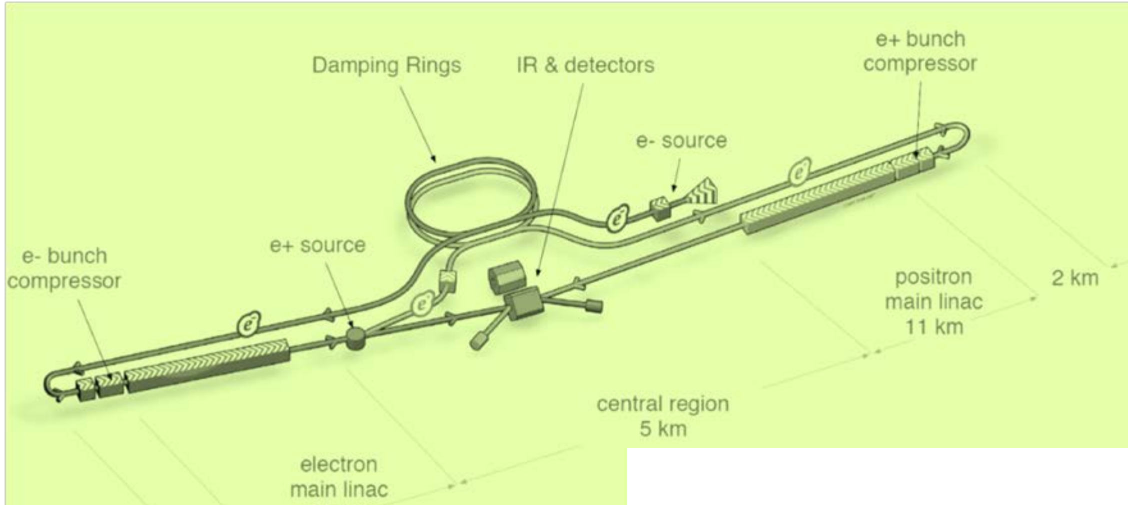

GREEN ILC

Collisionneurs Verts

L'Energie pour l'Innovation, Innovation dans l'Energie

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LAPP/IN2P3/CNRS - KEK

Power and Energy for Colliders

LHC-CERN ~ 180 MW - 1.35 TWh/year, 50% Geneva electr. consumption (~ 250,000)

FCC-ee : 354 MW @ 350 GeV (top ring and pre-injection not included)
FCC-hh : 468 MW @ 100 TeV (pre-injection NOT included (+100 MW ??) (P. Collier)
CLIC : 272 MW @ 500 Gev 589MW @ 3 Tev

ILC: 164MW @ 500GeV - 300MW @ 1TeV (TDR)
ILC lab. (Experiment, Computing, Buildings) => 180 MW @ 500 GeV, 320 MW @ 1 TeV.
TDR takes a large margin: 300 MW 500 MW
(240 MW @ 500 GeV, RDR estimation)

ILC 500 GeV 18% of Iwate prefecture electricity consumption, ~ Morioka (300,000)
ILC 1 TeV 32%
Cost:

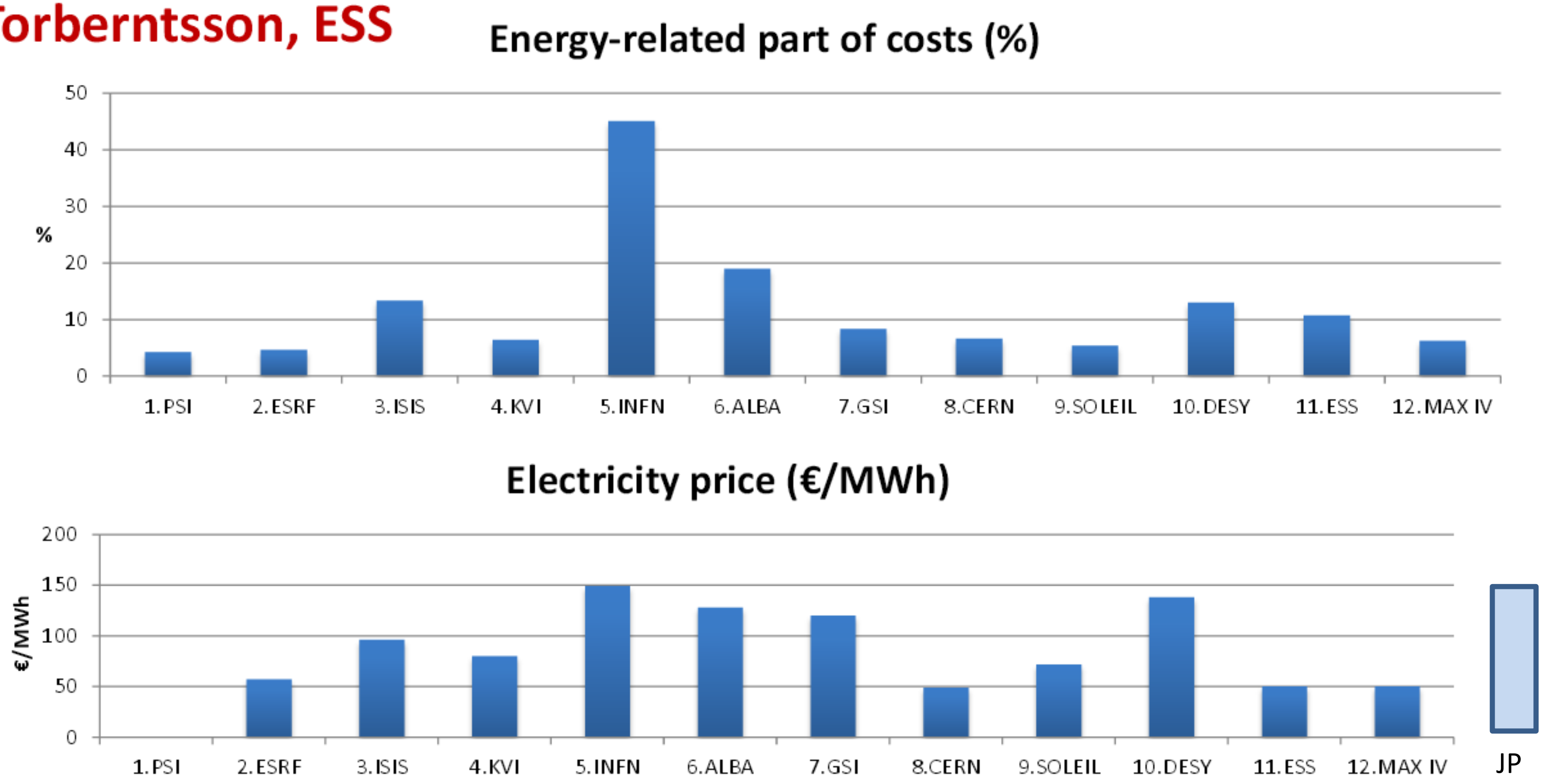
- 180$/MWh 2011 for industry (JP OECD 2013 report, special discount?, price volatility (2024))
- CERN (2011, ~ 70 $/MWh), ESS (Sweden, 110 $/MWh)

Yearly electricity running cost: 500 GeV ~ 240 M$ (10 years, ~25% of ILC capital cost)
1 TeV ~ 430 M$ (scaling on power)

HEP future: To be Green … or not to be !!

Presentation May, 2014…

J.Torberntsson, ESS



MAX IV LABORATORY

EuCARD²

EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

Les hautes-énergies…
c'est d'abord l'énergie

ILC est un convertisseur d'énergie: de (m)eV au TeV

avec

Une faible efficacité ~ 9.6 %

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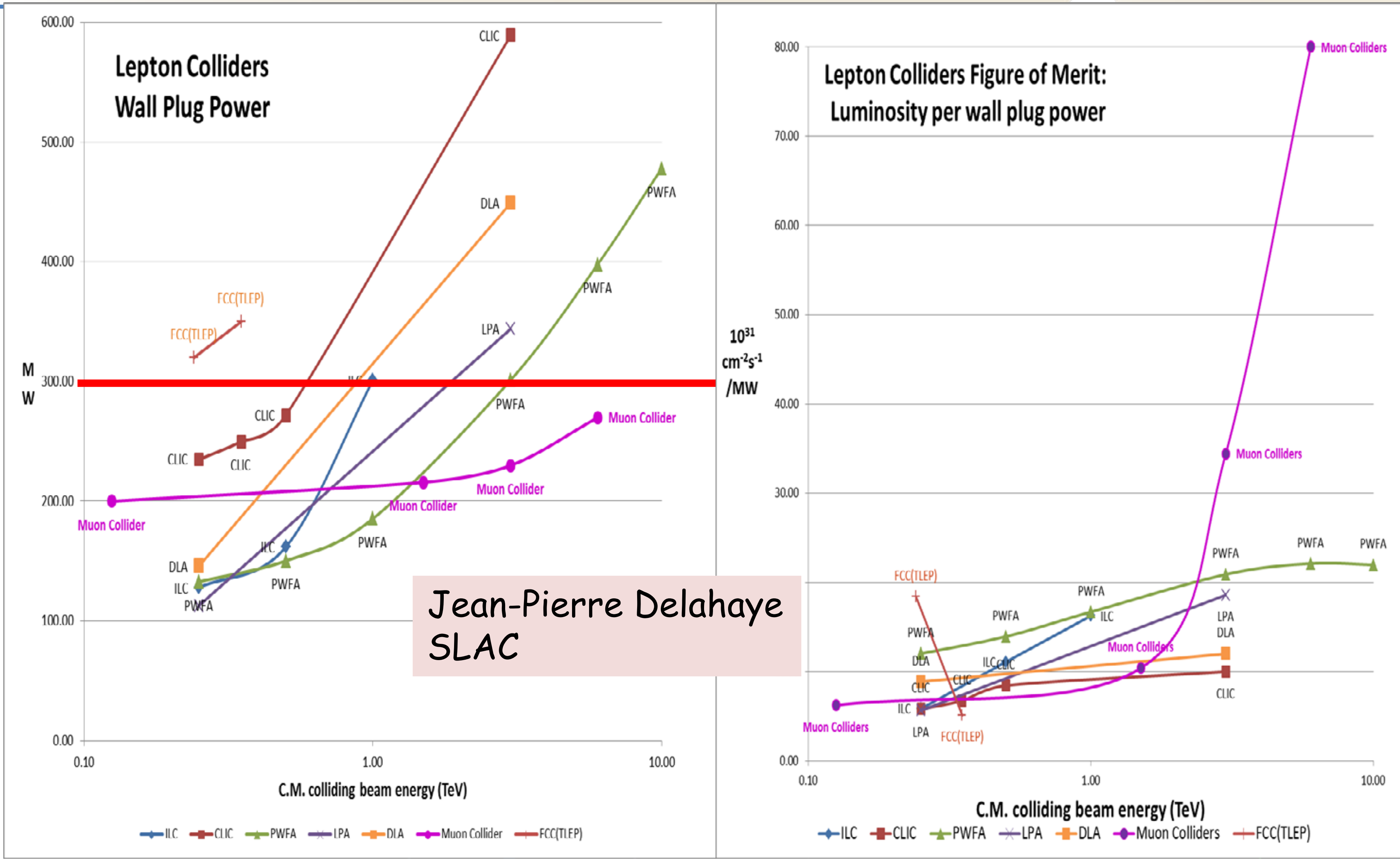
Muon Colliders extending high energy frontier with potential of considerable power savings



Jean-Pierre Delahaye
SLAC

ILC baseline energy budget
164 MW @ 500 GeV

Table 11.6
Estimated DKS power loads (MW) at 500 GeV centre-of-mass operation. 'Conventional' refers to power used for the utilities themselves. This includes water pumps and heating, ventilation and air conditioning, (HVAC). 'Emergency' power feeds utilities that must remain operational when main power is lost.

Accelerator section	RF Power	Racks	NC magnets	Cryo	Conventional		Total
					Normal	Emergency	
e^- sources	1.28	0.09	0.73	0.80	1.47	0.50	4.87
e^+ sources	1.39	0.09	4.94	0.59	1.83	0.48	9.32
DR	8.67		2.97	1.45	1.93	0.70	15.72
RTML	4.76	0.32	1.26		1.19	0.87	8.40
Main Linac	52.13	4.66	0.91	32.00	12.10	4.30	106.10
BDS			10.43	0.41	1.34	0.20	12.38
Dumps					0.00	1.21	1.21
IR			1.16	2.65	0.90	0.96	5.67
TOTALS	68.2	5.2	22.4	37.9	20.8	9.2	164 MW
Rank:	1	6	3	2	4	5	
% :	42	3	15	23	13	5	

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Green-ILC Objectives

ILC : lower running cost, better operational flexibility, eco-friendly

Revisiting all ILC components, in terms of:

1. Energy Saving: improving efficiency … 90% (if not 100%) lost as heat waste
2. Operational saving
3. Energy Recovery and Recycling

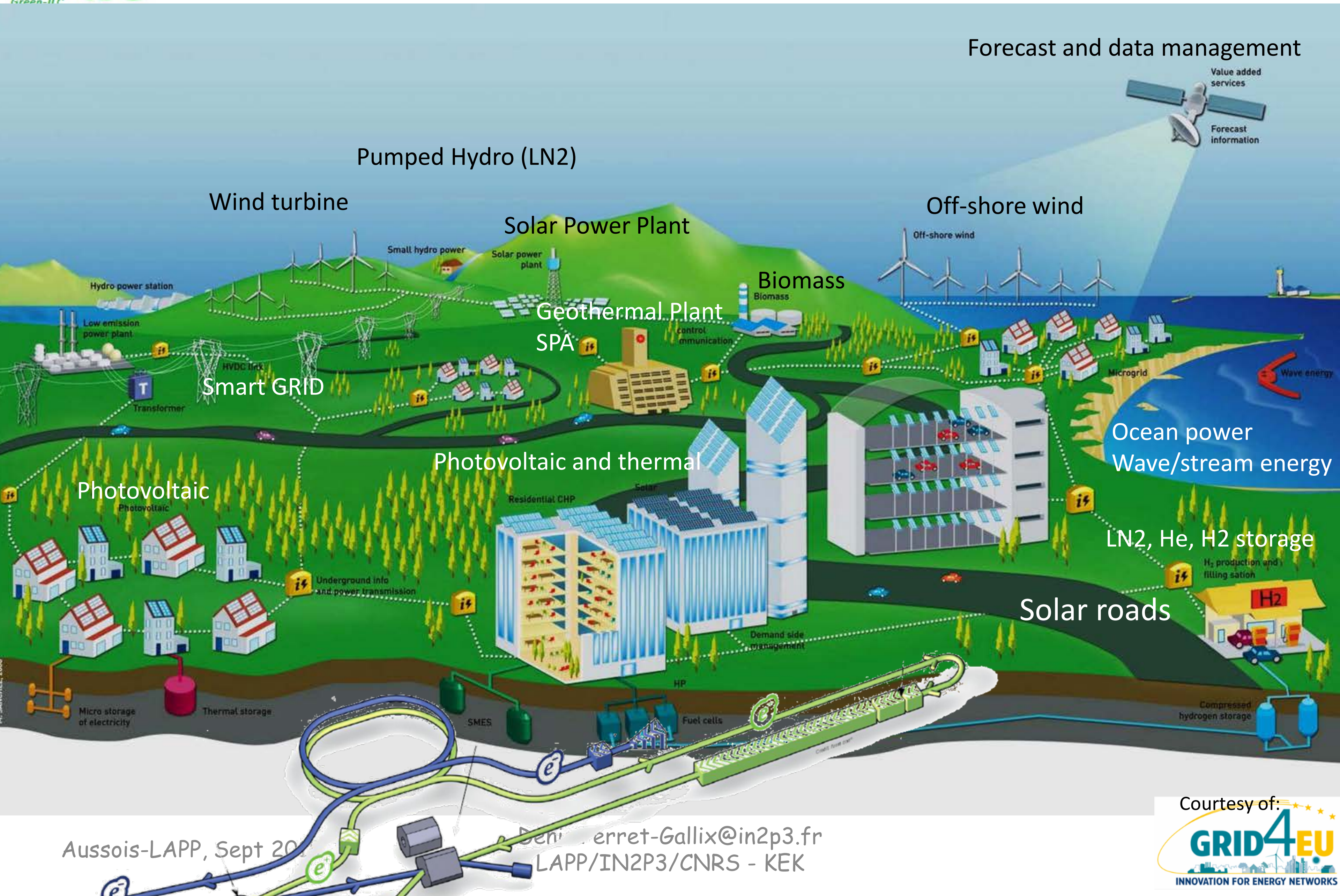
Renewable energies:

1. Renewable energy production, best for ILC and ILC site
2. Energy Storage (recovery, intermittency)
3. Distribution and Management: Smart Grid

Energy for: societal needs and world economy,

1. Needs for Energy Basic Research
2. Synergies: HEP expertise (SC, HF magnets, beams, computing), photon, neutron factories
3. Technology innovation and large scale infrastructure management
4. ILC as a test bench: Pilot plants for ILC

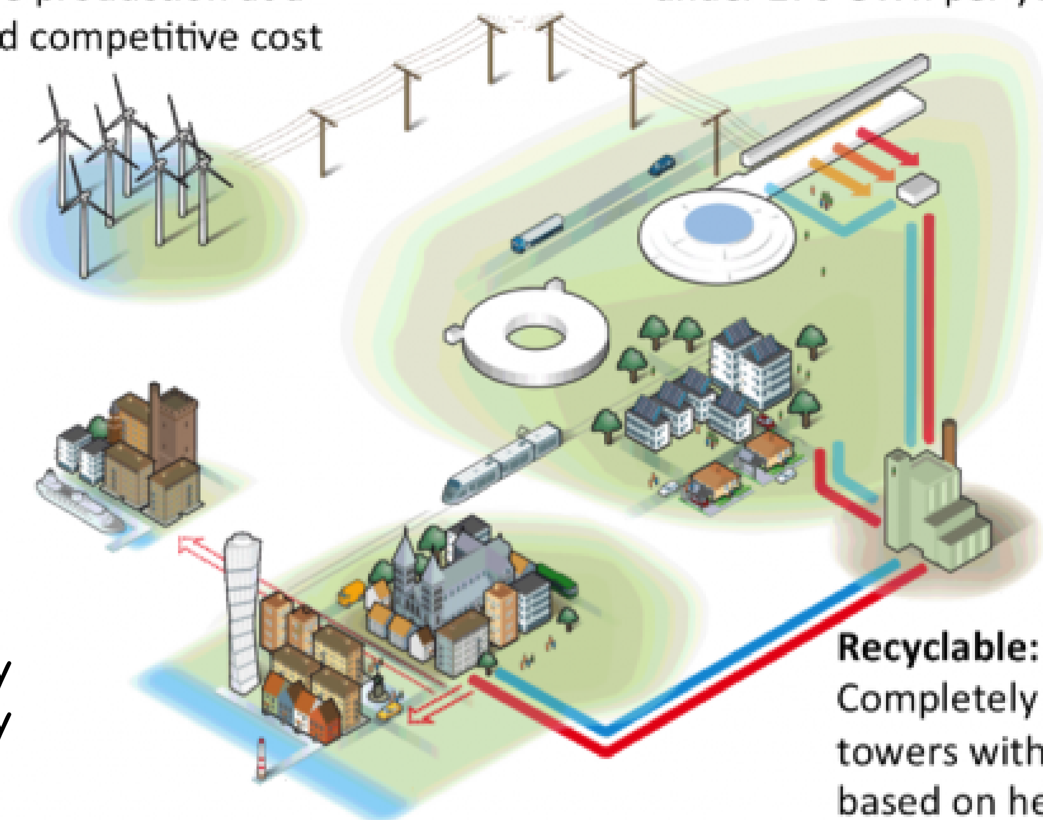
ILC Energy center view



The Green ESS
European Spallation Source -- 4R

Renewable:
All energy from new, dedicated renewable production at a stable and competitive cost

Responsible:
Reduce energy use to under 270 GWh per year



Reliable
stable electricity and cooling supplies

Recyclable:
Completely replace cooling towers with a cooling system based on heat recycling.

Wind Power:100 MW
Machine: 278 GWh/y
Cooling: 265 GWh/y

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ICFA

International Committee for Future Accelerators

http://www.fnal.gov/directorate/icfa/

ICFA: International Committee for Future Accelerators

ICFA, the International Committee for Future Accelerators, was created to facilitate international collaboration in the construction and use of accelerators for high energy physics. It was created in 1976 by the International Union of Pure and Applied Physics. Its purposes, as stated in 1985, are as follows:

- To promote international collaboration in all phases of the construction and exploitation of very high energy accelerators.
- To organize regularly world-inclusive meetings for the exchange of information on future plans for regional facilities and for the formulation of advice on joint studies and uses.
- To organize workshops for the study of problems related to super high-energy accelerator complexes and their international exploitation and to foster research and development of necessary technology.

The Committee has sixteen members, selected primarily from the regions most deeply involved in high energy physics.

