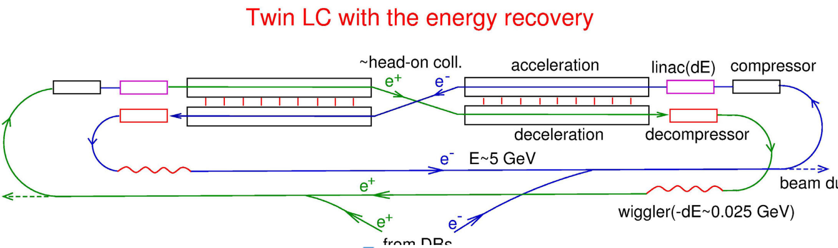
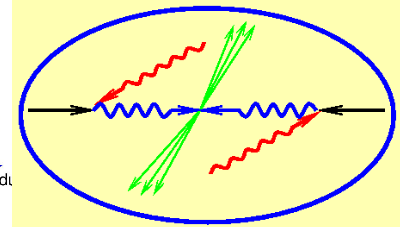
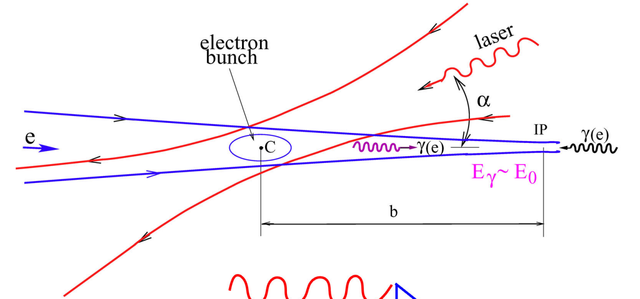
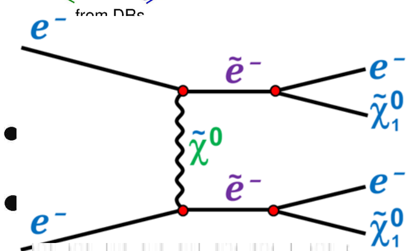
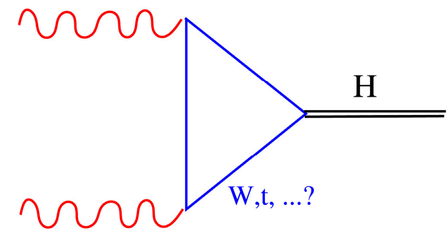
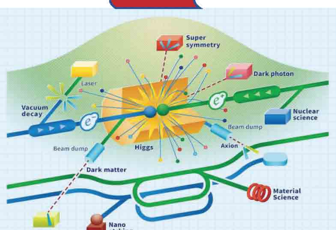


