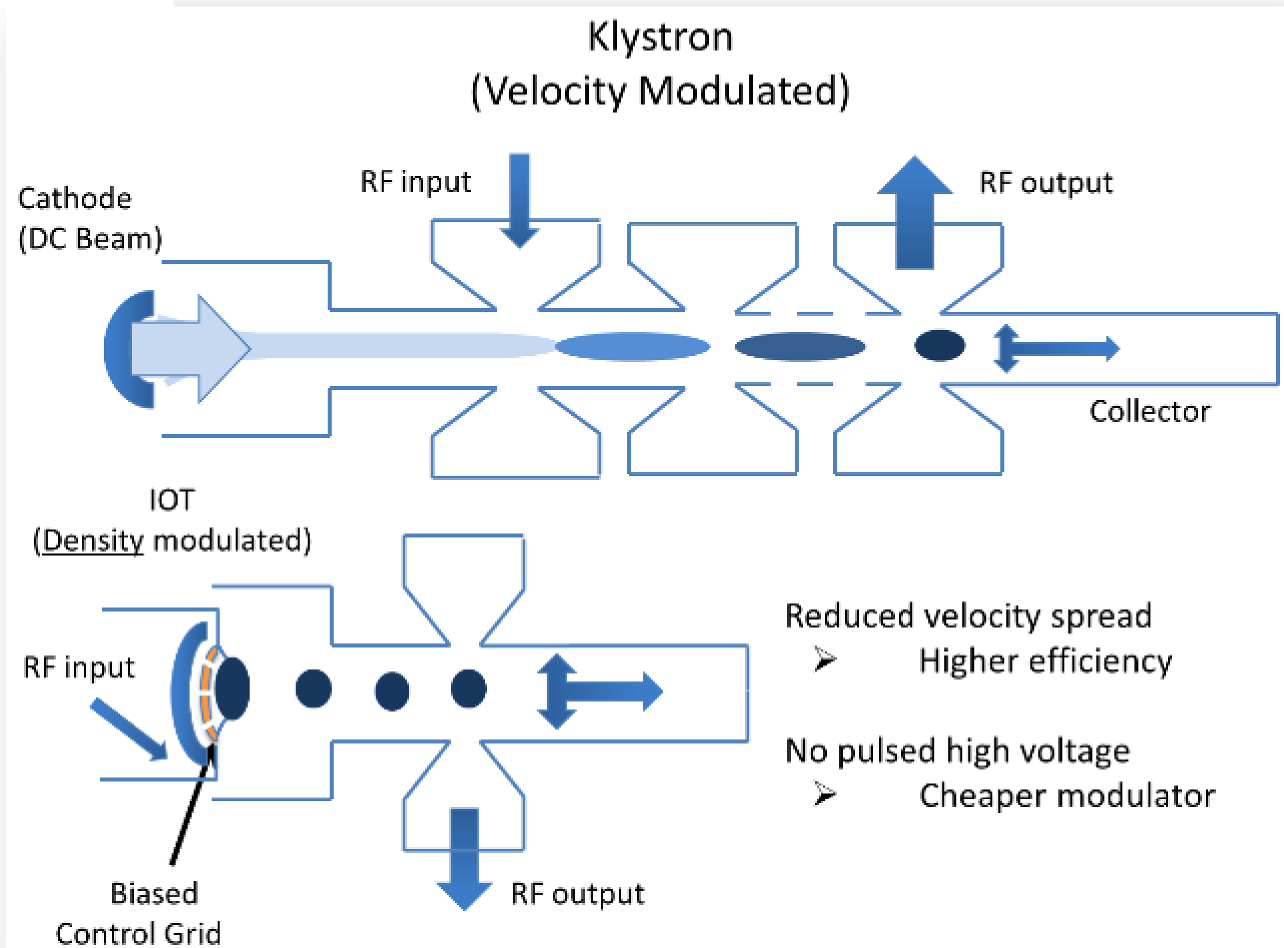
Frequency	1.3 GHz
Peak power	10 MW
Pulse width	1.6 ms
Rep. rate	5 Hz
Average power	78 kW
Efficiency	**65 %**
Gain	47dB
BW (- 1dB)	3 MHz
Voltage	120 kV
Current	140 A
Lifetime	40,000 h

Design Status of IOT for ILC

Hyoung Suk KIM
KNU
KOREA
CCAST ILC Accelerator Workshop and
1st Asian ILC R&D Seminar under JSPS Core University
November 7, 2007