ICFA Membership

August 2015: (new since July 2014)

CERN Member States

- H. Abramowicz
- R. Heuer
- J. Mnich (Chair)

USA

- N. Lockyer
- D. MacFarlane
- I. Shipsey

Japan

- T. Mori
- M. Yamauchi

Russia

- A. Bondar
- S. Ivanov

Canada

- M. Roney

China

- Y. Wang

Other Countries

- M. Cho
- L. de Paula
- V. Matveev

C11

- J. Fuster

Secretary: R. Rubinstein

Sustainable Accelerators and Colliders

J. Minch
ICFA President

> Panel proposed by A. Suzuki.

> Goals:

- Improve power efficiency of every accelerator component
- Have energy recovery from the accelerator, and re-use it
- Have a stand-alone system to provide all or part of the accelerator power needs

> Important topic, with connections i.e. to efforts at ESS, EUCARD energy efficiency network, etc.

- Region representatives looking into initiatives in this area, with the aim of producing mandate and goal for potential panel, if topic found to be appropriate for ICFA.

> ICFA asked proponents to propose a mandate and membership for such a Panel.

J. Minich | ICFA Report to Lepton-Photon 2015 — 21 August 2015 | page 8

Green-Colliders au LAPP

Quelles compétences ?

Groupe de réflexion et prospective (Labs-Universite-Industrie)

Efficacité énergétique, basse consommation

1. Accélérateurs et détecteurs
2. Electronique, mécanique, informatique, ingénierie des systèmes
3. Economies par la conception (design) ou par la mise en œuvre

Récupération et recyclage de l'énergie perdue (90%)

1. Thermodynamique, pompe à chaleur, conversion chaleur-froid
2. Stockage de l'énergie :
3. Distribution et gestion: Smart Grid

Energies renouvelables:

1. Solaire, éolienne, hydro, azote liquide(exemple "Air Liquide")
2. Meilleur mix énergétique pour un collisionneur en fonction de son fonctionnement et du site

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Green-Colliders au LAPP

Groupe de réflexion (Labs-Universite-Industrie)

Laboratoire de Recherche (Universite, CNRS CEA, INPG)

1. CEA (LITEN) (Grenoble, Chambery)
   énergies renouvelables (énergie solaire, biomasse), l'efficacité énergétique (véhicules et bâtiments basses consommations, filière hydrogène, gestion des réseaux électriques,….), les matériaux hautes performances pour l'énergie.
2. Grenoble INP Energie
3. G2Elab Génie électrique
4. Economie du développement durable et de l'énergie EDDEN
5. GreEn-ER (Grenoble énergie - enseignement et recherche)
6. ILL, ESRF, EMBL, LETI, MINATEC, ….

Industrie

1. Air liquide (Sassenage)
2. THALES, SOITEC, AlSTOM
3. Dassault, SKF, SAGEM, …

Rhône-Alpes: Première région de France pour:

- Composants fluidiques et pneumatiques
- Métallurgie et métaux
- Composants électroniques
- Réfrigération industrielle

Green-Colliders au LAPP

Ouverture Nationale et internationale

Synergie:

1. Labo HEP Français LAL, IPNO, CEA et dans d'autres domaines
2. Au cœur des projets futurs (CLIC, FCC, …)
3. CERN, KEK (AAA), ESS, SESAME, …

Relations avec l'industrie et la societe

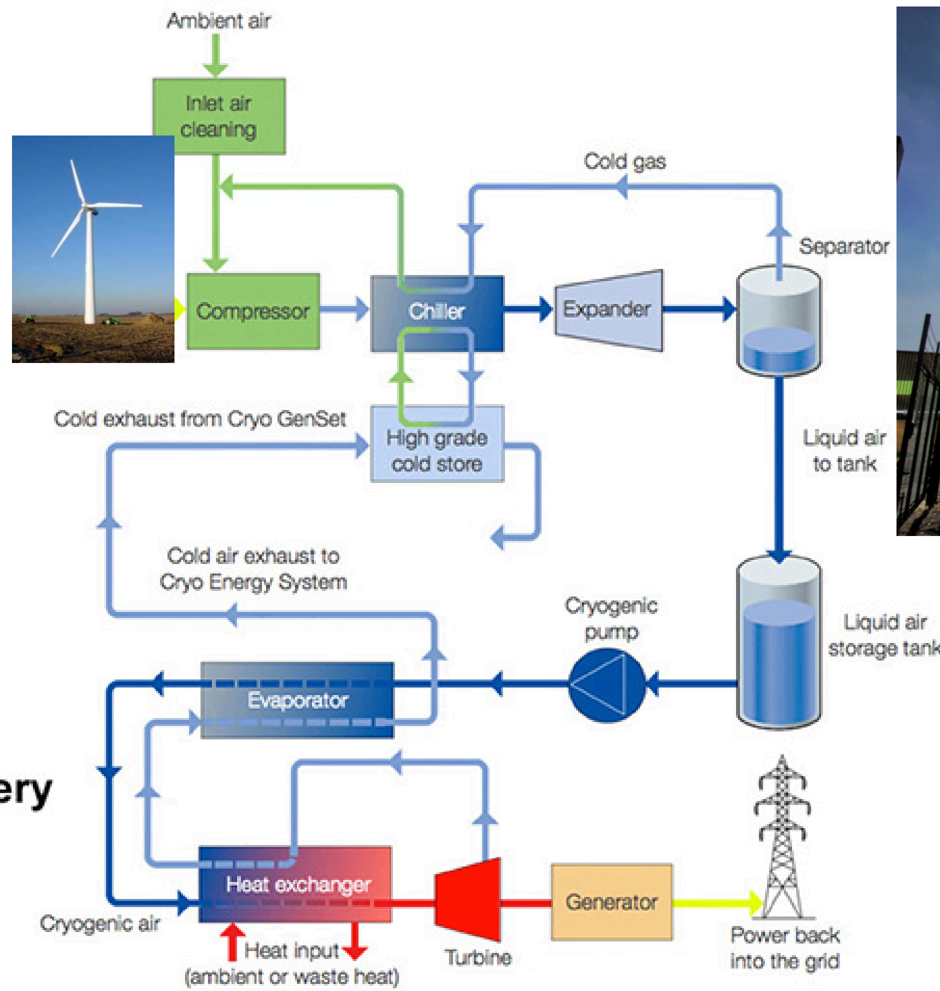
1. Besoins de R&D dans l'energie:
    1. Recherche de base
    2. laboratoire intégré. de la R&D aux applications finales
       le project Green-ILC réunit ces deux conditions
2. Expertise en HEP et accélérateurs: utile pour le R&D dans l'énergie
   (SC, aimant haut-champ, faisceaux, informatique), usine à photons, neutrons
3. Gestion de la construction et du fonctionnement de grandes infrastructures
4. Au cœur d'une région technologiquement et énergétiquement importante en France
5. Le LAPP engagé dans les questions énergétiques un + pour notre implantation locale

LN2 as energy storage

Liquefaction

Storage

Power Recovery

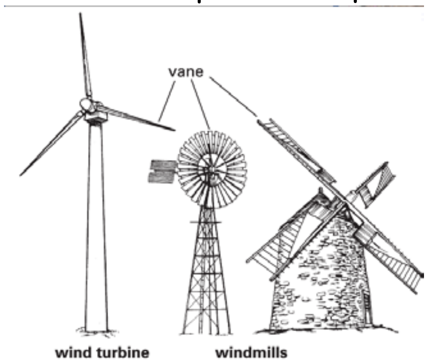


Highview Power Storage (UK)

Expected Efficiency up to 70% using heat waste (~ 115 C)

LN2 process cycle

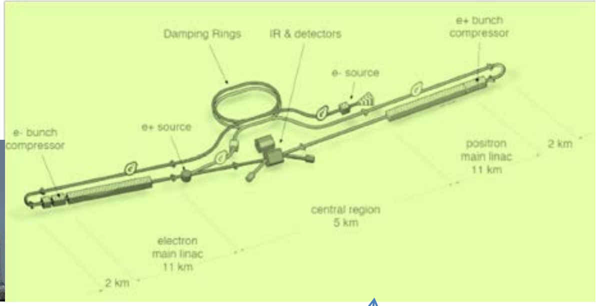
Compressor/liquefier Inside



LN2 →

- Cryocooler may save 30-50% electrical power
- Cooling NC magnets
- HTc power Transmission lines
- Cooling electronics and computers

Energy storage



LO2, LAr, SCO2 Dry ice

To Industry

For Cooling or Sequestration

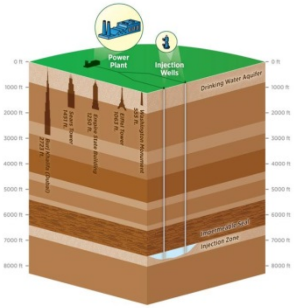
LN2 heat waste

Turbine → electrical generator

N2 gas applications

Electricity Back to ILC/GRID

i.e. Drying and preservation industry



Air cleaning !!!

Green ILC

http://green-ILC.in2p3.fr

Green-ILC Project

Energy for Innovation, Innovation in Energy

Home | Blog | Archives | ► Research | Conferences | Documents | Links | Contacts | Search | RSS

The Green ILC Project

ILC, the International Linear Collider, is the next fundamental science project in high energy physics and the first ever true global basic science center.

What CERN did for the European HEP community, ILC will do for the world. But the e+e- ILC project may go even beyond mere fundamental science and contribute to one of the world most pregnant issue: Energy, not merely high-energy but, more generally: energy for the society.

Artistic view of the ILC center in Kitakami (Japan) ILC-Iwate

The ILC scientific goal is simple: high precision study of the Higgs particle recently discovered at LHC (CERN) and other signals LHC could possibly single out. New effects will also be searched for, effects which could have been missed by the LHC due to the heavy background. Higher precision here concerns, more particularly, the various Higgs couplings, limited at LHC, in part, by the complex structure of the interacting particles, the protons compared to the elementary electrons.

Recent Posts

- Green-ILC in LC Newsline
- New Hydraulic Wind Turbine
- Green Session at LCWS 2014
- EUCARD2 EnEfficient
- Liquid Air in the Energy and Transport Systems

Links

- email: green.accelerators@gmail.com
- Green-ILC wiki
- Green-ILC group discussion

Merci pour votre attention

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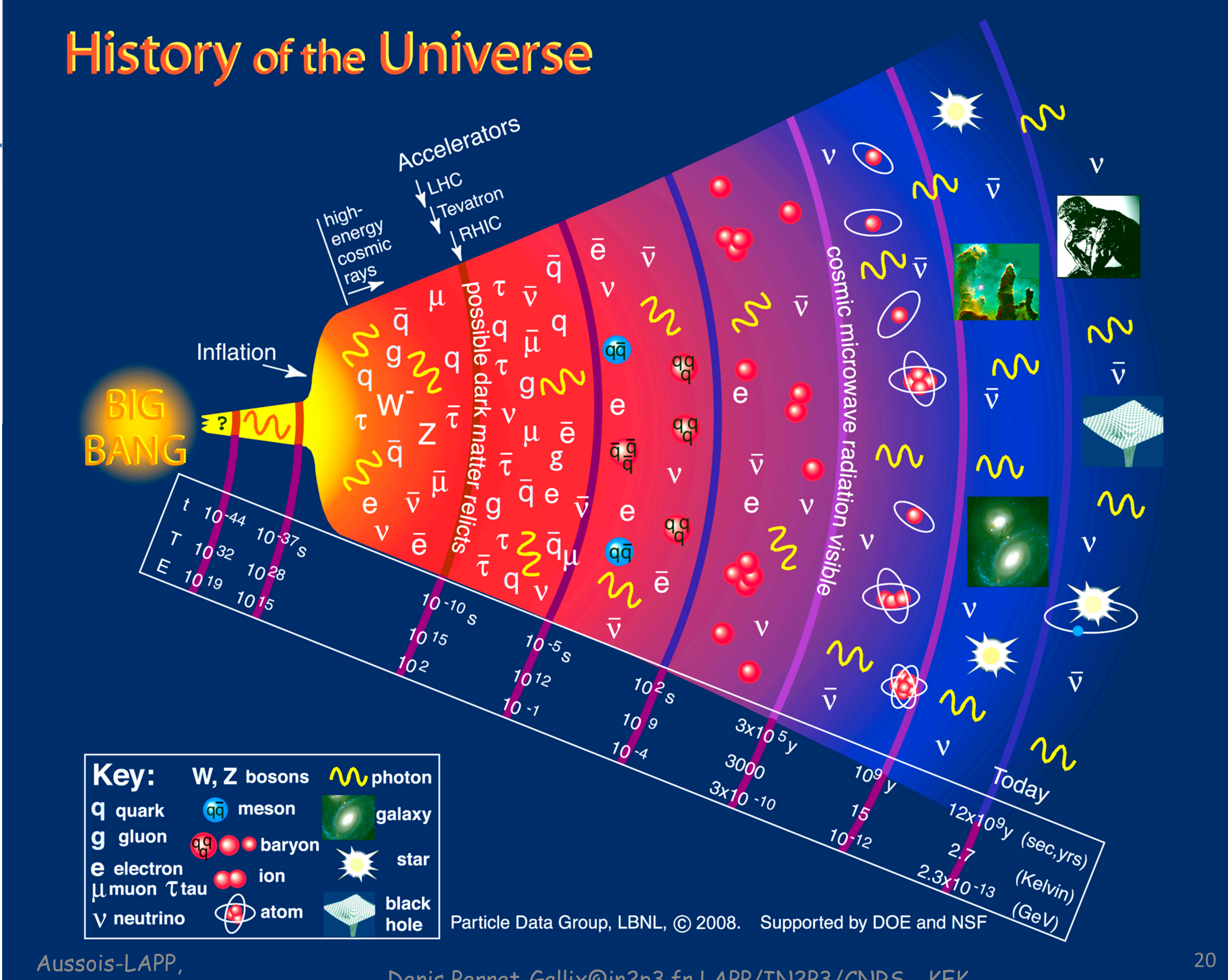
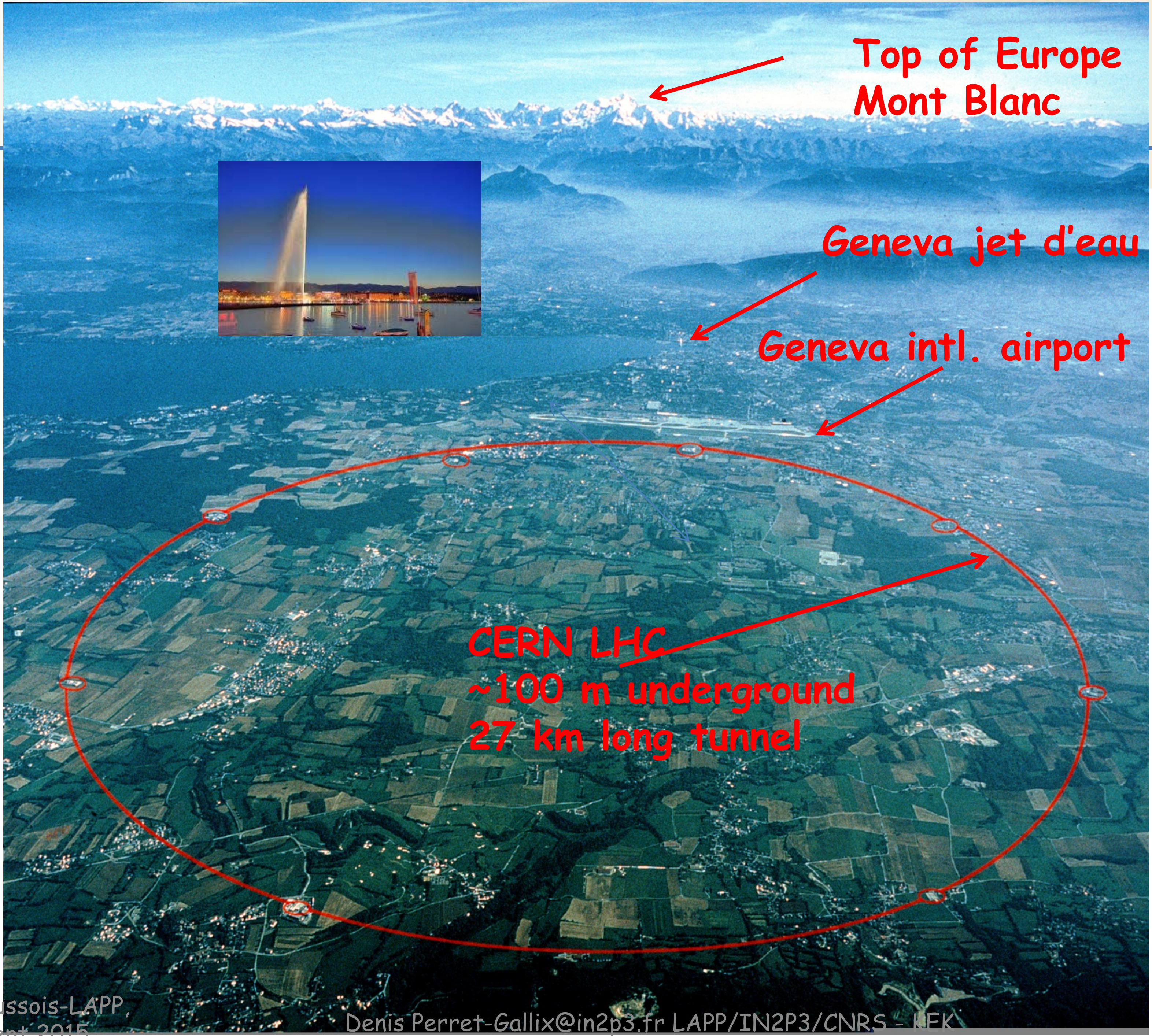
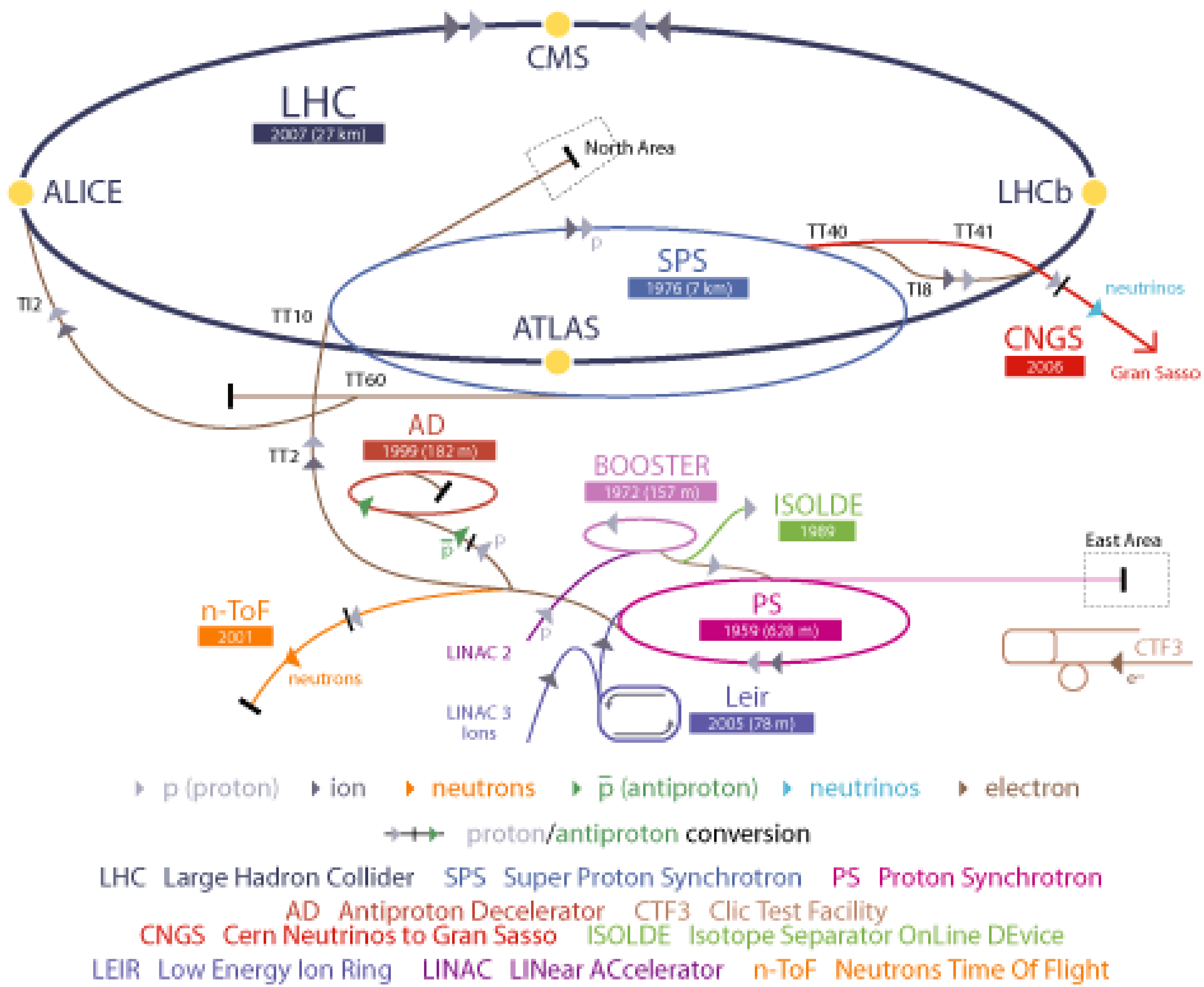