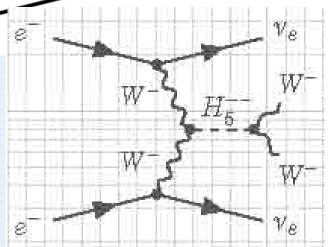




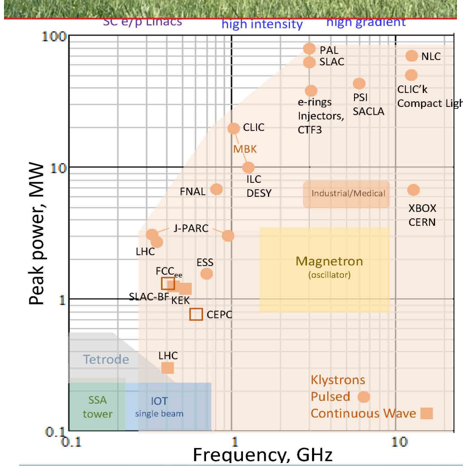


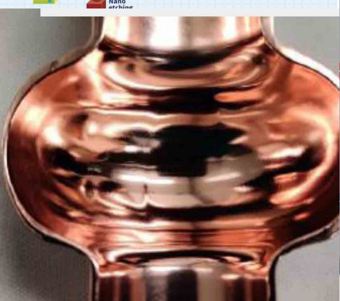


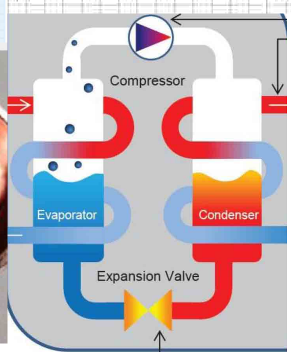




Alternative collider modes & Green ILC

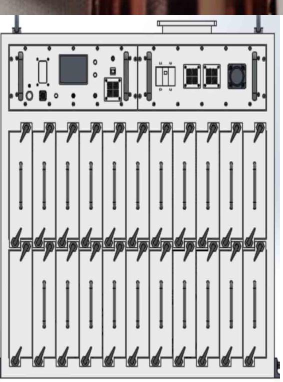


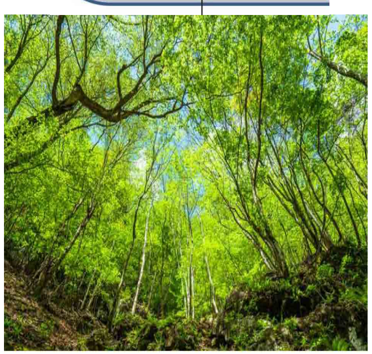




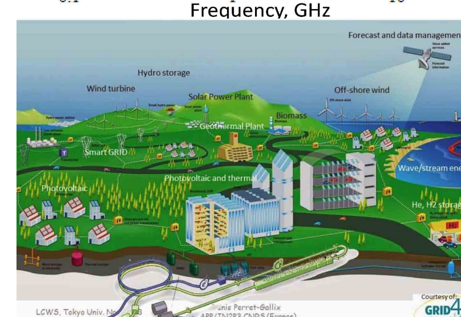
Valery Telnov (BINP)

Takayuki Saeki (KEK)





Summary session
ILCX-2021, Oct. 2021

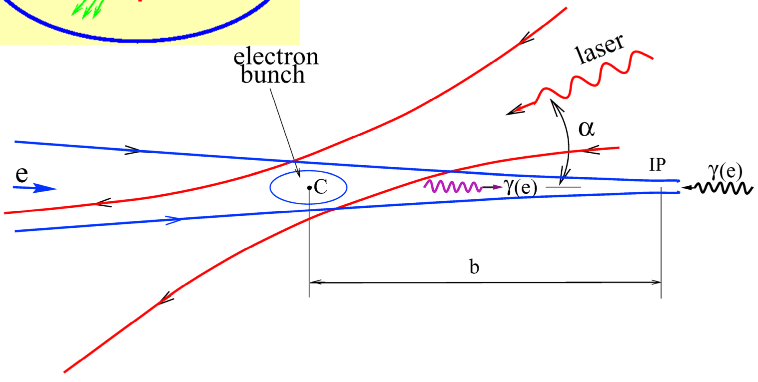


V: Alternative collider modes

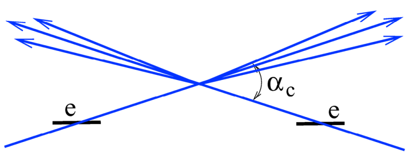
Conveners:
Gudrid Moortgat-Pick, Hitoshi Murayama, Tim Barklow (SLAC), Valery Telnov, Alexey Drutskoy

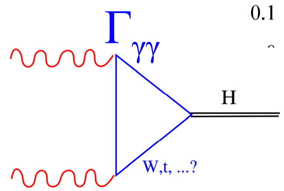
Photon collider at the ILC, first forty years	*Prof. Valery Telnov*	
Room #3, Zoom Meeting ID: 814 7454 2635		15:30 - 16:10
Photon collider based on the EU XFEL linac as a prototype of the PLC at the ILC	*Prof. Valery Telnov*	
Room #3, Zoom Meeting ID: 814 7454 2635		16:10 - 16:30
Potential BSM searches in e-e- collisions at ILC.	*Alexey Drutskoy*	
Room #3, Zoom Meeting ID: 814 7454 2635		16:30 - 16:50
Doubly-charged Higgs boson production at electron-electron colliders in the Georgi-Machacek model	*Takahiro Ueda*	
		16:50 - 17:10
Leptoquarks and Zeros of Amplitude at Electron-Photon Collider	*Anirban Karan*	
Room #3, Zoom Meeting ID: 814 7454 2635		17:10 - 17:30