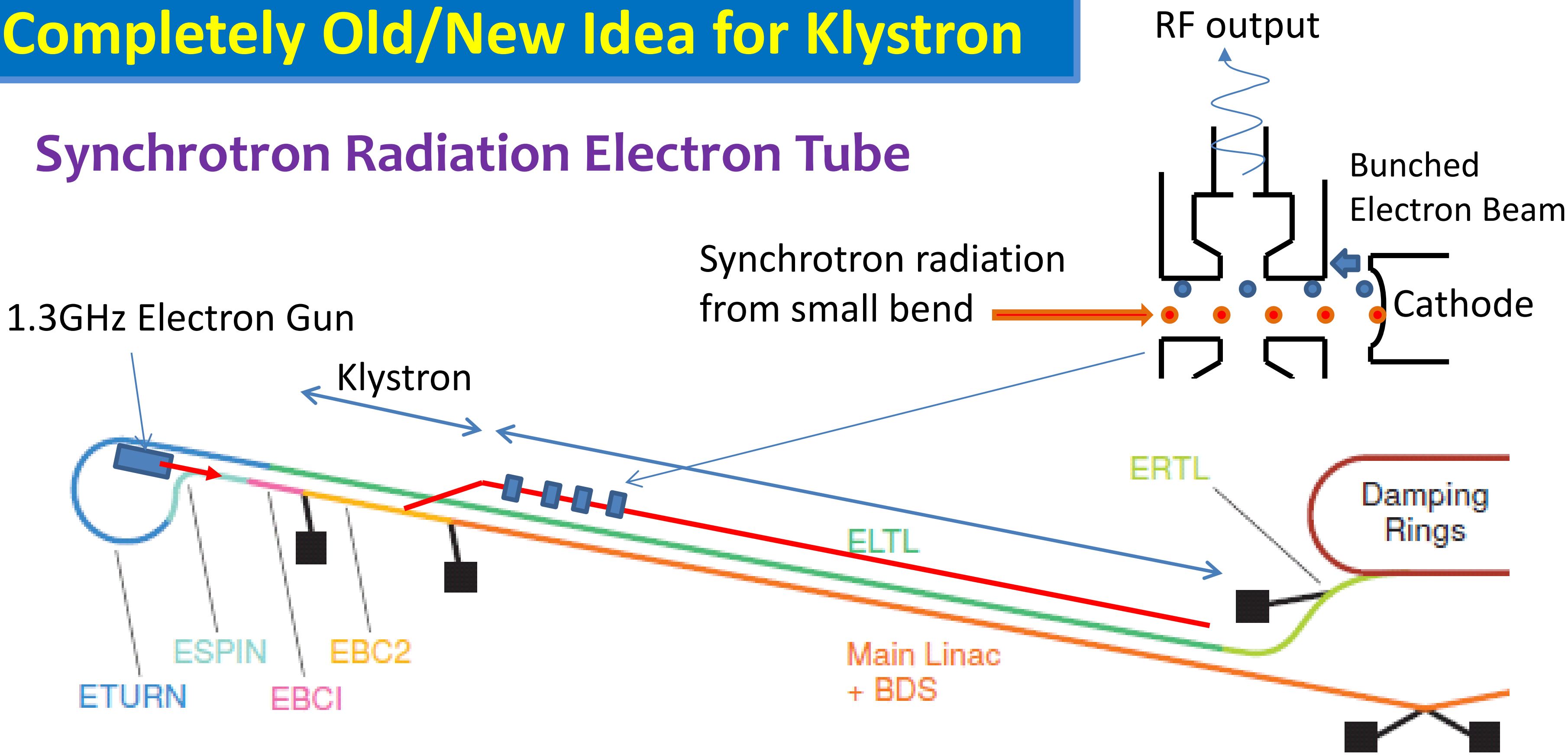
Inductive Output Tube

function : Vacuum Tube



Completely Old/New Idea for Klystron

- **Synchrotron Radiation Electron Tube**



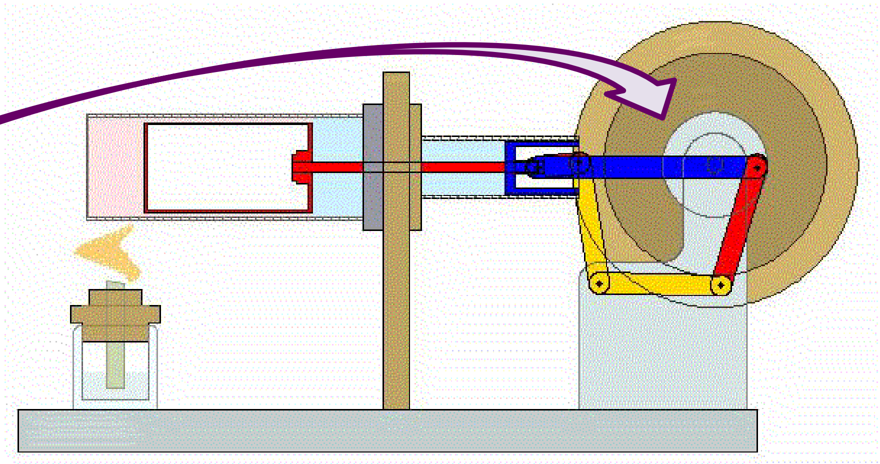
Advantages

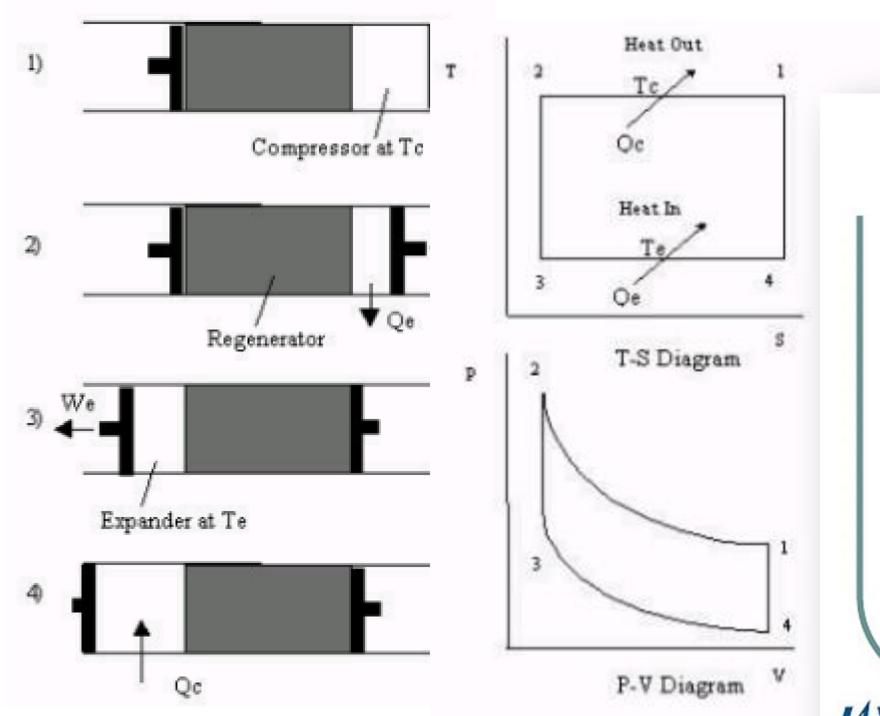
- > 90% efficiency (small transient time factor by short bunch)
- Stabled by space charge limit operation