History of the Universe
Accelerators
LHC
Tevatron
RHIC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
t 10^-44 10^-37 s
T 10^32 10^28
E 10^19 10^15
10^-10 s
10^15
10^2
10^-5 s
10^12
10^-1
10^2 s
10^9
10^-4
3x10^5 y
3000
3x10^-10
10^9 y
15
10^-12
Today
12x10^9 y (sec,yrs)
2.7 (Kelvin)
2.3x10^-13 (GeV)
Key:
W, Z bosons
photon
q quark
meson
galaxy
g gluon
baryon
star
e electron
ion
µ muon τ tau
atom
black hole
ν neutrino
Particle Data Group, LBNL, © 2008.
Supported by DOE and NSF


Top of Europe
Mont Blanc
Geneva jet d'eau
Geneva intl. airport
CERN LHC
~100 m underground
27 km long tunnel

CERN Accelerator Complex



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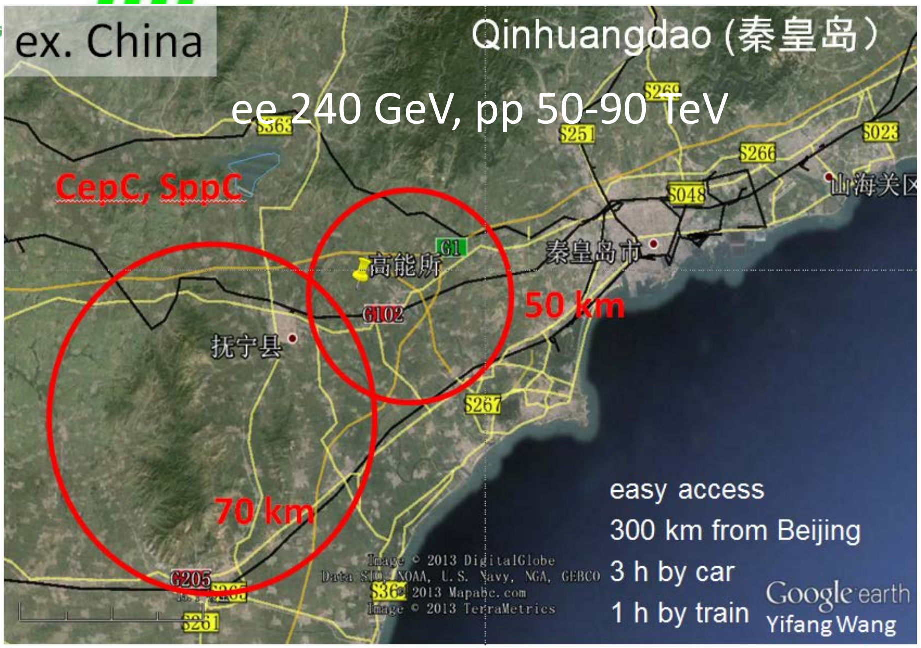
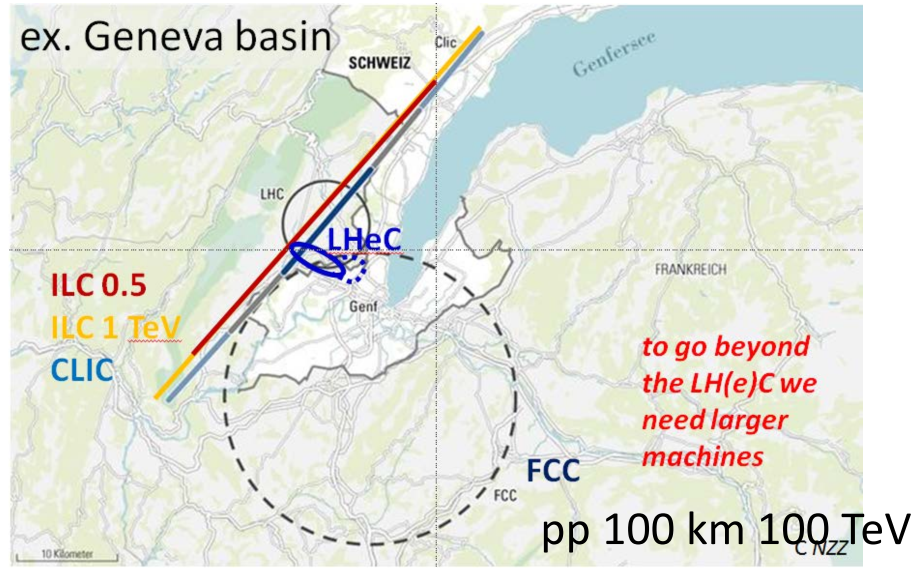
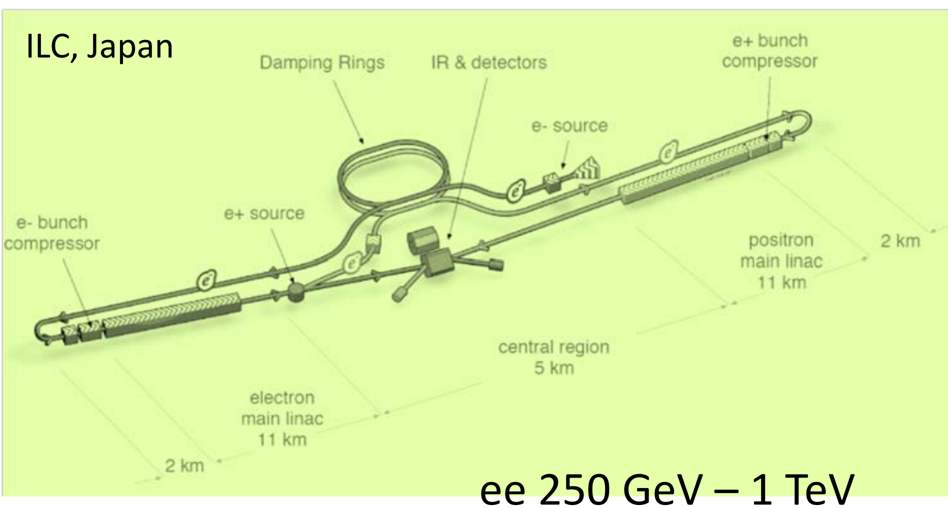
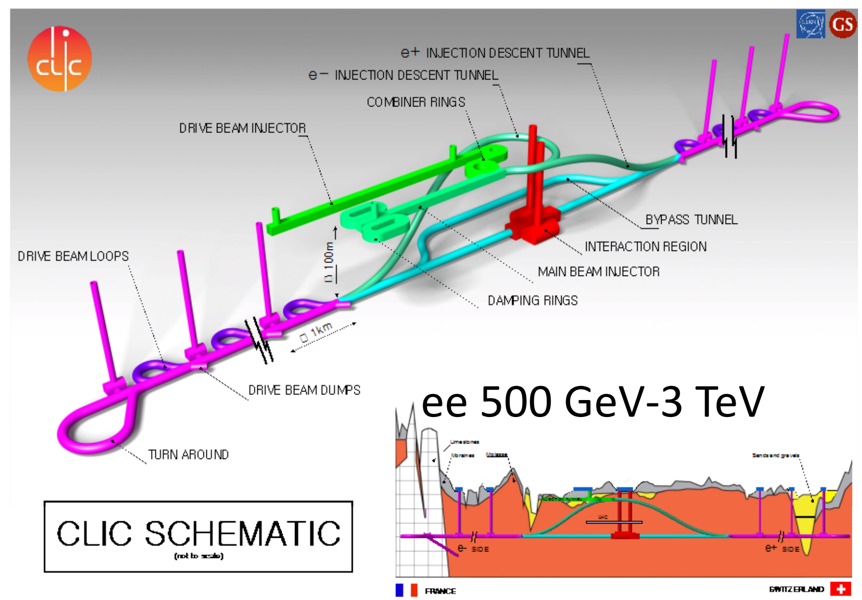
High-energy frontier infrastructures projects









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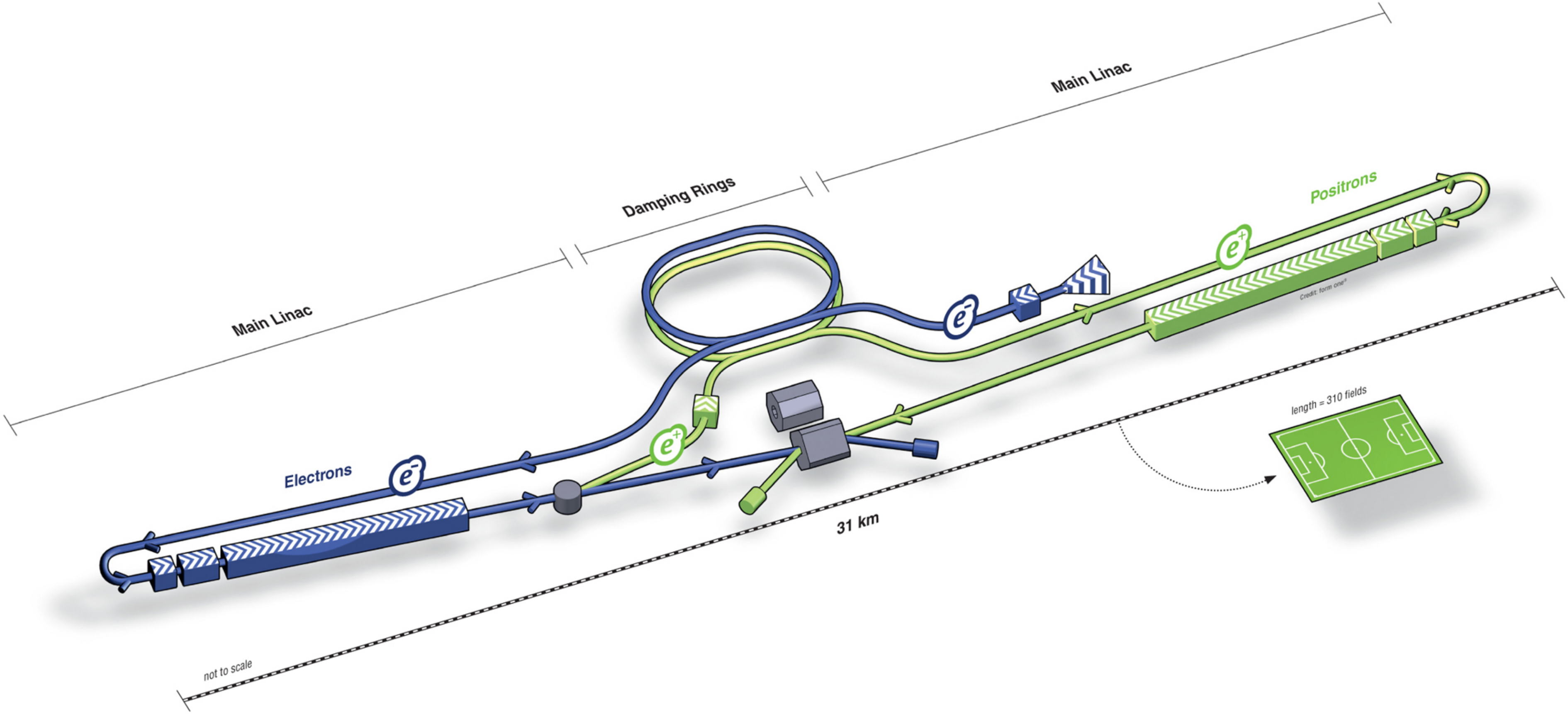

ILC Scheme | © www.form-one.de

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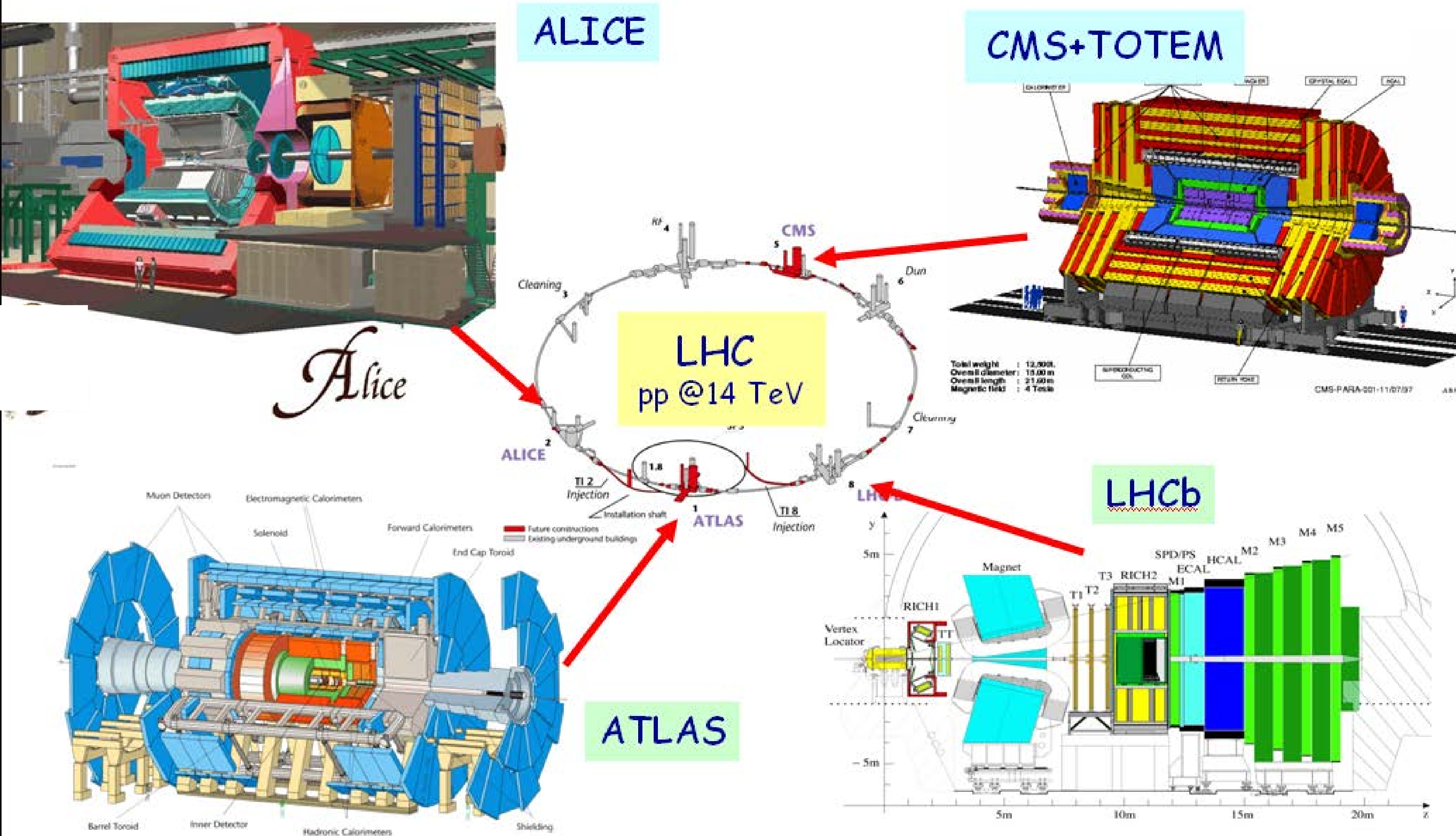
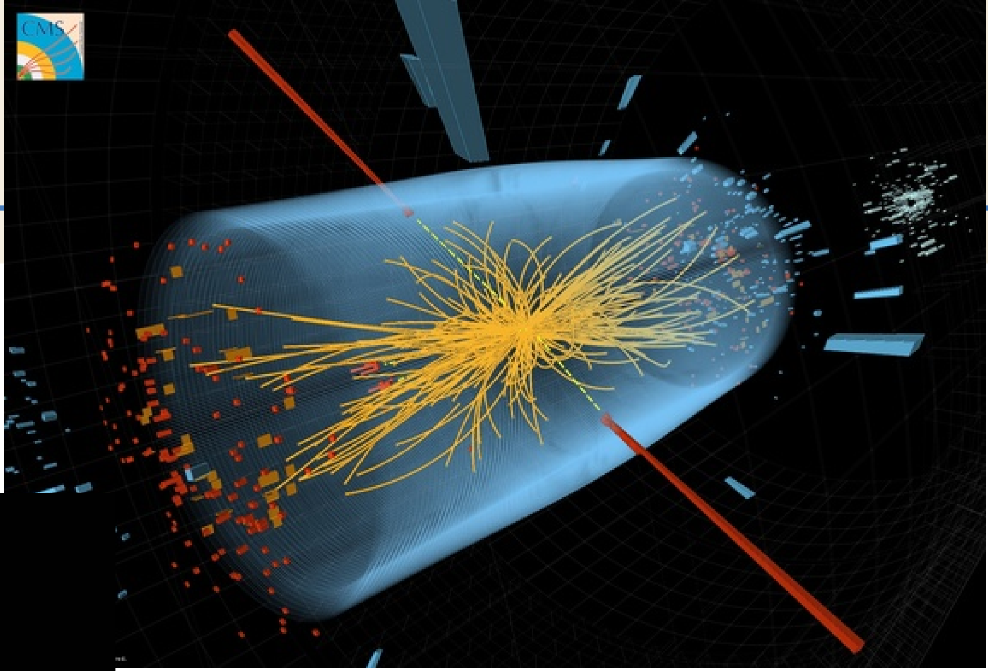
Geant 4

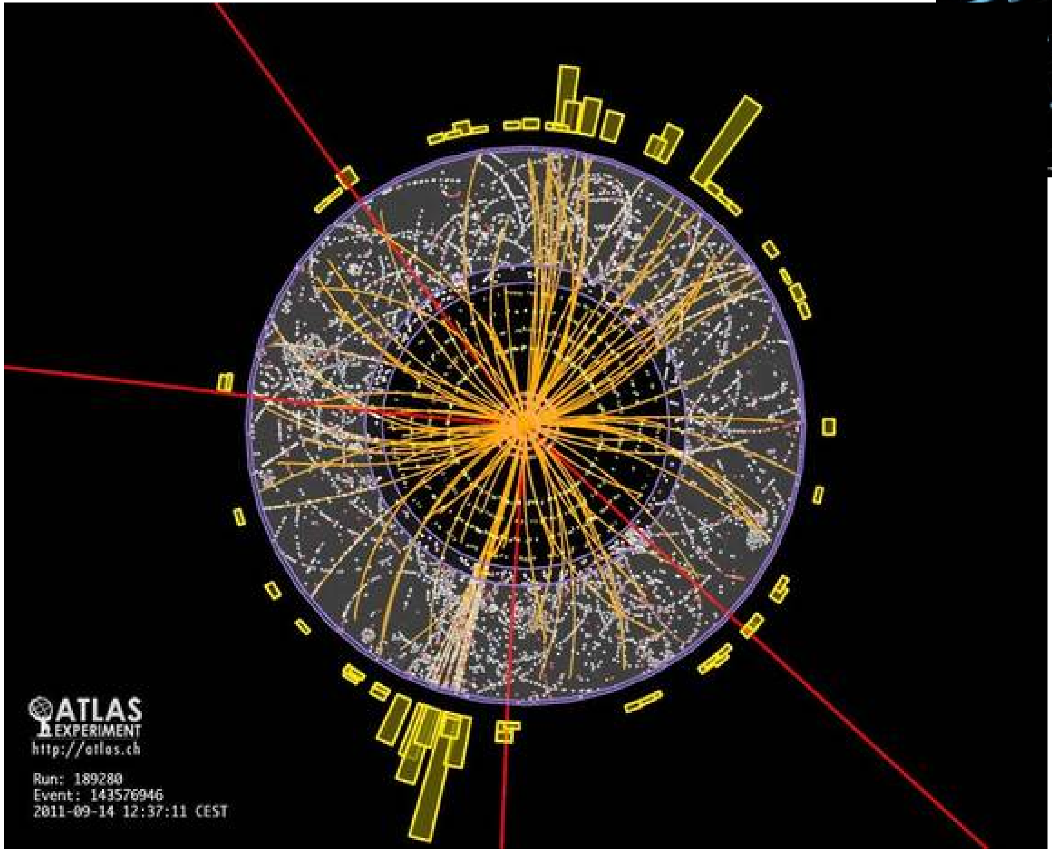
The Large Hadron Collider Experiments



Albert De Roeck (CERN) 2

LHC Events @ 7.5 TeV





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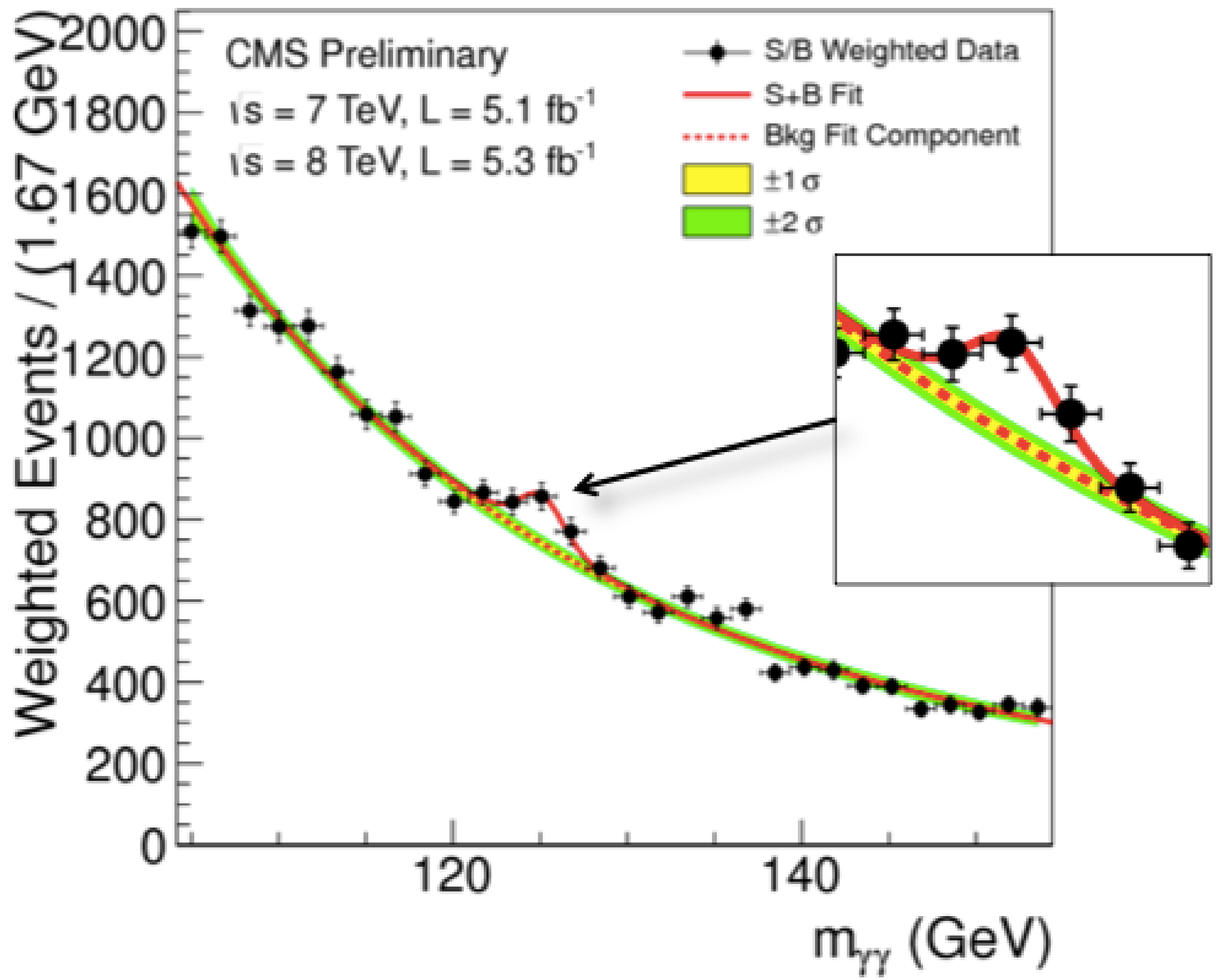
CERN-LHC "New Boson" discovery
PP -> H+X -> γγ +X



Global organization for Green ILC

ILC Energy Center

ILC High-Energy Research Center
- Fundamental Research
- HEP Applications

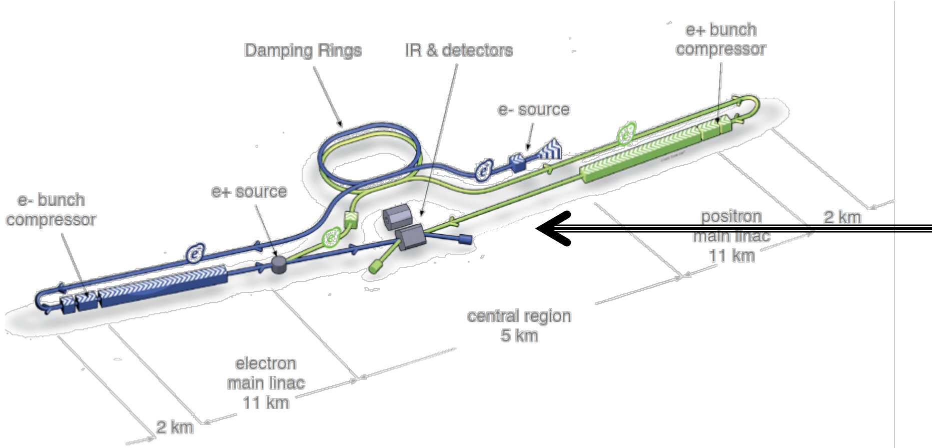
ILC Sustainable Energy Research Center
- Basic Research
- Application R&D
- Pilot Power plant for ILC

Industry

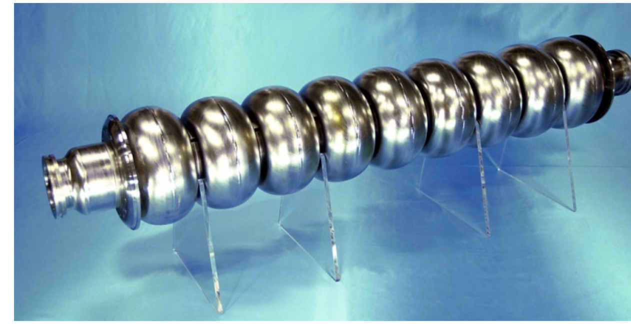
Electrons, photons, neutrons factories
HPC/GRID Computing

High-Energy community

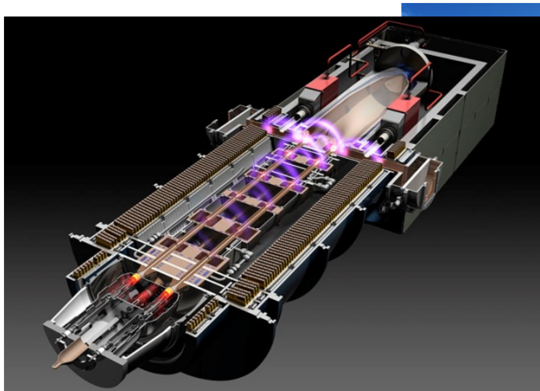
Energy community

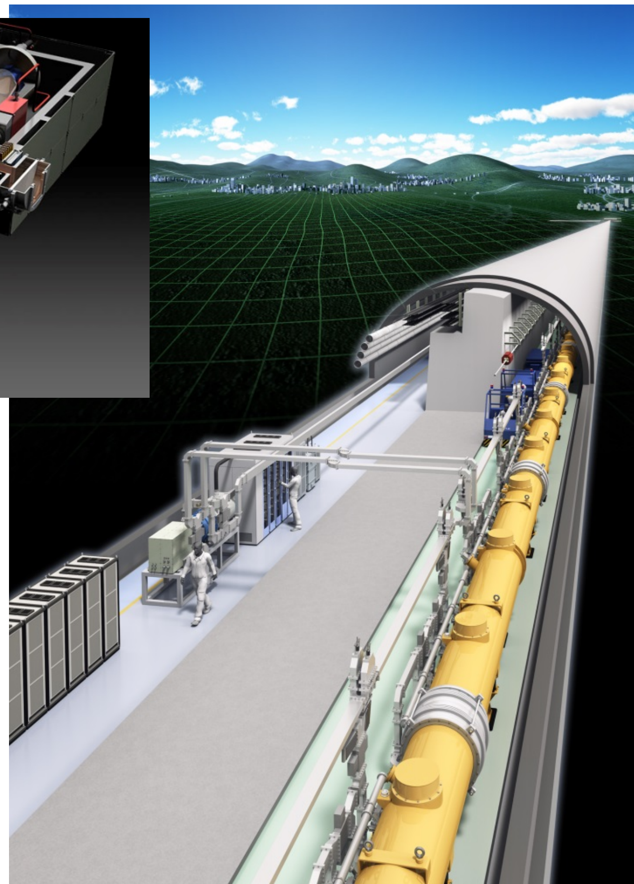


Energy Saving and recovery



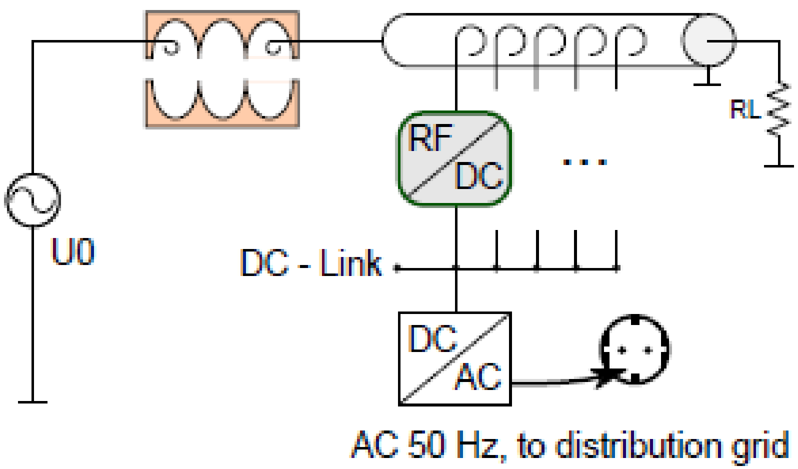
- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)



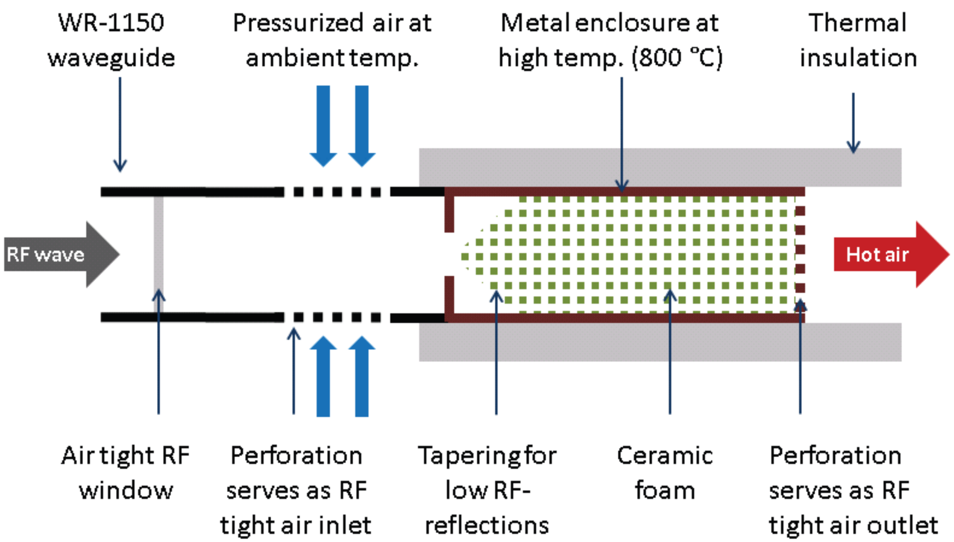


Recover non-used RF power: Smart RF loads

Idea 1) – reconvert to DC power!



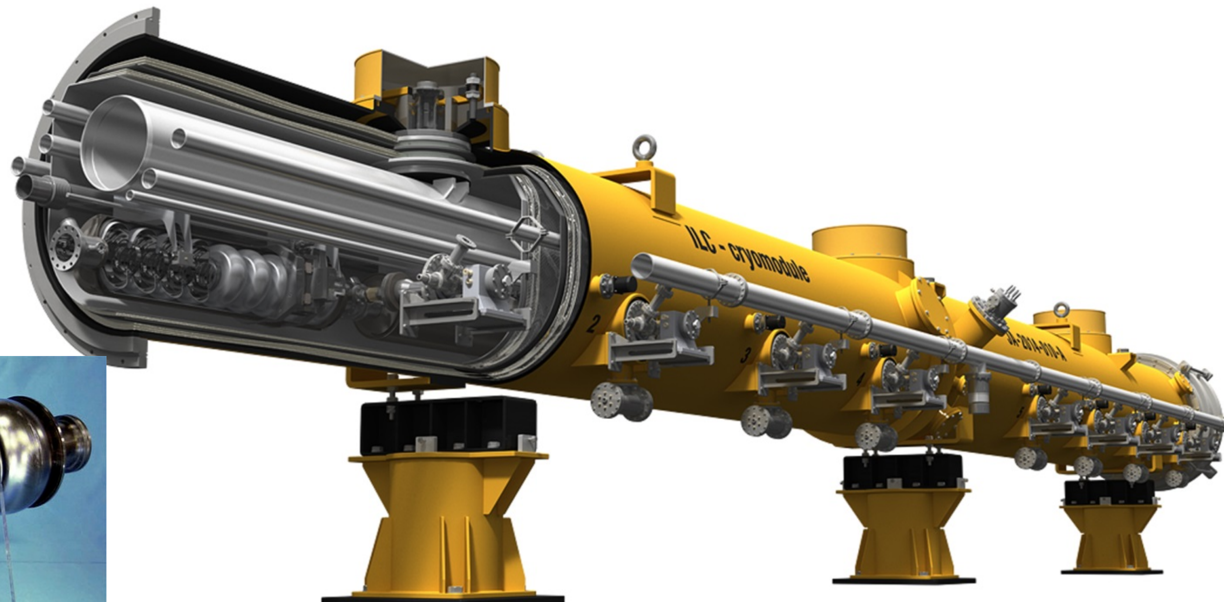
Idea 2) – use high-*T* loads!



1) http://accelconf.web.cern.ch/AccelConf/IPAC10/papers/wepd090.pdf
2) http://accelconf.web.cern.ch/AccelConf/IPAC2012/papers/thppc023.pdf

Energy Saving and recovery

- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)
- Cavities: 2 Magnetic shields -> Increase cavity Q_0
  -> decrease cryo -> save 62 ME (10 years running)
  (O. Napoly AWLC 2014 and JLC 2013)



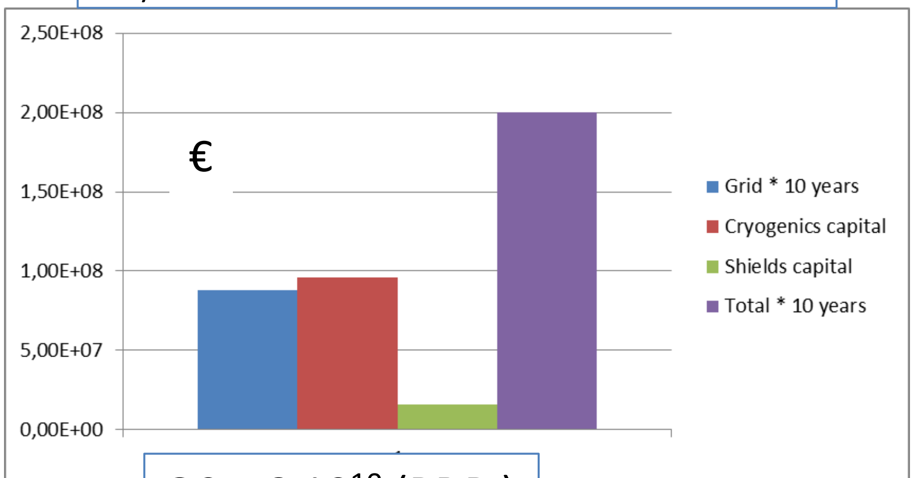
Cryonomics

O. Napoly AWLC 2014 and JLC 2013

If I am allowed to extrapolate the 75% increase of Q_0 shown by E. Kako with a double magnetic shielding, to ILC cavities with Eacc = 31.5 MV/m

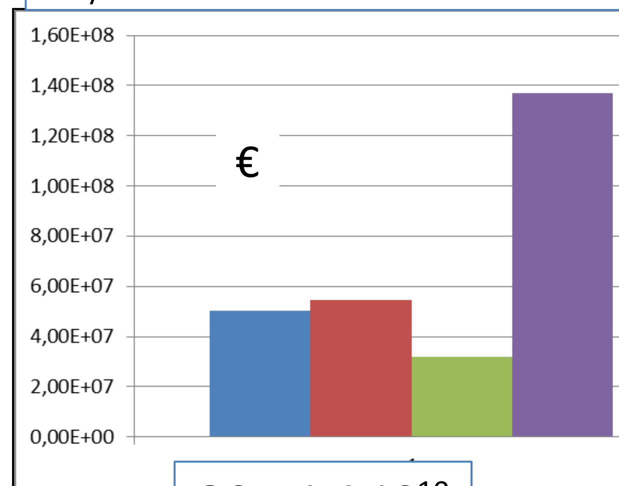
and with the assumptions: grid power = 0,15 € /kWh@300 K
CoP(2K) = 700 W/W
magnetic shield = 1000€ / cavity
cryogenics = 1 M€/100 W@2K

$P_{dyn.}$ = 9.6 kW@2K , 6.7 MW @ 300 K



Q0 = 8 10^{10} (RDR)

$P_{dyn.}$ = 5.5 kW@2K , 3.8 MW

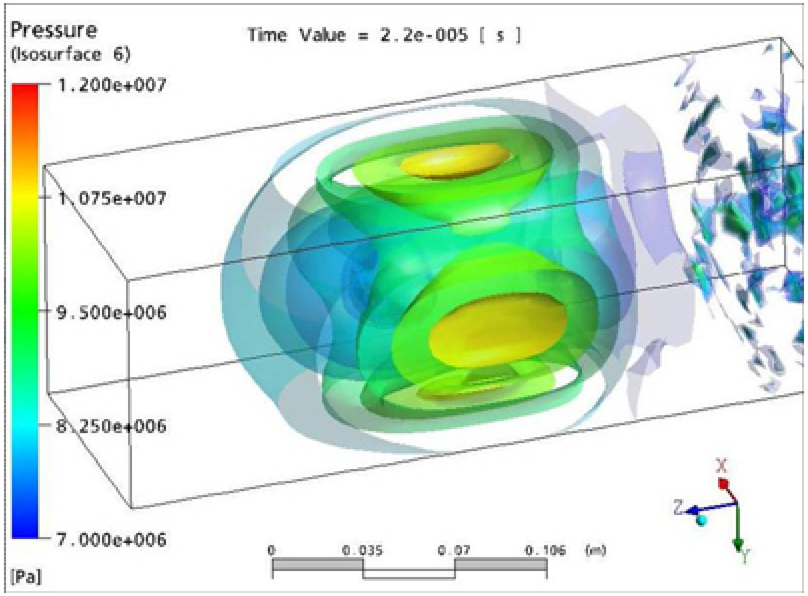


Q0 = 1.4 10^{10}

Saving 62 Meuros on cavity cooling (10 years)

Energy Saving and recovery

- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)
- Cavities: 2 Magnetic shields -> Increase cavity Q_0
  -> decrease cryo -> save 62 ME (10 years running)
  (O. Napoly AWLC 2014 and JLC 2013)
- Beam dumps
  - Wakefield deceleration for beam dump, project and test