- Drivn from low charge low energy 1.3GHz electron beam (1/10 klystron ?)
- Very low cost and long lifetime
- Low cost beam line
- No switch, only HV & capacitor

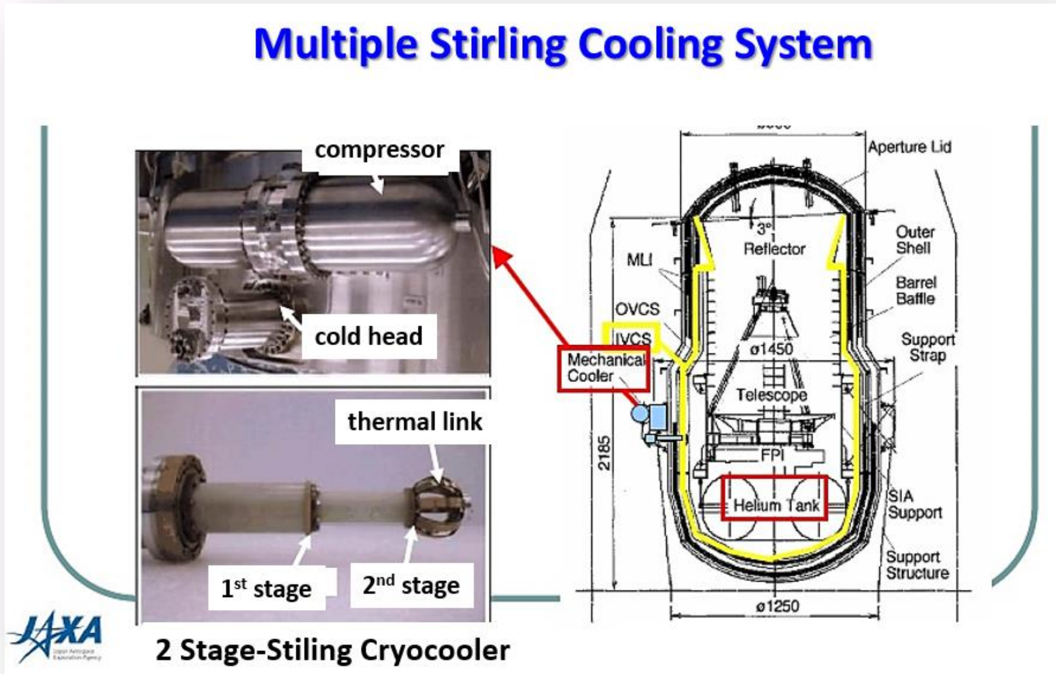
How to Save Power in Cryogenics

Cryogenics/Stirling Cryocooler

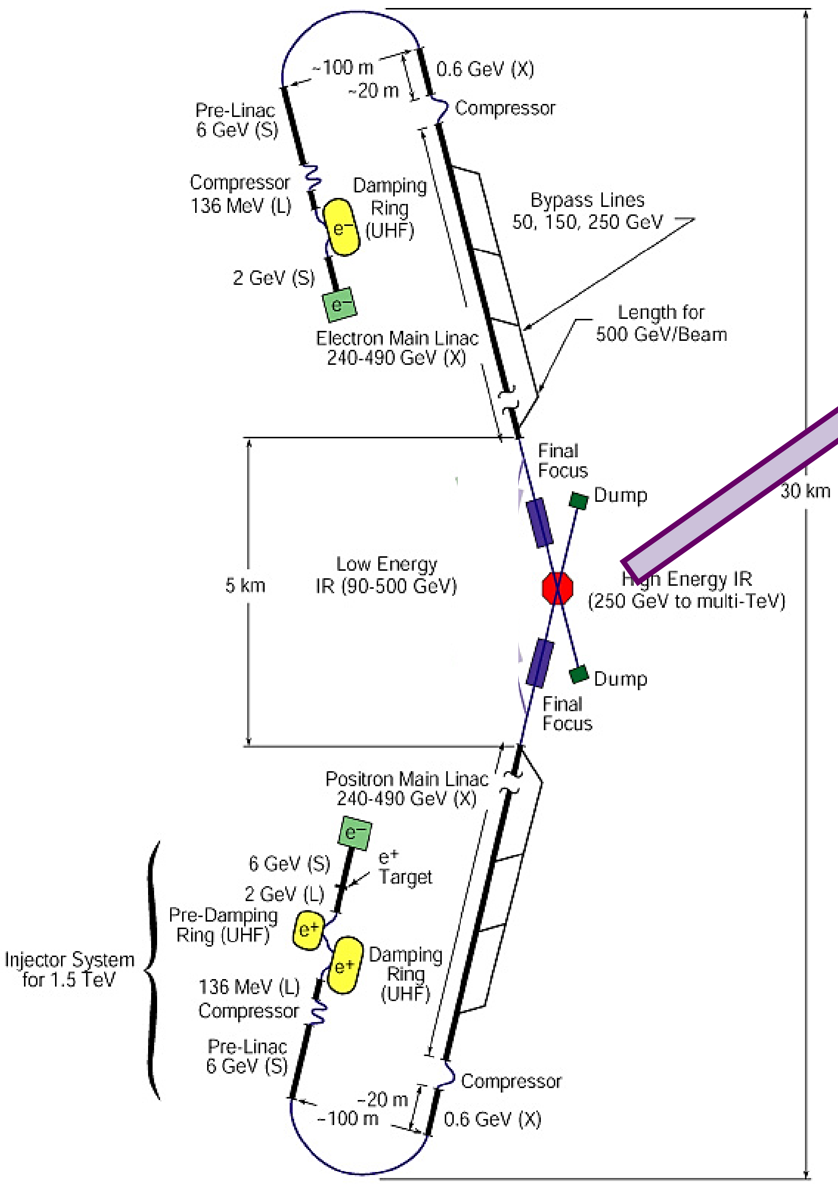
- High temperature operation
  - Klystron collector
  - RF Dummy load