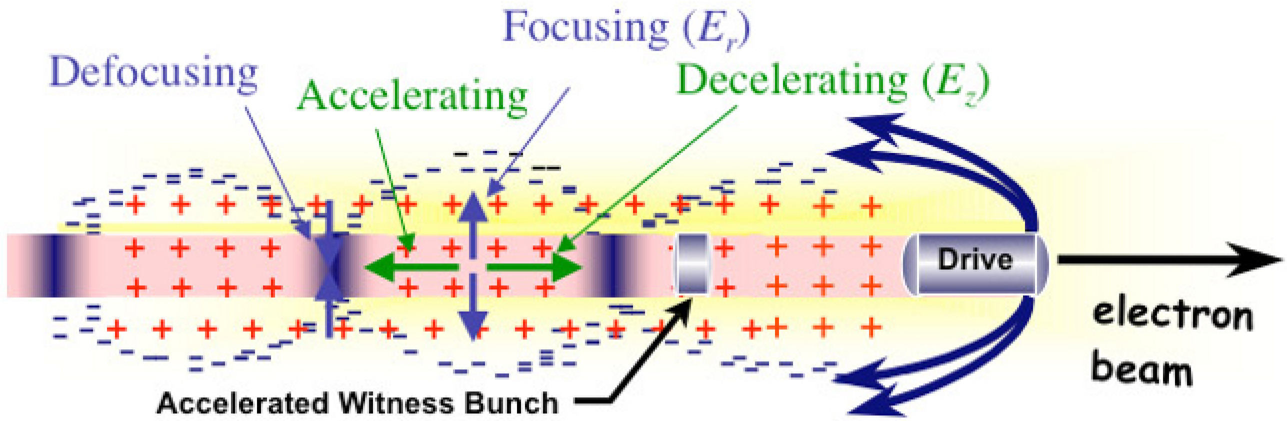


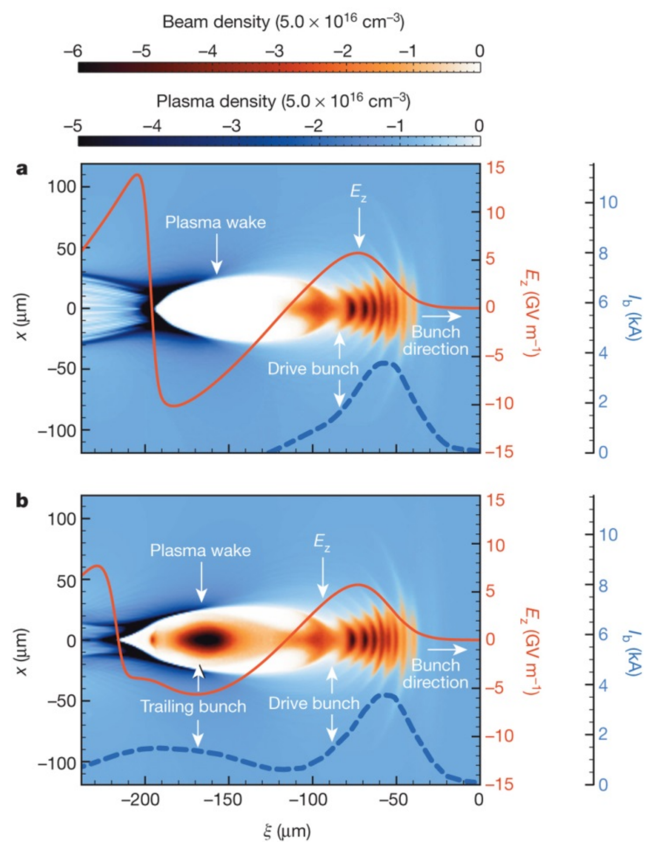
Pros/cons

J. Fujimoto (KEK)

	Water dump	Gas dump
length	10 m	1000 m
Window pressure	10 bar static, 0.5 bar dyn.	1 bar static, 0.01 bar dyn
Window diameter	30 cm	8 cm
Hydrogen gas producing	Several liter/sec @ 20 MW	no
Tritium production	300 TBq	30 TBq (in Iron)
Component Activity	1.2 mSv/h	~ 1 … 10 mSv/h

Plasma Acceleration, wakefield acceleration





Plasma Deceleration Dumping

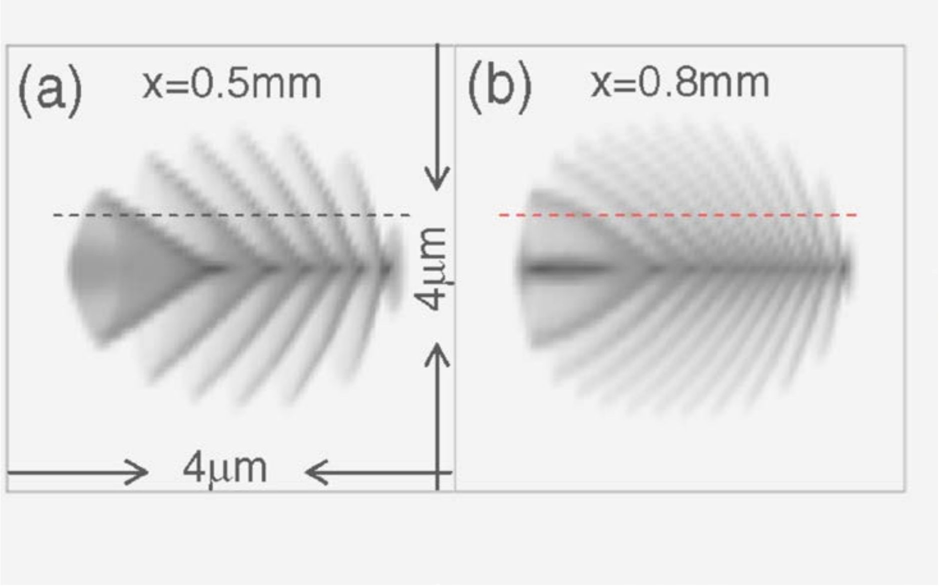
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 13, 101303 (2010)

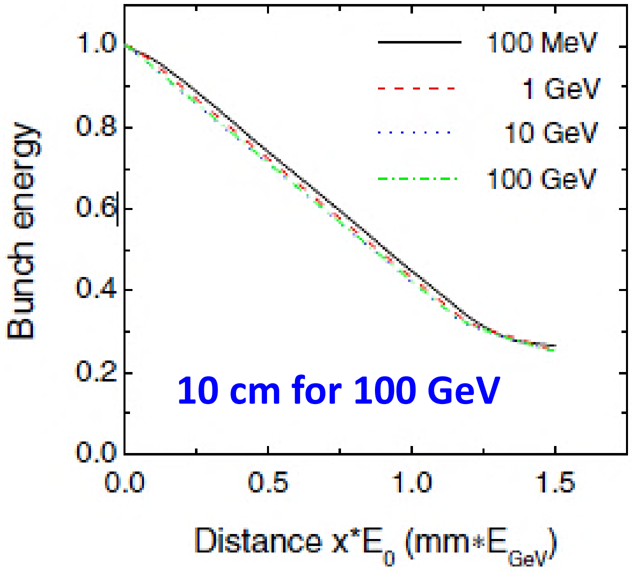
Linear Collider WS
Tokyo Nov. 15 2013
A. Suzuki (KEK DG)

Collective deceleration: Toward a compact beam dump

H.-C. Wu,[1] T. Tajima,[1,2] D. Habs,[1,2] A. W. Chao,[3] and J. Meyer-ter-Vehn[1]
[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.

Application for a grant (MEXT, JSPS) for 2015

Collective Stopping Power for ILC

M. Yoshida KEK (IZEST)

I ZEST
International Zeta Exawatt Science Technology

$$L_{dump}\,[\mathrm{m}] \approx 1.7\times 10^{13}\frac{\sigma_T^2\,[\mathrm{cm}]}{N_b}E_0\,[\mathrm{GeV}]$$

here $\sigma_T \geq 0.6\sigma_L$ & $\sigma_T \geq 1.9\times 10^{-6}\sqrt{N_b\sigma_L}$

(electron bunch)

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

$$L_{dump}\,[\mathrm{m}] \approx 4.3\times 10^{5}\sigma_T^2\,[\mathrm{cm}]$$

$\sigma_T \approx 50\ \mu m$, $\sigma_L \approx 3\ \sigma_T \approx 150\ \mu m$ Compress x 2

→ L = 10 m for Li gas

Next Trials

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

Energy Saving and recovery

- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)
- Cavities: 2 Magnetic shields -> Increase cavity Q_0
  -> decrease cryo -> save 62 ME (10 years running)
  (O. Napoly AWLC 2014 and JLC 2013)
- Beam dumps
  - Wakefield deceleration for beam dump, project and test
- Cryogenics
  - Helium refrigerator saving
  - LN2 pre-cooling
-

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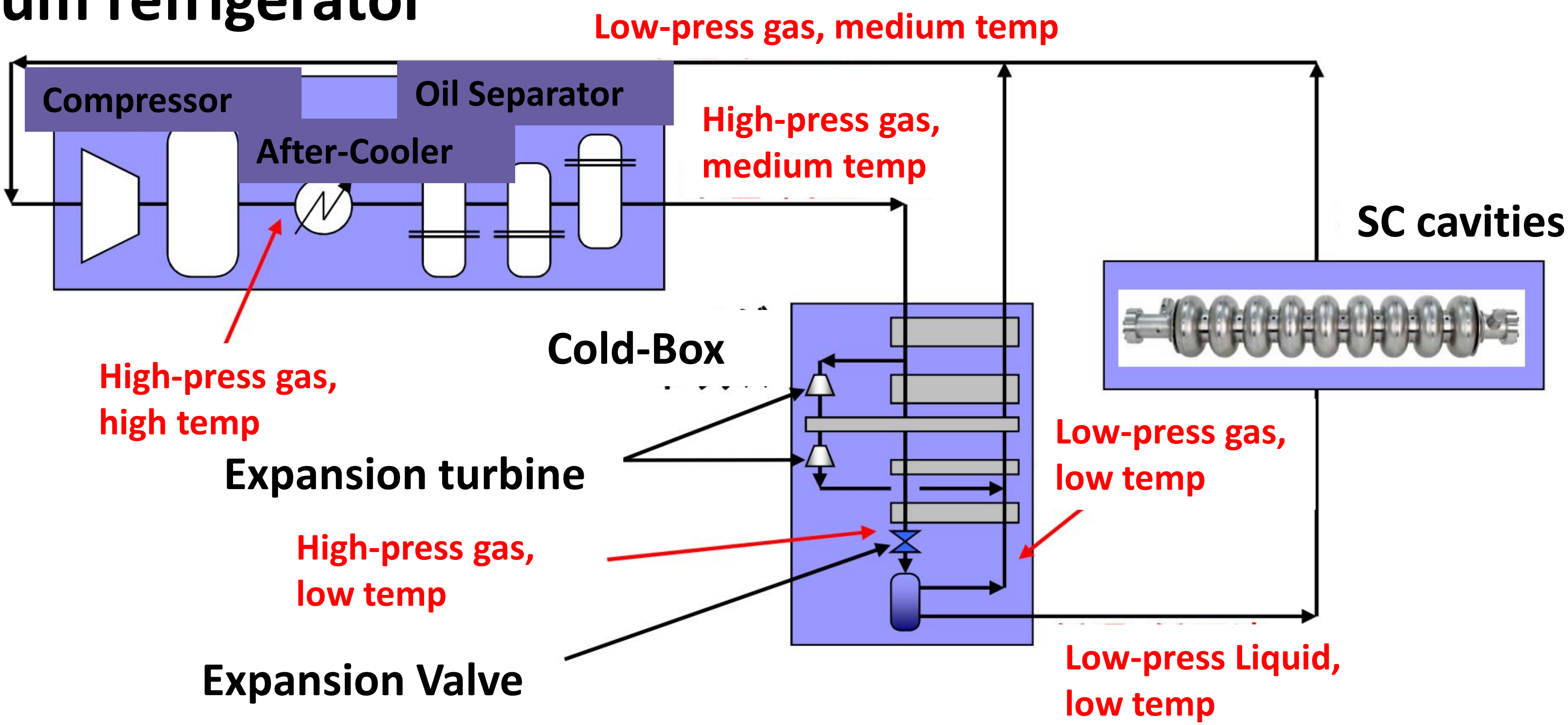
H. Hayano (KEK) : ALCW April 2015

Proposal Pickup from AAA Green-ILC WG in 2014

(1) Helium compressor efficiency improvement

(Maekawa Co.)

Helium refrigerator



Compressor power reduction by using Adsorption Refrigerator [AdRef]

Characteristics;

1. non-CFC gas, but use water
2. Low temperature heat exhaust
3. Economy operation (only water pump)
4. Easy maintenance
5. Safe operation

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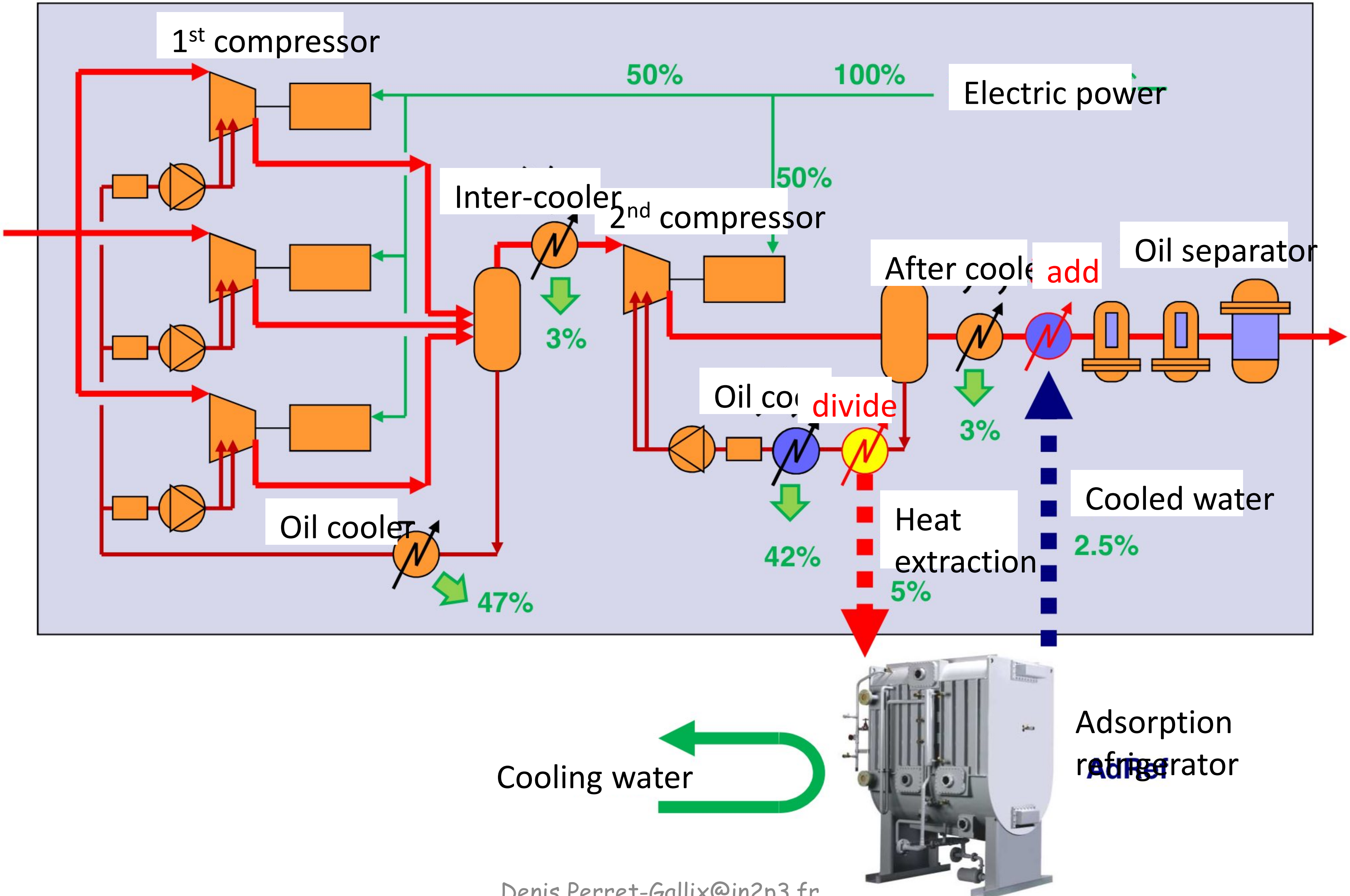
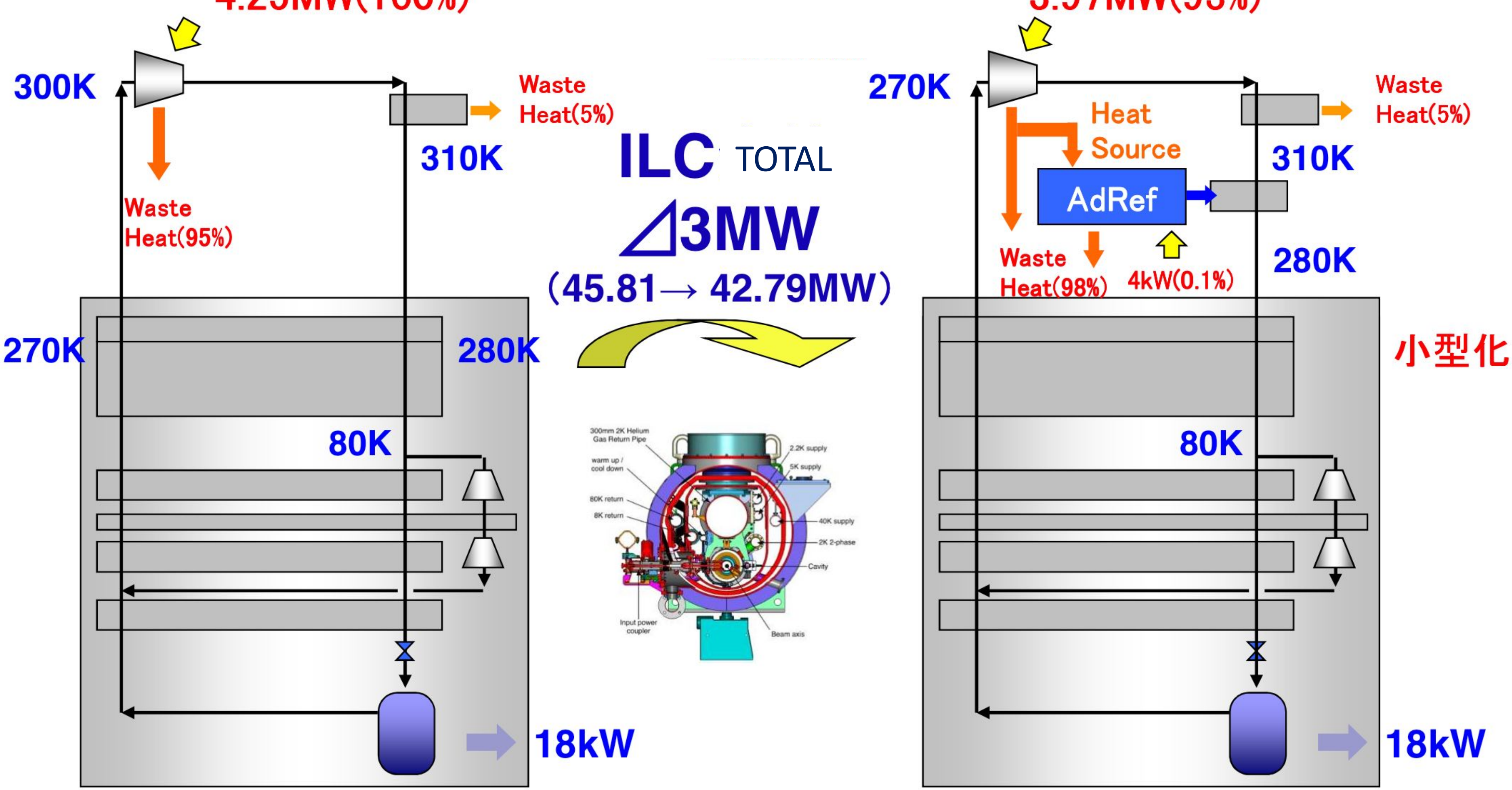
Cooled water by Adsorption Refrigerator [AdRef]



New refrigeration cycle with AdRef

7% saving

Gas Temperature down (310K -> 280K)
Then Compressor power reduce.



Conventional cycle

New cycle with ADR

20

Energy Saving and recovery

- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)
- Cavities: 2 Magnetic shields -> Increase cavity Q_0
  -> decrease cryo -> save 62 ME (10 years running)
  (O. Napoly AWLC 2014 and JLC 2013)
- Beam dumps
  - Wakefield deceleration for beam dump, project and test
- Cryogenics
  - Helium refrigerator saving
  - LN2 pre-cooling
- Transmission power lines

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(2) HTS cable for primary power transmission

(Fujikura Co.)

Y-High-Tc (HTS) cable element

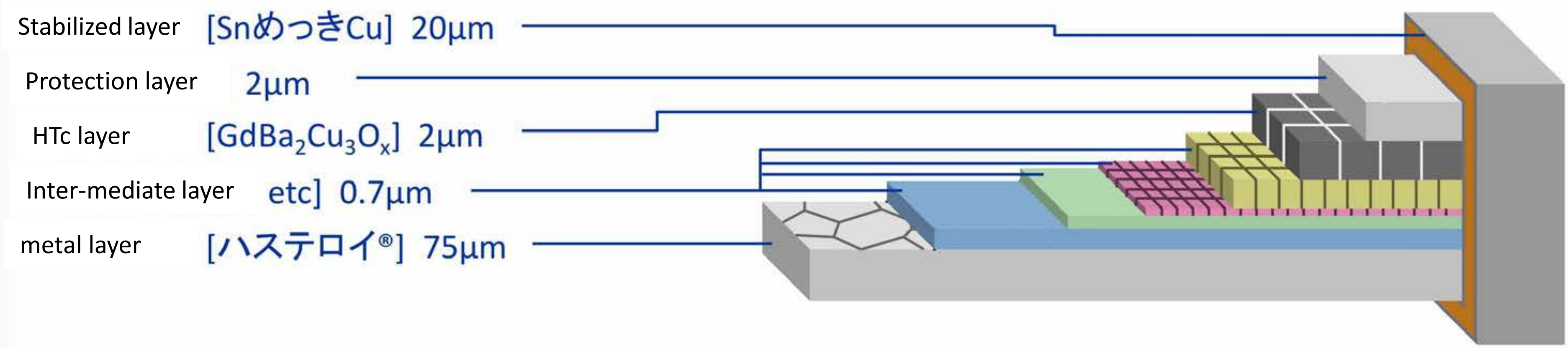
Fujikura

Product

Type	Width [mm]	thickness [mm]	Metal layer [µm]	Stab. layer [µm]	Critical current [A] @77K, S.F.
FYSC-SCF04	4	0.14	75	20	> 200

※ 2015年度より4mm幅標準線材を提供開始予定

Cable structure (formed by copper structure)



Fujikura succeeded to develop 5kA HTS power cable in 2013 with 1.37W/m AC loss.

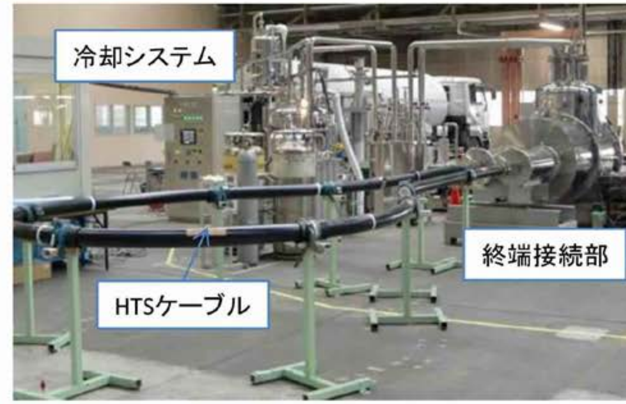
66kV/5kA High-Tc power cable

Fujikura

■ Power cable using 500A HTS cable element

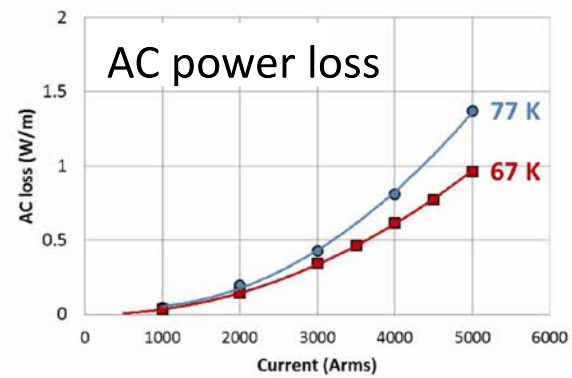
- 高Ic線材による交流損失低減を検証
- 66kV-5kA級単心ケーブルシステム(10m)
- 長期荷電試験: 20 cycles (1 cycle = 8h ON / 16h OFF)
- 目標交流損失 < 2 W/m @5kA

  実測交流損失: 1.4W/m@77K, 0.95W/m@67K



<ケーブル設計・仕様>

項目	仕様
フォーマー	銅撚り線 (140 mm²)、20 mmϕ
HTS線材 (Ic=14 kA)	4mm幅線材、4層 Ic = 240 A/4 mm-w
絶縁	クラフト紙 (6mm厚)
HTSシールド (Ic=12.7 kA)	4mm幅線材、2層 Ic = 240 A/4mm-w
銅シールド	銅テープ (100mm²)、44mm
ケーブル保護	不織布、45mmϕ
冷却管 外層シース	ステンレス2重コルゲート管、PEシース、114mmϕ



NEDOプロジェクト(2013):フジクラ

5kA級超電導ケーブル開発に成功、
1.37W/mの低交流損失を達成(2013)
現用の電力ケーブル(代表的な154kV 600MVA級)と比較、冷却効率を考慮した上で、1/4以下の送電損失

Fujikura proposed to use 5kA HTS power cable in ILC AC-HV power line.

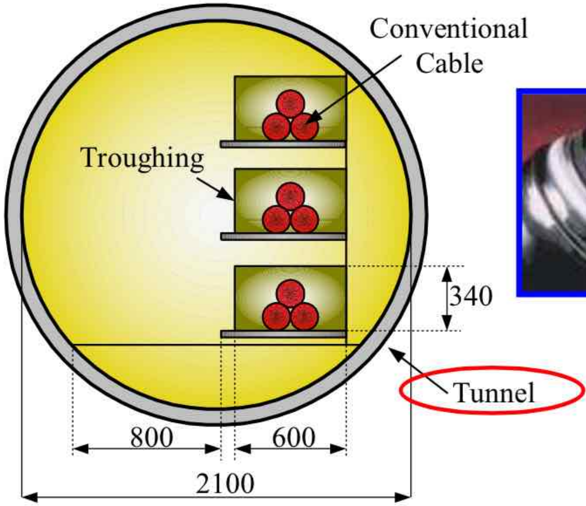
(3) High efficiency cryogenics for HTS cable

(Maekawa Co.)

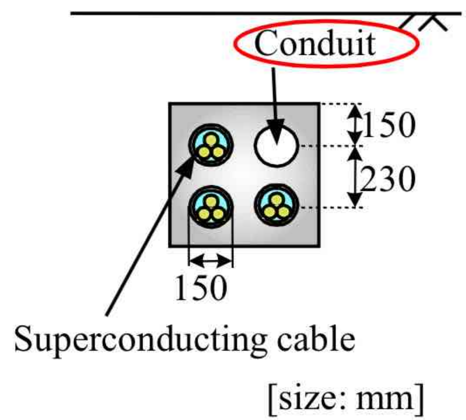
Advantages of HTS cable system

HTS cable is key technology for next generation grid.

- **Large capacity** : equivalent to conventional cable with **lower voltage**
- **Compact size** : installed within conduit
- **Low loss** : **less than 1/2** of conventional cable



Conventional cable
275 kV, 700 MVA/3cc



HTS cable
66 kV, 700 MVA/3cc

HTS cable will be applied to power plant in service, conduit of urban area etc.

Project overview

Project outlines

- Asahi S/S, Yokohama, TEPCO's power system
- 66 kV - 2 kA - 200 MVA class HTS cable with 1G DI-BSCCO wire
- Compact 3-in-One cable design for 150 mm conduit
- Approx. 250 meter cable with a joint and terminations

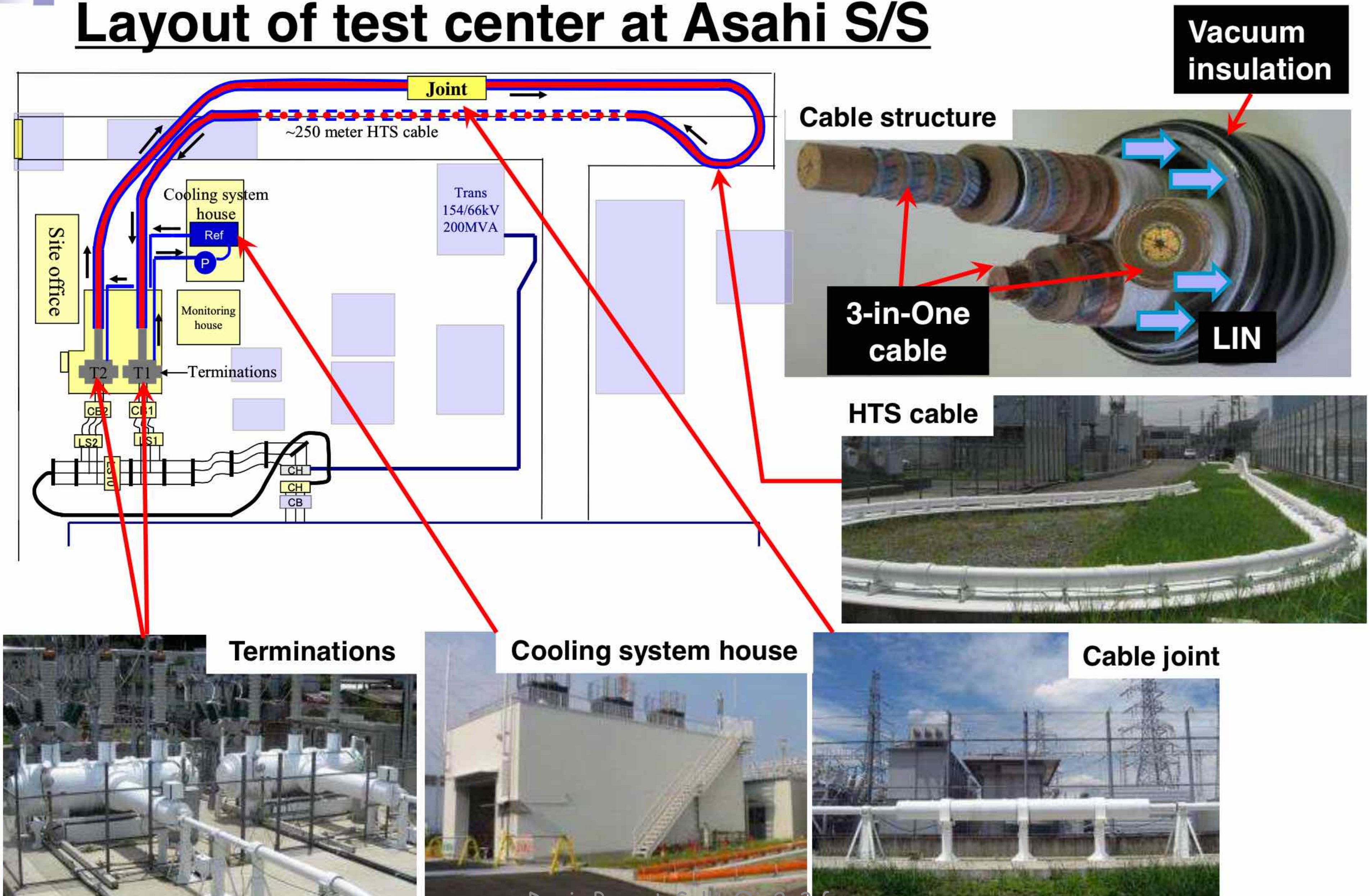
Project members

TEPCO	Host power company
SEI	HTS cable system design, manufacture and installation
MAYEKAWA	Cooling system design, manufacture and Installation. Refrigerator development

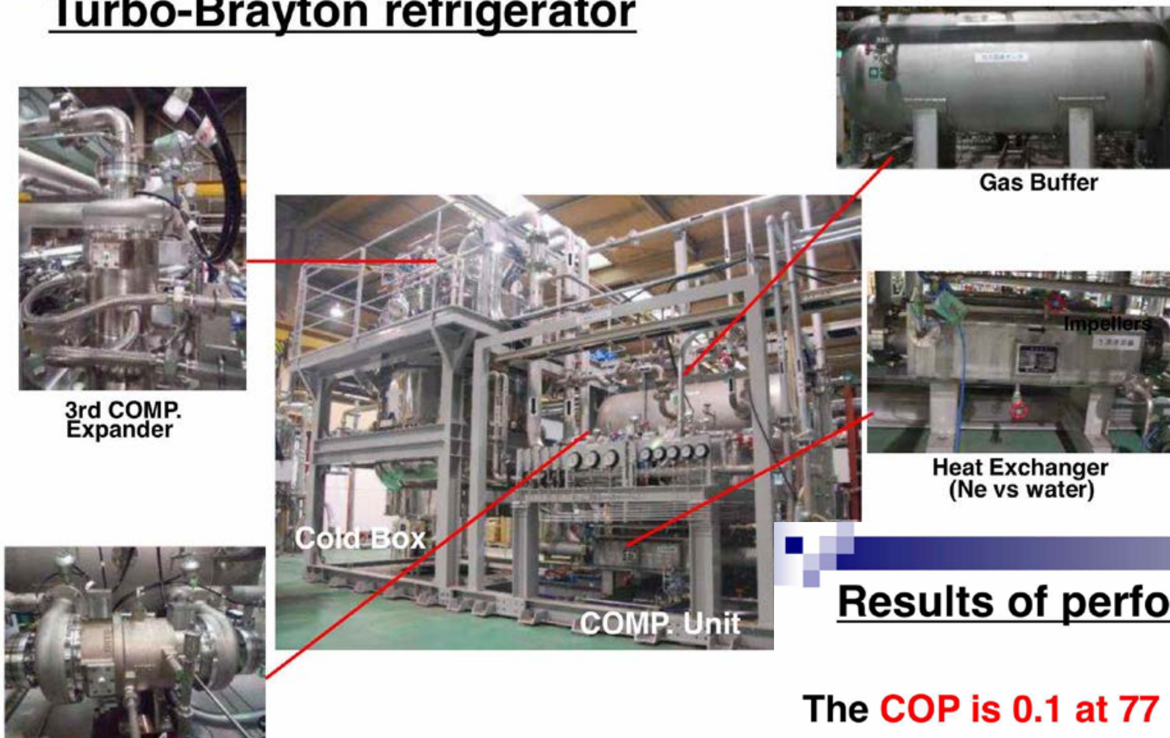
Supported by NEDO & MTEI

HTS cable

Layout of test center at Asahi S/S

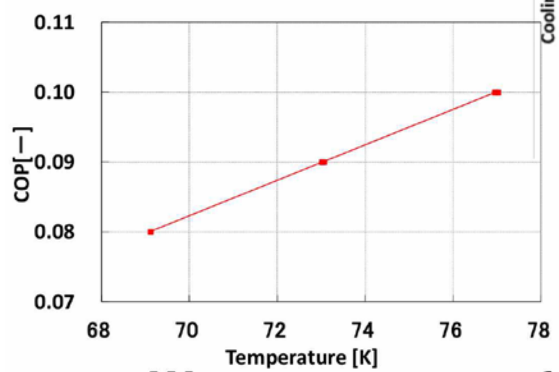


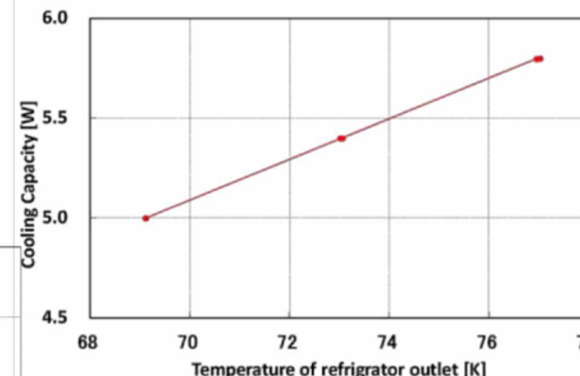
Turbo-Brayton refrigerator



Results of performance test

The **COP is 0.1 at 77 K** with respect to motor input power.





The Cooling Capacity is **5.0 kW at 69 K** and **5.8 kW at 77 K.**

We were successful in developing the high performance refrigerator.

Energy Saving and recovery

- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)
- Cavities: 2 Magnetic shields -> Increase cavity Q_0
  -> decrease cryo -> save 62 ME
  (O. Napoly AWLC 2014 and JLC 2013)
- Beam dumps
  - Wakefield deceleration for beam dump, project and test
- Suiren, KEK computer ranking 2nd in the GREEN500 Nov. 2014 listing
  - ~ 5 GFLOP/S/W for a 0.185 PFLOP/S machine

- Cryogenics
  - Helium refrigerator saving
  - LN2 pre-cooling
- Transmission power lines

Green500 Rank	MFLOPS/W	Site*	Computer*	Total Power (kW)
1	5,271.81	GSI Helmholtz Center	L-CSC - ASUS ESC4000 FDR/G2S, Intel Xeon E5-2690v2 10C 3GHz, Infiniband FDR, AMD FirePro S9150 Level 1 measurement data available	57.15
2	4,945.63	High Energy Accelerator Research Organization /KEK	Suiren - ExaScaler 32U256SC Cluster, Intel Xeon E5-2660v2 10C 2.2GHz, Infiniband FDR, PEZY-SC	37.83
3	4,447.58	GSIC Center, Tokyo Institute of Technology	TSUBAME-KFC - LX 1U-4GPU/104Re-1G Cluster, Intel Xeon E5-2620v2 6C 2.100GHz, Infiniband FDR, NVIDIA K20x	35.39

Accelerator Energy Consumption Calculation Package
AECC

Integrated Power and Energy consumption calculation package for colliders

- Integrating existing computing tools for the various subsystems
- Implementation of analytical scaling formulae (for hot and cool colliders)
- Input from accelerator design/simulation packages
- Testing various staging and operation scenarios

First meeting KEK
Dec. 2014

Amaterasu
Goddess of the sun and of the Universe
Mother of all Energy
And a famous Manga figure

Scaling laws for e+/e- linear colliders

J.P. Delahaye, G. Guignard, T. Raubenheimer, I. Wilson

In the low beamstrahlung regime:

$$M = L\frac{U_\mathrm{f}}{\delta_\mathrm{B}^{1/2}P_\mathrm{AC}} \propto \frac{\eta_\mathrm{beam}^\mathrm{RF}}{\varepsilon_\mathrm{ny}^{*\,1/2}} \propto \frac{\omega^{1/30}G_\mathrm{a}^{-1/6}}{\varepsilon_\mathrm{ny0}^{1/3}(1+\Delta\varepsilon_\mathrm{ny}/\varepsilon_\mathrm{ny0})^{1/2}},$$

$$L \propto \frac{\delta_\mathrm{B}^{1/2}\eta_\mathrm{RF}^\mathrm{AC}}{U_\mathrm{f}}\frac{\eta_\mathrm{beam}^\mathrm{RF}}{\varepsilon_\mathrm{ny}^{*\,1/2}}P_\mathrm{AC} \propto \frac{\delta_\mathrm{B}^{1/2}\eta_\mathrm{RF}^\mathrm{AC}}{U_\mathrm{f}}\frac{\omega^{1/30}G_\mathrm{a}^{-1/6}}{\varepsilon_\mathrm{ny0}^{1/3}(1+\Delta\varepsilon_\mathrm{ny}/\varepsilon_\mathrm{ny0})^{1/2}}P_\mathrm{AC},$$

$$P_\mathrm{AC} \propto \frac{U_\mathrm{f}^3}{\delta_\mathrm{B}^{1/2}\eta_\mathrm{RF}^\mathrm{AC}}\frac{\varepsilon_\mathrm{ny0}^{1/3}(1+\Delta\varepsilon_\mathrm{ny}/\varepsilon_\mathrm{ny0})^{1/2}}{\omega^{1/30}G_\mathrm{a}^{-1/6}}.$$

$U_f = E_{beam}$

δ_B = % loss by beamstrahlung

η^{AC}_{RF} = wall plug power to beam power

In the high beamstrahlung regime:

$$M = \frac{L}{\delta_\mathrm{B}^{3/2}}\frac{U_\mathrm{f}^{1/2}}{P_\mathrm{AC}} \propto \frac{\omega^{1/4}(a/\lambda)^{1/2}}{\varepsilon_\mathrm{ny}^{*\,1/2}} \propto \frac{\omega^{7/20}}{\varepsilon_\mathrm{ny_0}^{1/2}(1+\Delta\varepsilon_\mathrm{ny}/\varepsilon_\mathrm{ny0})^{1/2}},$$

$$L \propto \frac{\delta_\mathrm{B}^{3/2}}{U_\mathrm{f}^{1/2}}\frac{\eta_\mathrm{RF}^\mathrm{AC}}{\beta_y^{*1/2}}\frac{\eta_\mathrm{b}^\mathrm{RF}}{\sigma_z^{1/2}\varepsilon_\mathrm{ny}^{*\,1/2}}P_\mathrm{AC} \propto \frac{\delta_\mathrm{B}^{3/2}}{U_\mathrm{f}^{1/2}}\frac{\eta_\mathrm{RF}^\mathrm{AC}}{\beta_y^{*1/2}}\frac{\omega^{7/20}}{\varepsilon_\mathrm{ny_0}^{1/2}(1+\Delta\varepsilon_\mathrm{ny}/\varepsilon_\mathrm{ny0})^{1/2}}P_\mathrm{AC},$$

$$P_\mathrm{AC} \propto \frac{U_\mathrm{f}^{5/2}}{\delta_\mathrm{B}^{3/2}}\frac{\beta_y^{*1/2}}{\eta_\mathrm{RF}^\mathrm{AC}}\frac{\varepsilon_\mathrm{ny_0}^{1/2}(1+\Delta\varepsilon_\mathrm{ny}/\varepsilon_\mathrm{ny0})^{1/2}}{\omega^{7/20}}.$$

Would be nice to compare with actual data..