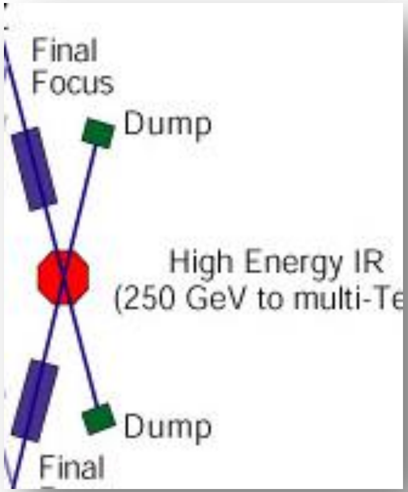






How to Recover Beam Dump Energy (～10 MW)

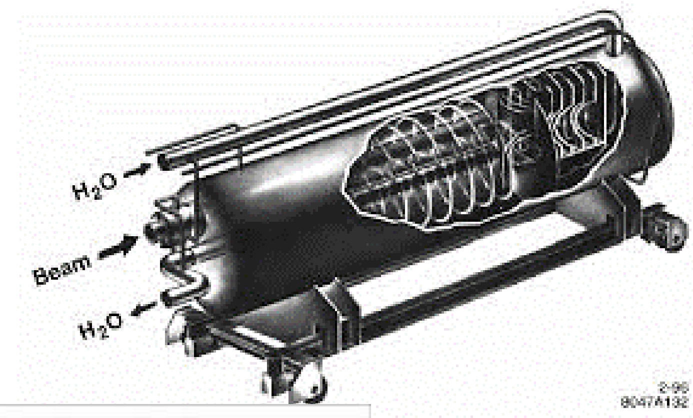




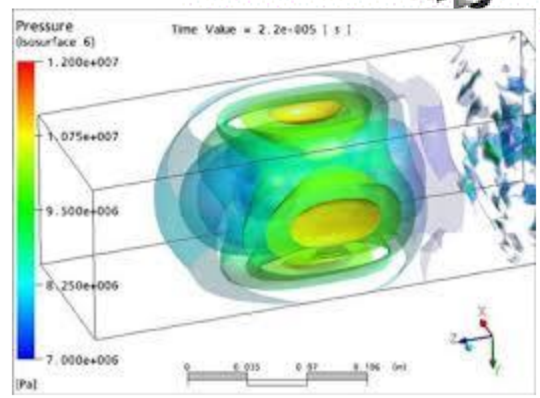
- ➢ **Recover Beam Energy**
- ➢ **Reduce Radio-Activation**

Water Dump

SLAC Dump
for 800 kW



Water Vortex Dump
(25 m long x 15 m height for 1 TeV)



- Issue : shock wave management
- Issue : management of tritium gas and tritiated water in vapor form

Noble Gas Dump for ILC

- About 1km of a noble gas (Ar looks the most promising) enclosed in a water cooled iron jacket (transport the heat).
- This gas dump design may ease some issues such as radiolysis and tritium production.
- Issue : particle beam heating of the gas and ionization effects.

Plasma Deceleration Dumping

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 13, 101303 (2010)

Collective deceleration: Toward a compact beam dump

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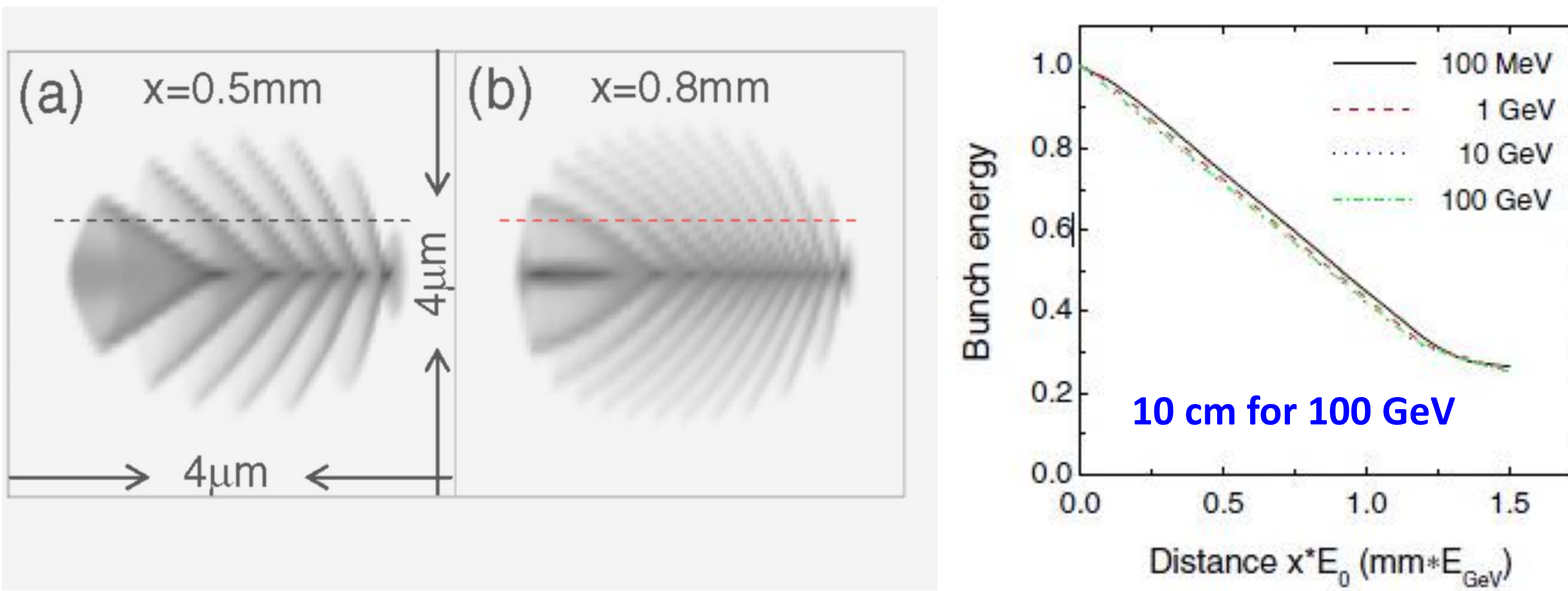
[1]*Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany*
[2]*Fakultät für Physik, Ludwig-Maximilians-Universität München, D-85748 Garching, Germany*
[3]*SLAC National Accelerator Center, Stanford University, Stanford, California 94309, USA*
(Received 10 December 2009; published 5 October 2010)

Use Collective Fields of Plasmas for Deceleration



- The deceleration distance in the underdense plasma is 3 orders of magnitude smaller than the stopping in condensed matter.
- The muon fluence is highly peaked in the forward direction.

Collective Stopping Power for ILC

$$L_{dump}\,[\mathrm{m}] \approx 1.7\times10^{13}\,\frac{\sigma_T^2\,[\mathrm{cm}]}{N_b}\,E_0\,[\mathrm{GeV}]$$

$$here\quad \sigma_T \geq 0.6\sigma_L \;\&\quad \sigma_T \geq 1.9\times10^{-6}\sqrt{N_b\sigma_L}$$

(electron bunch)

ILC $\quad N_b = 2\times10^{10} \quad E_0 = 500\mathrm{GeV}$

$$L_{dump}\,[\mathrm{m}] \approx 4.3\times10^{5}\sigma_T^2\,[\mathrm{cm}]$$

$\sigma_T \approx 50\ \mu m$, $\sigma_L \approx 3\ \sigma_T \approx 150\ \mu m$

→ L = 10 m for Li gas

Next Trials

- Experiment of Proof-of-Principle
- Deposit mechanism of Wake-Field energy

Improve
:
Power Storage to Reuse

Improve efficiency

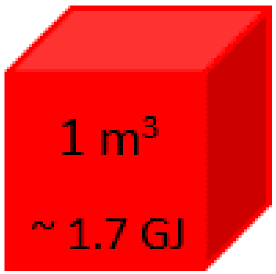
	Ross Rate
Infrastructure : 50 MW	50 % : 25 MW
RF System : 70 MW	40 % : 28 MW
Cryogenics : 70 MW	100 % : 70 MW
Beam Dump : 10 MW	100 % : 10 MW
	~ 130 MW

Increase recovery

Storage of Thermal Energy

Heat Capacity Iron vs. Water

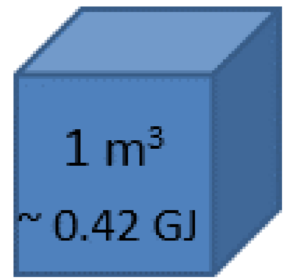
Heat Capacity of Iron



$\Delta T = 500$ ºC

$\Delta E = m \times Cp \times \Delta T$
= 8000 kg
x 0.1 kcal/kg/ºC
x 500 ºC
x 4.2k J/ kcal
= 1680000 k J
= 1.68GJ