An LN_2 Economy for ILC

ILC cryogenics ~ 38 MW (23% of ILC total AC power)

- In current design all cooling is done with LHe. LN_2 as a primary coolant -> - 20 MW
- LN_2 cooling: HTc (MgB2) power transmission lines, NC magnets, electronics/computers,
- LN_2 could be used to recycle low grade heat waste (including beam dumps)
- And produce electricity with high-pressure gaz turbine

LN_2 could be produced by sustainable energies

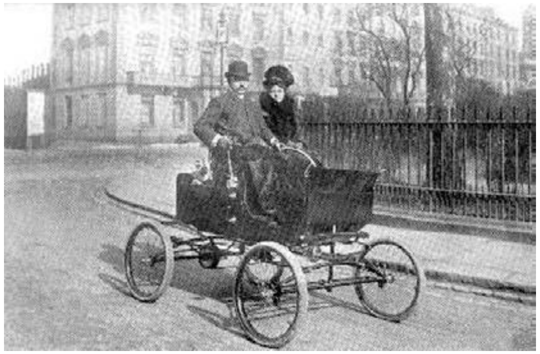
- Close to or at the ILC site (wind, solar, geothermal energy)
- Wind energy: from electricity or direct liquefaction

LN_2 Energy storage

- With the heat waste, turbine produce electricity when needed. 70% efficiency

Sumimoto

First LN2 car



Liquid air energy network

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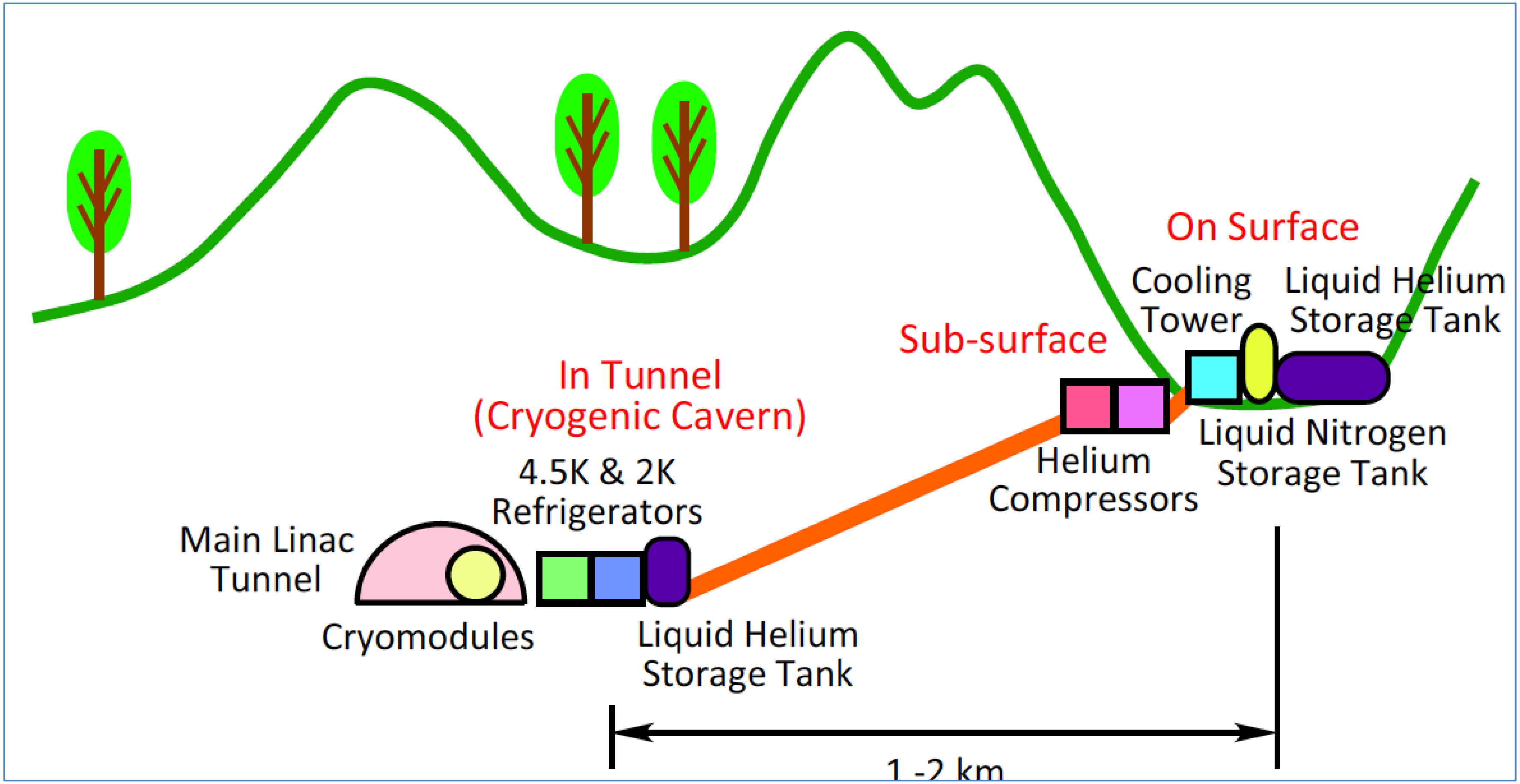
ALCW 2015 change proposal

CR – ?? Cryogenic Concept



Green ILC
Sustainable Energies

1) Energy Production:

- Study the pros/cons of various sources: solar, wind, geothermal, sea, …, smr,…
  - Availability, Price, Flexibility, Potential for improvement, Environmental impact
- Find the best energy mix to cover ILC specific needs ? 24/7, long shutdowns, …
- Power conversion: Match ILC component to the energy sources specifics:
  - RF power converter: PhotoVoltaic, fuel cells (DC)
  - Cryocooler or asynchronous liquefactors ?

2) Energy Storage: HEP, experts in some of these technologies

- Liquid Helium, Nitrogen, SMES(Sc Magnetic Energy Storage), Flywheel, Pumped hydro, Compressed air, Batteries, …

3) Distribution: Local Smart GRID:

Full scale multi-sourced, AC/DC, GRID management and control

- Smooth and rapid switching between energy sources, including conventional supply
- Energy Monitoring, Management and forecast: production, storage and backup

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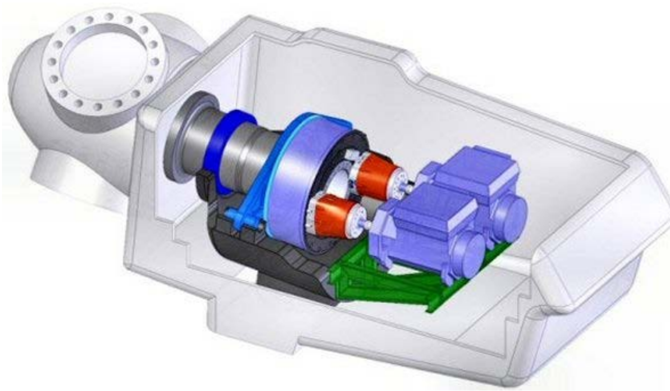
Hydraulic Wind engine

"Liquid nitrogen economy" update:

- The Fukushima Offshore Wind Consortium project update:
- November 2014: 7MW first large scale hydraulic wind engine (MHI, Artemis)



Many technical advantages:

- Smaller, lighter nacelle
- Less mechanical parts and vibration
- Hydraulic accumulator
  - Larger wind speed range
  - No electrical frequency converter
- Easier maintenance at ground level

Good for the LN2

- "Base" based LN2 liquefier
- Many mills to one liquefier
- Hybrid: LN2 and electricity

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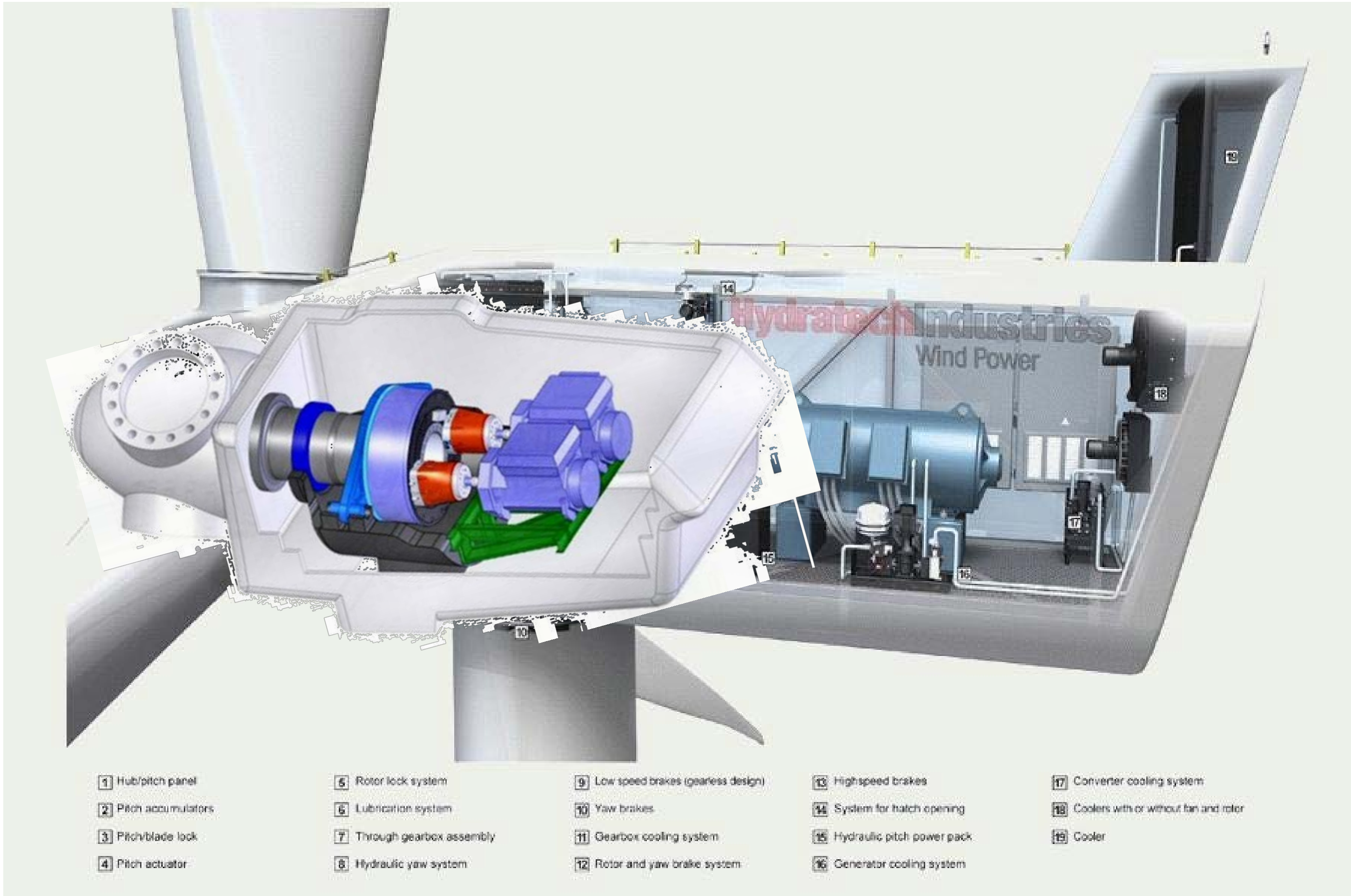
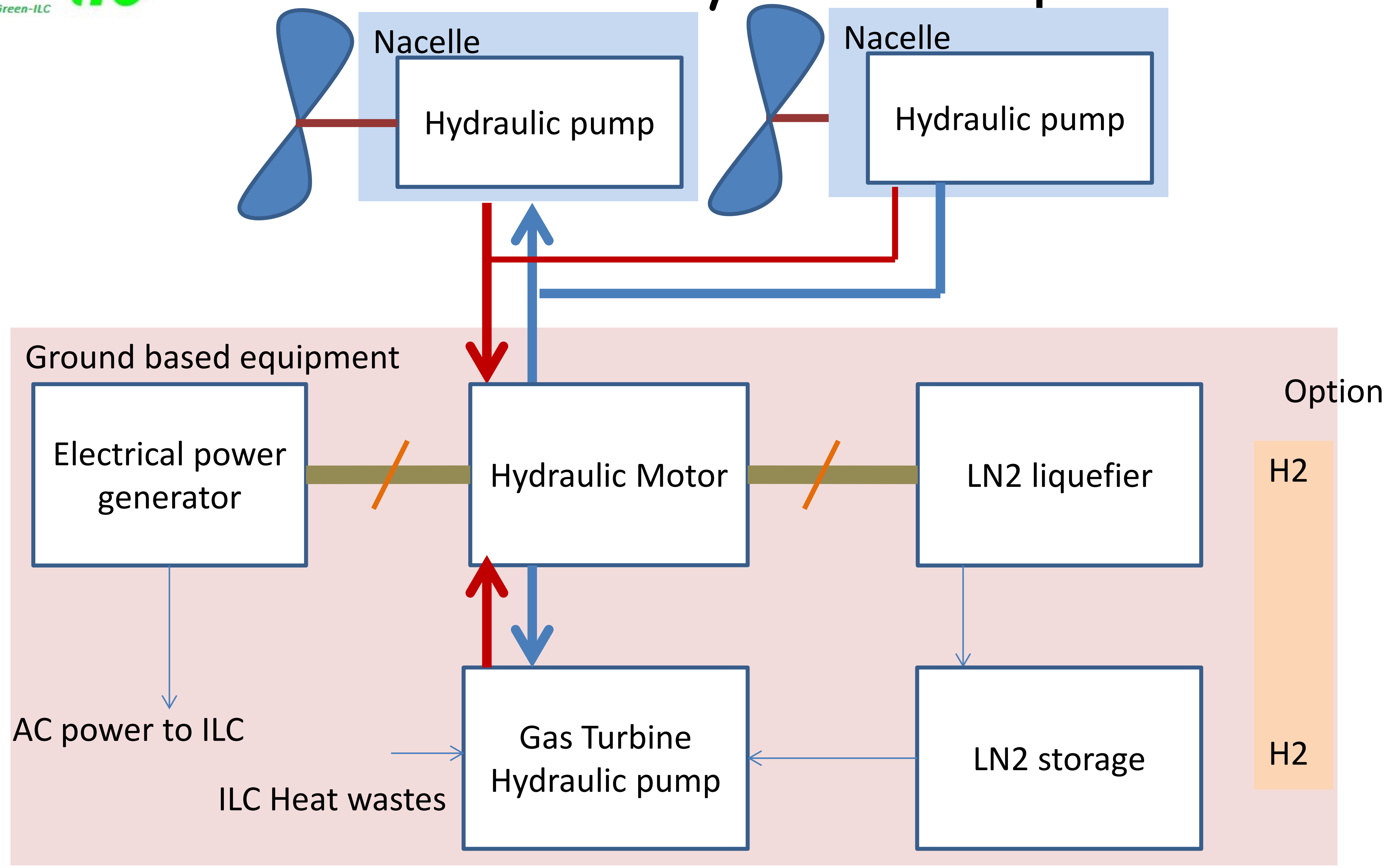

HydratechIndustries
Wind Power
1 Hub/pitch panel
2 Pitch accumulators
3 Pitch/blade lock
4 Pitch actuator
5 Rotor lock system
6 Lubrication system
7 Through gearbox assembly
8 Hydraulic yaw system
9 Low speed brakes (gearless design)
10 Yaw brakes
11 Gearbox cooling system
12 Rotor and yaw brake system
13 Highspeed brakes
14 System for hatch opening
15 Hydraulic pitch power pack
16 Generator cooling system
17 Converter cooling system
18 Coolers with or without fan and rotor
19 Cooler

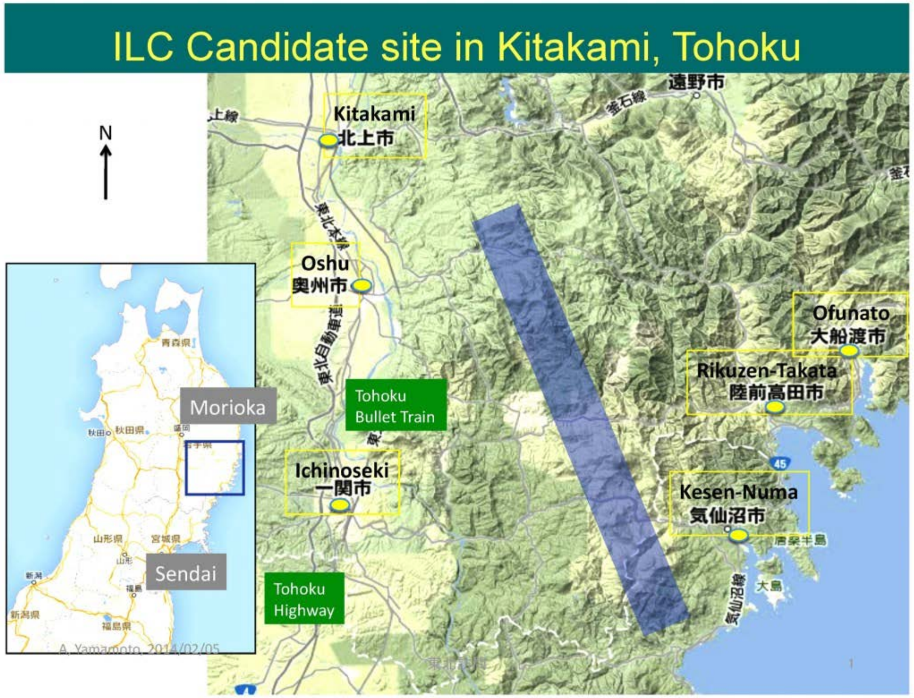
Ground based hybrid wind power



Access tunnels: Power plants

- 10 access points on ILC main Linac
- Proposal: Each house a renewable energy plant
- ~ 10-20 MW at each of the 10 tunnel/pit access
  - 3 - Geothermal/biomass: close to cities, ILC lab site
  - 3 - Wind power: electricity and LN2:ILC lab site, costal side
  - 3 - Solar (best orientation)
  - 3 - 1 - Ocean Power: ocean side

~ Total 100-200 MW



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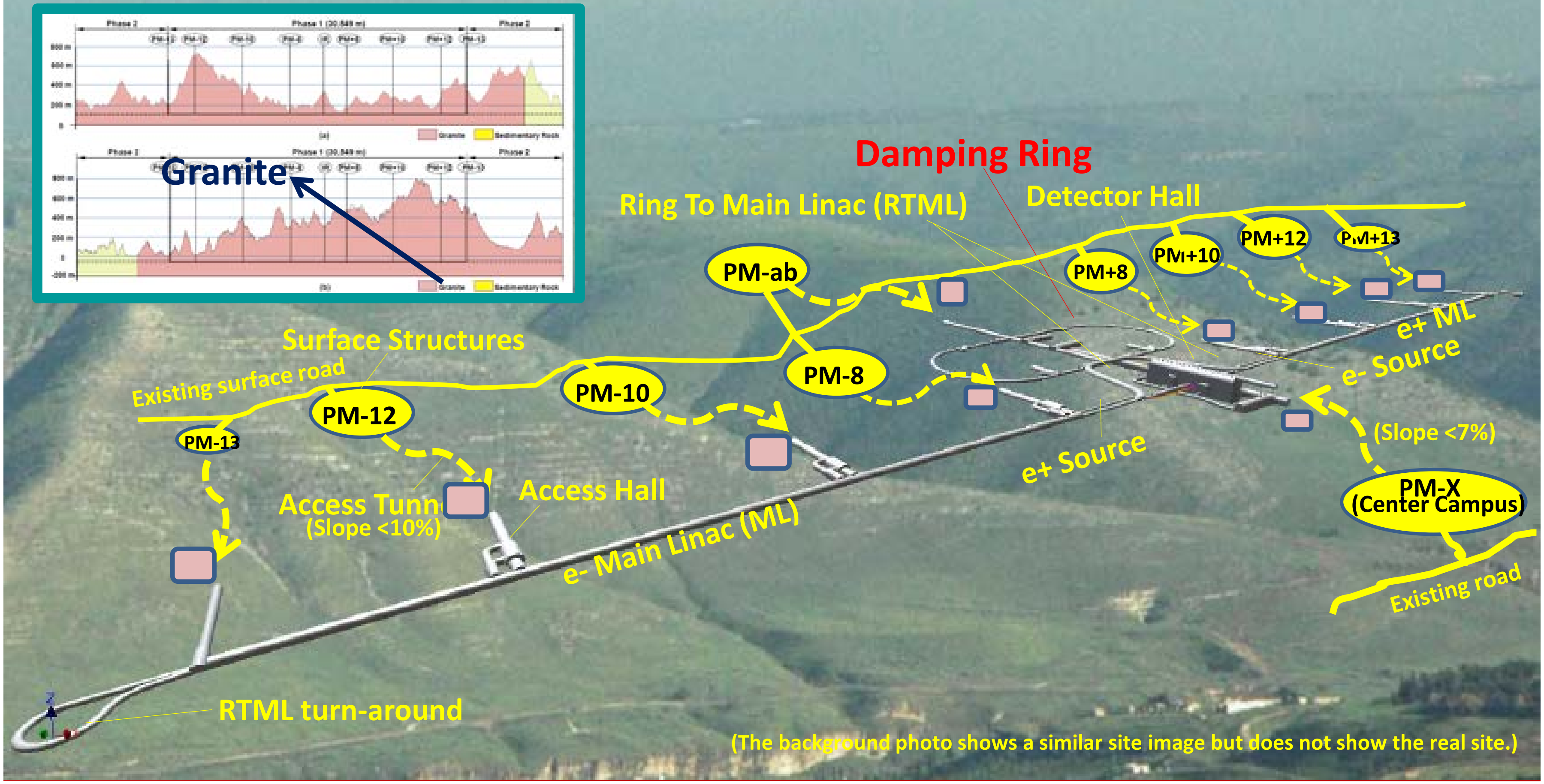
Asian Site Conventional Facility – Introduction

(Site) Mountainous green field not far from big towns, accessible with existing roads.
(Facility) Smaller surface structures and underground structures.