Heat Capacity of Water

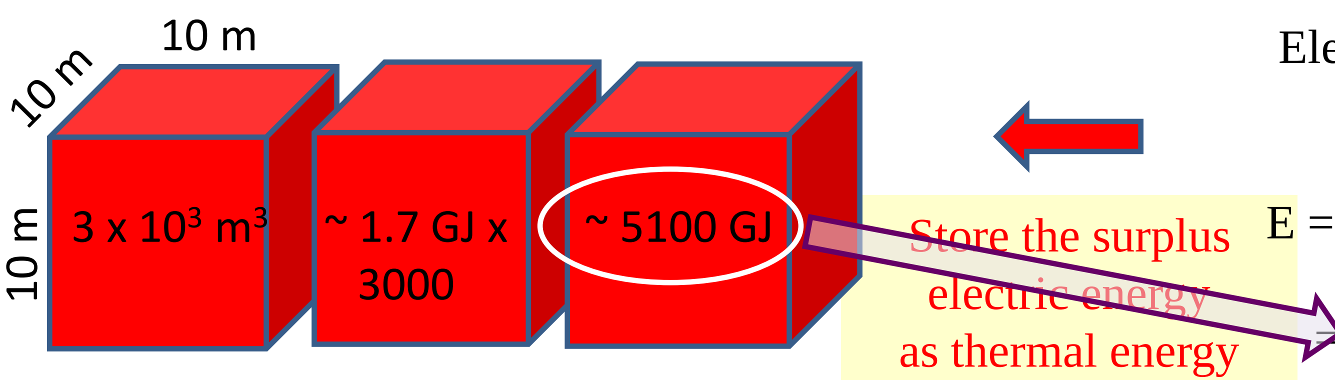


$\Delta T = 100$ ºC

Heat Capacity of Water

Cc.c.	=	4.2	J/c.c./ºC
C_L	=	4.2	kJ/ L / ºC
C_{m3}	=	4.2	MJ/m^3/ ºC

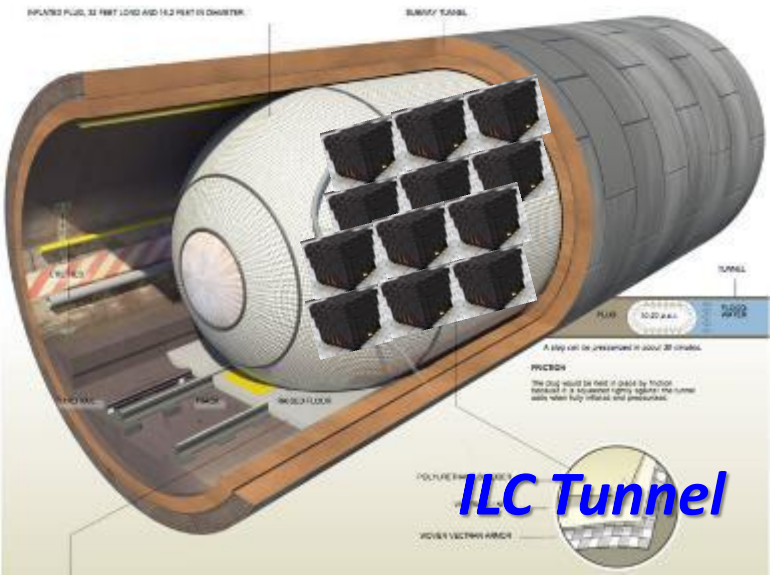
Storage of Electric Energy as Heat in Iron



Electric Energy
100 MW x 1 0 hours

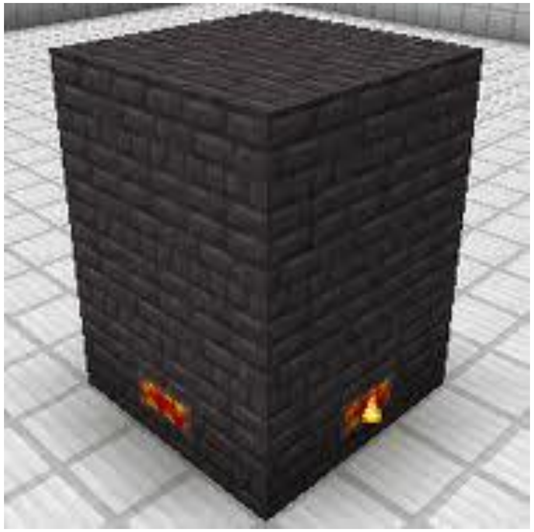
E = 100 M J / sec
x 3600 sec / hr x 10 hr
= 3600 GJ

how to keep iron heat



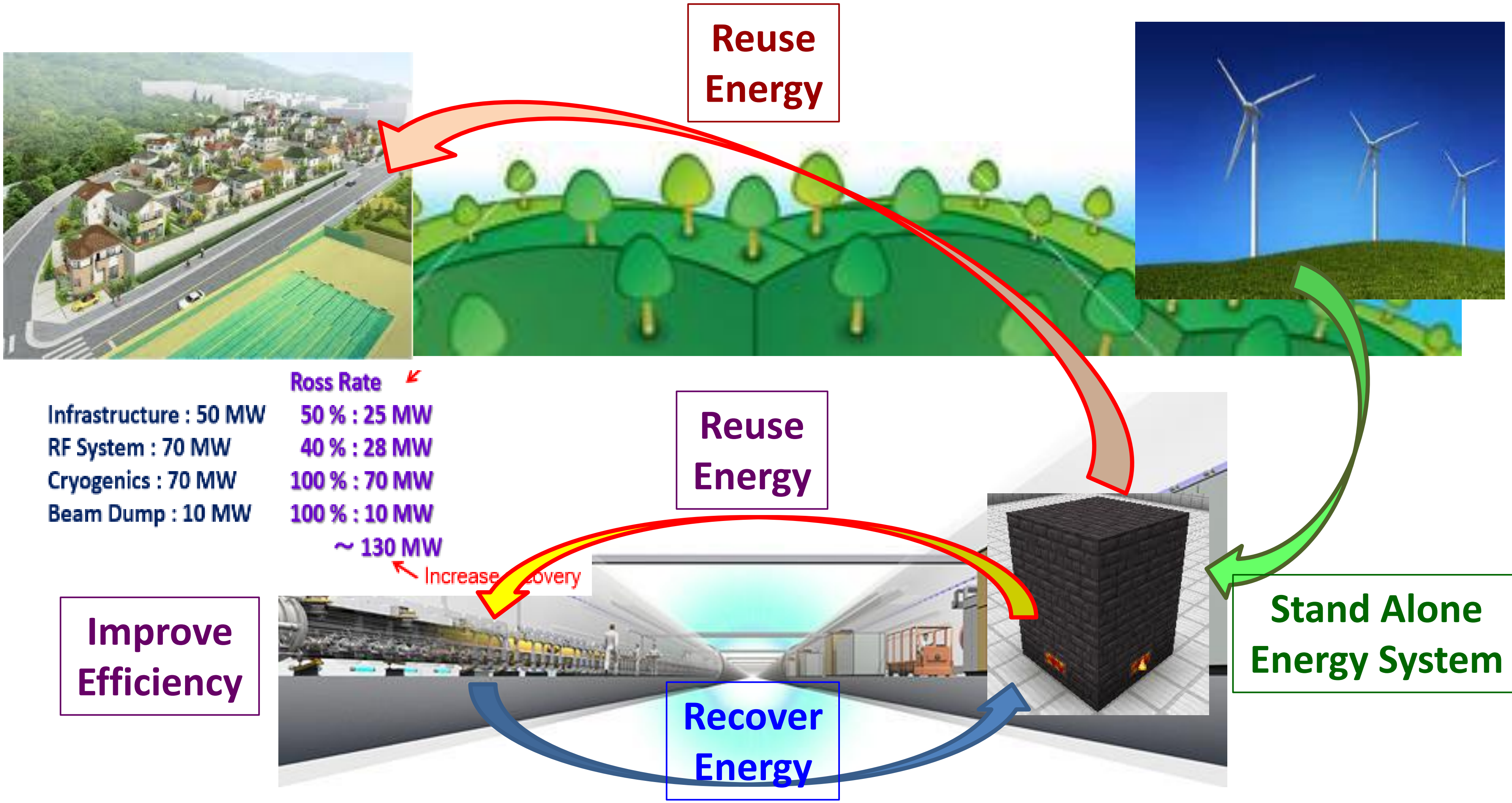
Blast Furnace

Fire Brick

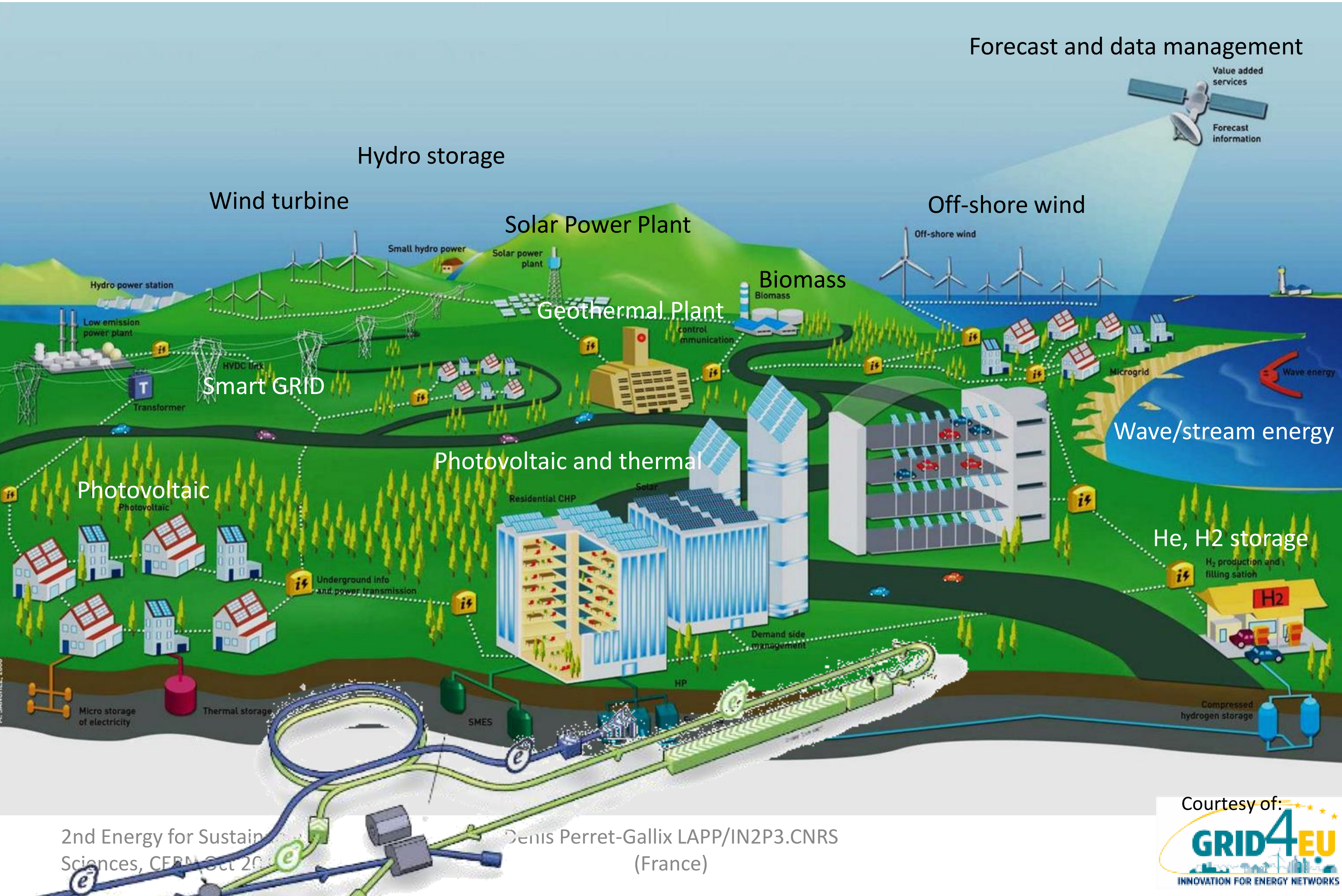



ILC

Summary


Reuse Energy
Ross Rate
Infrastructure : 50 MW
50 % : 25 MW
RF System : 70 MW
40 % : 28 MW
Cryogenics : 70 MW
100 % : 70 MW
Beam Dump : 10 MW
100 % : 10 MW
~ 130 MW
Increase
Reuse Energy
Improve Efficiency
Recover Energy
Stand Alone Energy System

ILC center futuristic view



Courtesy of:
GRID4EU
INNOVATION FOR ENERGY NETWORKS

2. Yellow ILC

P5 Face-to-Face Meeting #1

2-4 November 2013 *Fermi National Accelerator Laboratory*
US/Central timezone

Strategic Planning for the Japanese Program

Atsuto Suzuki (KEK)

INTER-UNIVERSITY RESEARCH INSTITUTE CORPORATION
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

P5 Report → Government (Nov. 7)

- The world HEP scientists are strongly disappointed with media remarks about the JSC findings on the ILC project. This damage looks too serious.