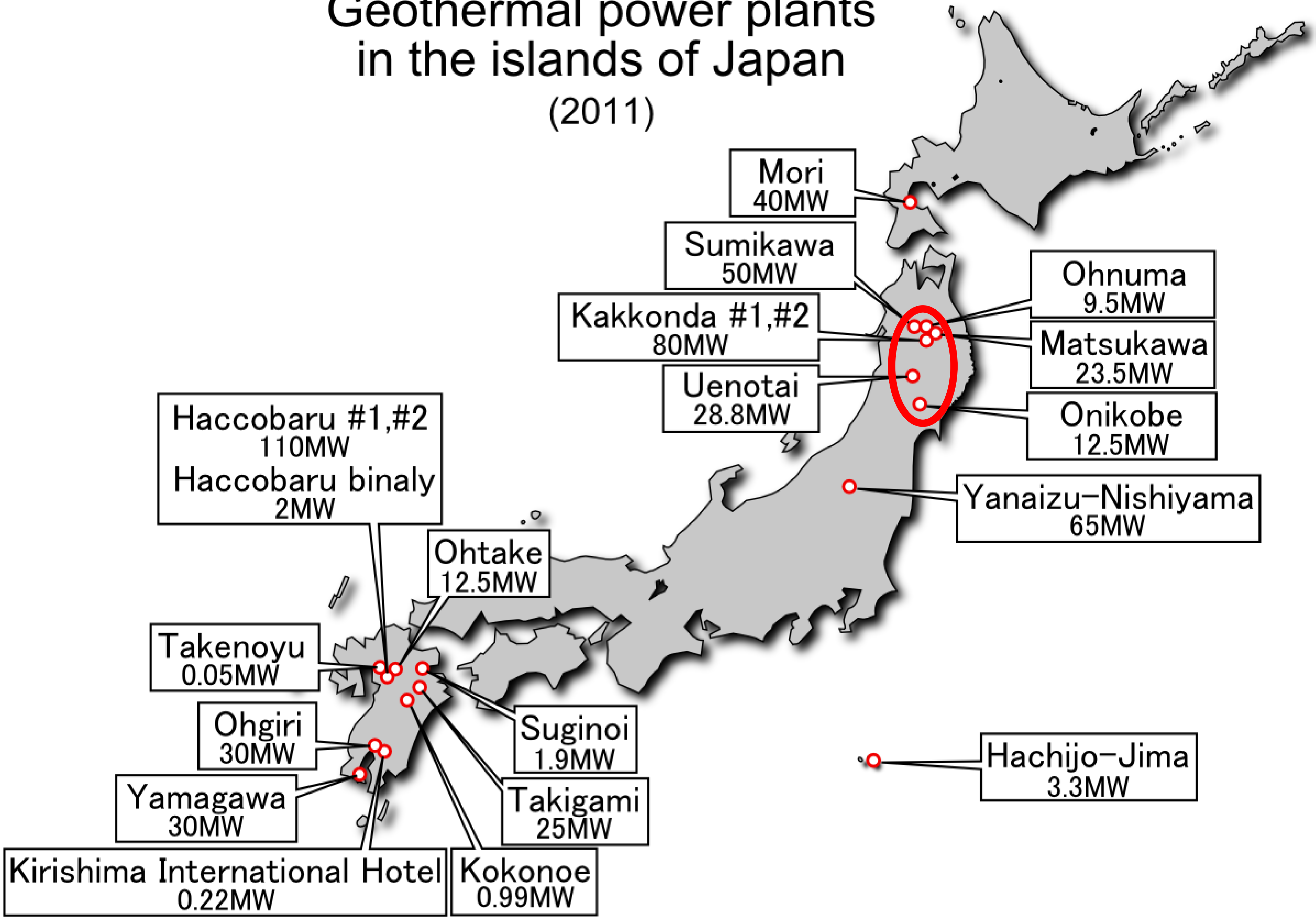
Geothermal power

- Japan has a huge potential
- No fracking, medium depth…
- Let's work with the onsen/spa industry for hybrid projects
- Output warm water: Many applications:
    - Onsen/spa for the local community
    - Heating close-by cities/villages
    - Greenhouses for vegetable and flowers growing
    - Fish farming needs to adjust water temperature

Similar for Biomass power

Geothermal power plants in the islands of Japan

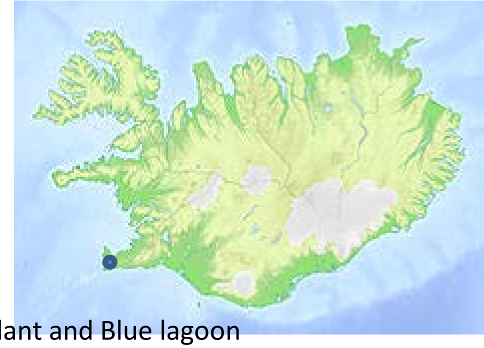
(2011)



Geothermal Energy and SPA center

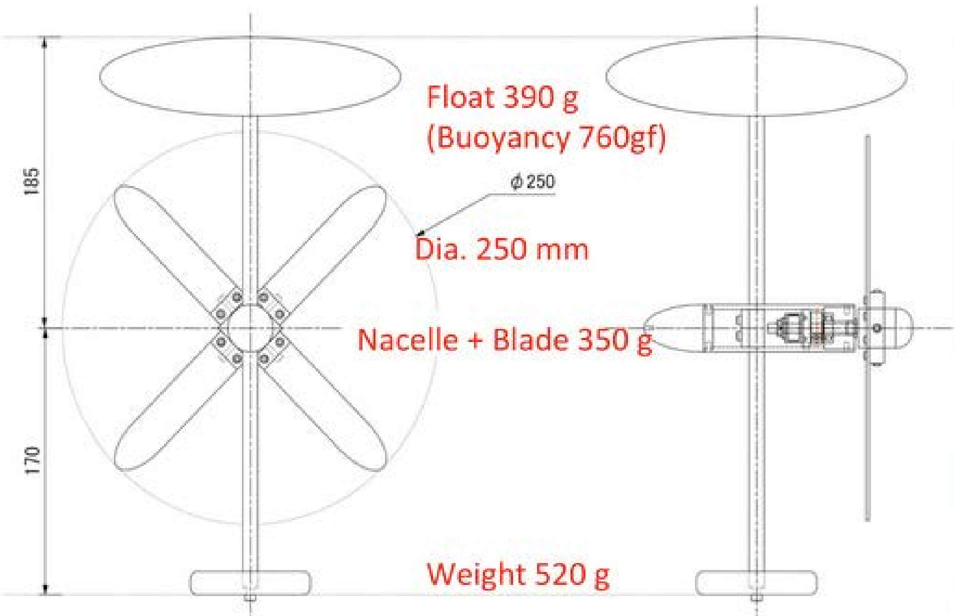
Iceland Svartsengi

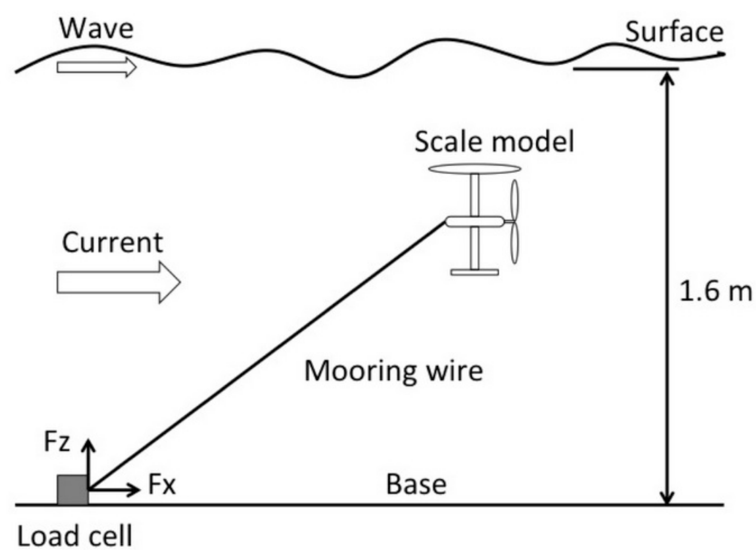
- Geothermal plant: electricity 75 MW, thermal 150 MW
- 37 years of operation
- 600 m drill 240 C + 1000m and 2000m steam wells
- Hot drinking water to the city



Swartsengi Power plant and Blue lagoon

Ocean Power (by Tsumoru Shintake, OIST)





- Many big projects:
    - Little impact on landscape
    - little intermittency,
      but variable power
    - Could be close to the shore
- Prof. T. Shintake future presentation

0.5 MW France

Tide power (Canada)

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LAPP/IN2P3/CNRS - KEK

Tidal power

Rance Tidal Power station (1966), France

Type of dam	Barrage
Length	700 m (2,300 ft)
Reservoir	
Tidal range	8 m (26 ft)
Power station	
Type	Tidal barrage
Turbines	24
Power generation	
Nameplate capacity	240 MW
Capacity factor	40%
Annual generation	600 GWh

Solar power on Infrastructure

Infrastructures, not very eco-friendly, but necessary,
Better to use them to produce energy ?

Assuming: solar panels (thermal or PV) ~200 W/m2

- ILC Buildings: ~ 103 buildings ~ 91,000 m2 (80%) -> ~15 MW
- Roads: 10 tunnel access → 10 semi-private roads (1-2 Km each)
  - ~ 10-20 km
    - Side road: * 3m = 30-60.000 m2
    - Top road: * 10 m = 100-200,000 m2
- Parking lots: covered by solar panels

- PB.: cleaning, snow, support structures, storage, … price …

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"Renault" car company to install 450,000m2 of solar panels: 60 MW
140W/m2

Shandong Huayi Sunlight Solar Energy
115W/m2

SRB and CERN: Thermal panels, Geneva airport roof

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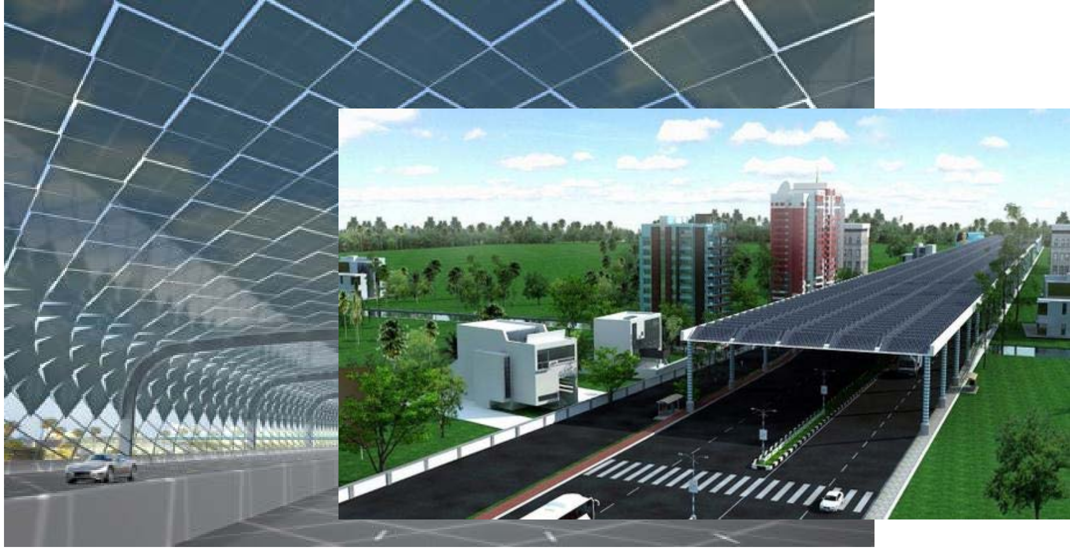
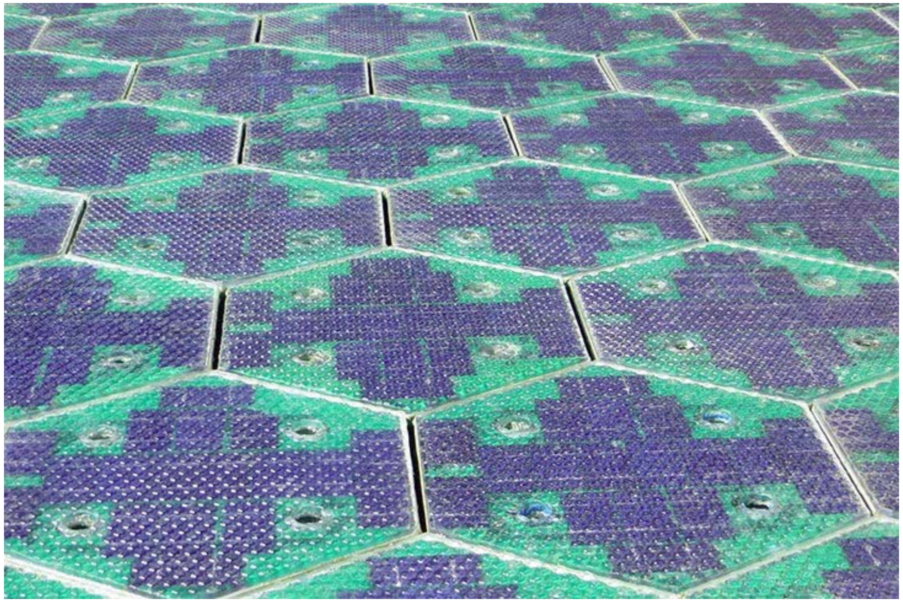


http://www.greenpepperenergy.com/index.php/roof-over-roads-to-tap-solar-power/



Solar roadways

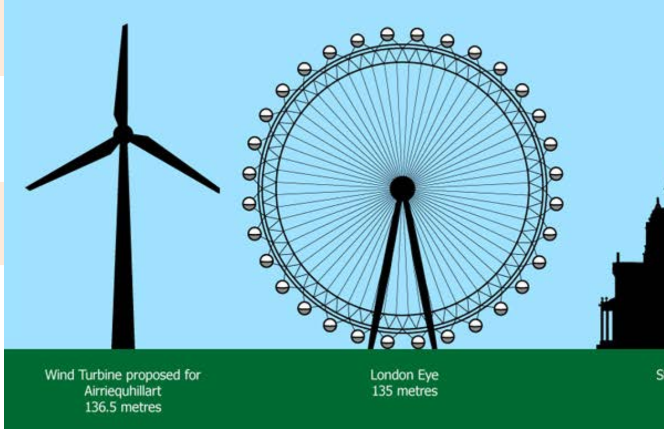
Visually disruptive equipements

Industrial complex, reuse of polluted zone,

Fos sur mer (France)

Off-shore

Amusement parks (Ferris Wheel ~165 m high)



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Excavated earth for pumped hydro dam

~ 3.2 Mm^3 will be removed from tunnels digging

Can be used to build earth dams see for comparison:

Kutataragi Pumped Storage Power Station (奥多々良木発電所) 1.9 GW

Kansai Electric Power Company (Hyōgo Prefecture

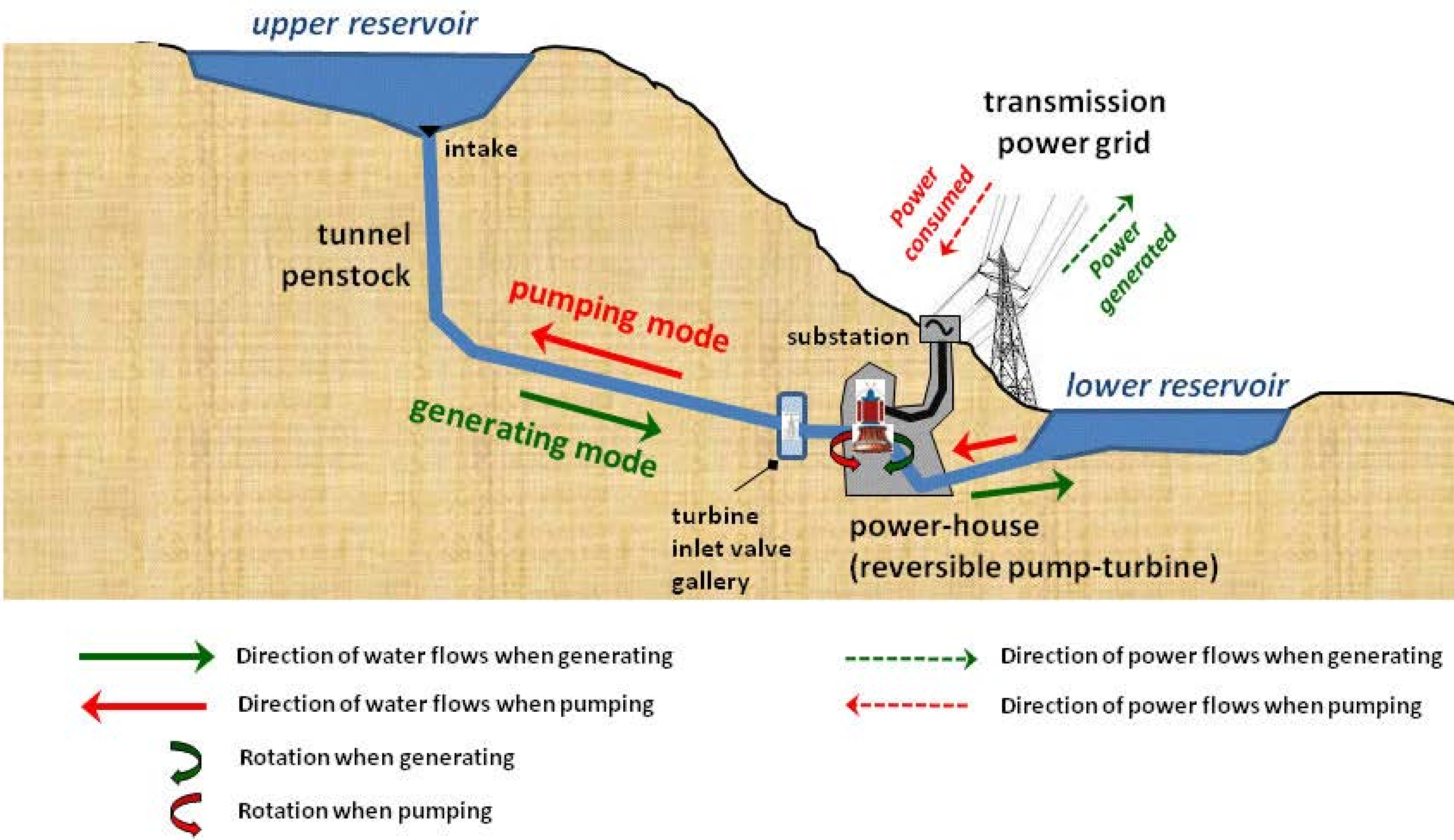
Kurokawa Reservoir (3.6 Mm^3 earth)

98 m tall, 325 m long

Tataragi Reservoir (1.4 Mm^3 earth)

64.5 m tall, 278 m long

Principle of a pumped-storage power plant



International Linear Collider

I L C

Innovation = Leadership x Creativity

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Energy University Network in Japan

Energy for Innovation, Innovation in Energy

- Energy basic research and practical applications suited to ILC similar to medium-large city
  - Based on HEP type cooperation paradigm: open-science, international,…
- Energy issues, pluri-disciplinary … very transversal in Universities
  - Physics: thermodynamics, condensed matter and solid state physics
  - Environment: climate change,
  - Engineering: electronics, high-current, high-voltage electricity, mechanics
  - Bio: artificial photosynthesis
  - Nanotechnology: H2 storage, menbranes, …
  - Computational science: modeling, simulation, Smart grid management,
- Industry network
  - Already: Japan AAA "Green-ILC" every 2-3 month meeting
  - Local companies

- Pickup the university individual expertises on each of these topics
- Build-up a comprehensive R&D program

- Expand the network to international partners

Collaborations

- First joint Green-Session Belgrade/Beijing ILC, CLIC, FCC, CepC, SppC
  "HEP future: to be green or not to be"

- ICFA proposal (A. Suzuki KEK DG)
  "Sustainable accelerator/collider panel" (decision Jul. 2015)

- Industry participation
  - Japan AAA "Green-ILC" every 2-3 month meeting
  - Air Liquide

- Green-ILC available at interactions.org
  http://newsline.linearcollider.org/archive/2014/20141030.pdf

- Comprehensive paper in preparation (Co-authors, H. Hayano, T. Saeki, A. Suzuki, D.P-G, ….)

- Website: http://green-ILC.in2p3.fr (LAPP)