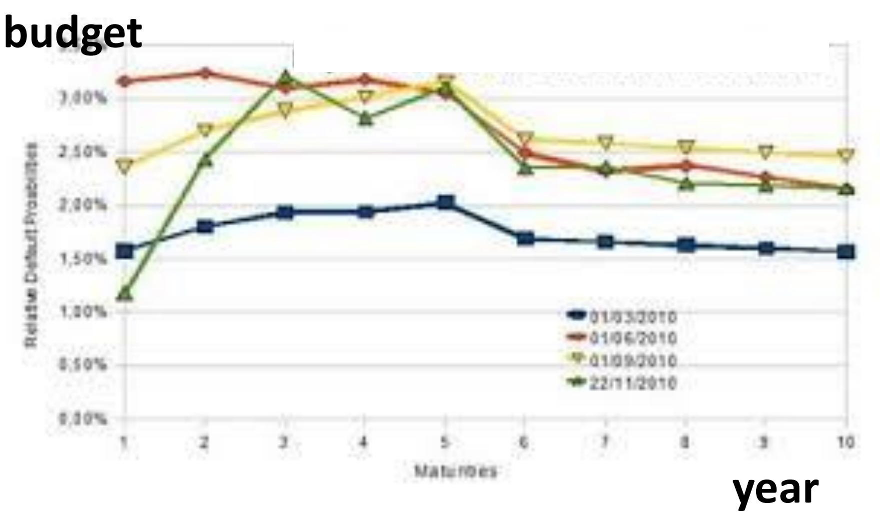
- Scientists are deeply concerned that the Japanese government would hesitate to advance the realization of the ILC project.

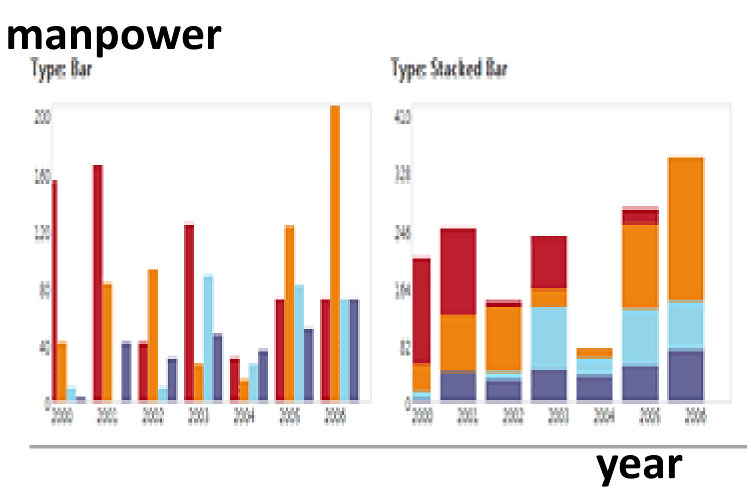
- Given these, it is urgent that the government unfolds its view on the JSC findings.

- The government should now pay much attention on how to define interests to host the ILC in Japan. It is the next step to start governmental discussions about the budget and man-power sharing.

- The world HEP community understands that the next FALC is the best opportunity for the government message.

- The Rolf Heuer (CERN), Nigel Lockyer (FNAL) and A.S (KEK) had the consensus that the timeprofiles of budget-breakdown (CFS, accelerator, detector ･･･) and man-power-breakdown are essential for the governmental negotiation.





3. Red ILC

Summary

More/More Efforts on Hosting the ILC in Japan