Photon collider at the ILC, first forty years Valery Telnov

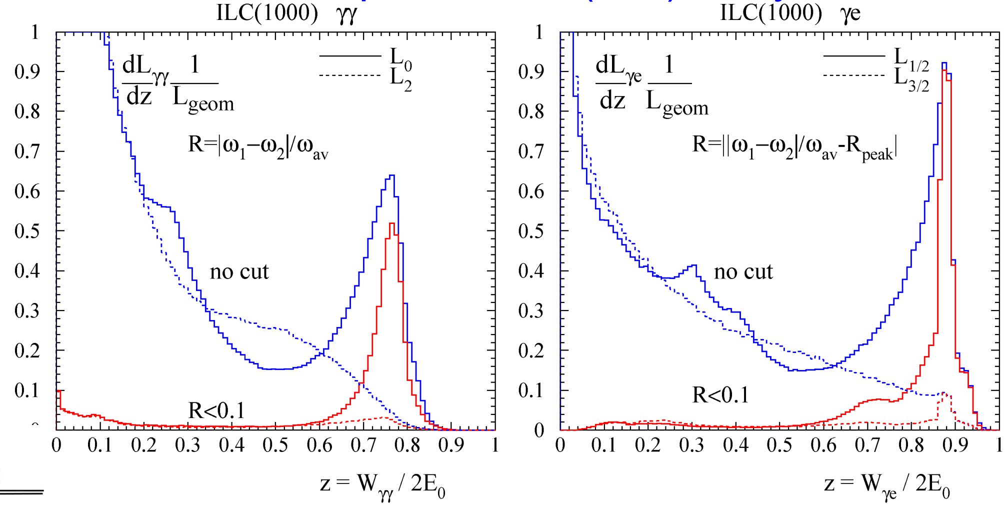


a)





Lum. spectra for X(750) study

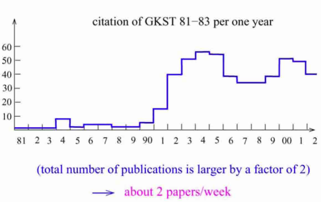


- the energy is smaller only by 10-20%
- access to higher particle masses
- higher precision for some phenomena (Γγγ, CP)
- different types of reactions

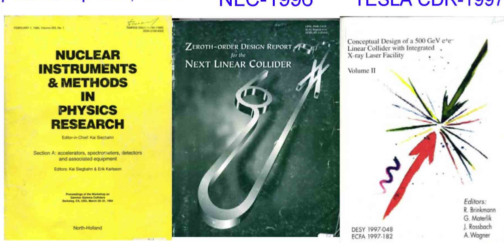
Photon colliders is a very cost effective addition for e+e- linear colliders. The physics case (after LHC runs) is not obvious, but situation may change unexpectedly, the ILC design should reserve the possibility of γγ collider from the very beginning:

the crossing angle 25 mrad is needed!

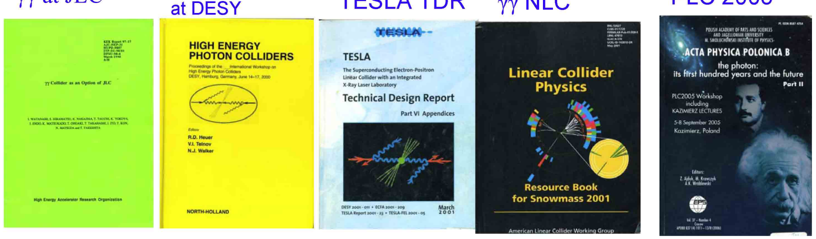
Activity on photon colliders



γγ workshop LBL, 1994 NLC-1996 TESLA CDR-1997



γγ at JLC γγ workshop at DESY TESLA TDR γγ NLC PLC 2005



Photon colliders were suggested in 1981 and since ~1990 are considered as a natural part of all linear collider projects.

+thousands papers on γγ, γe physics

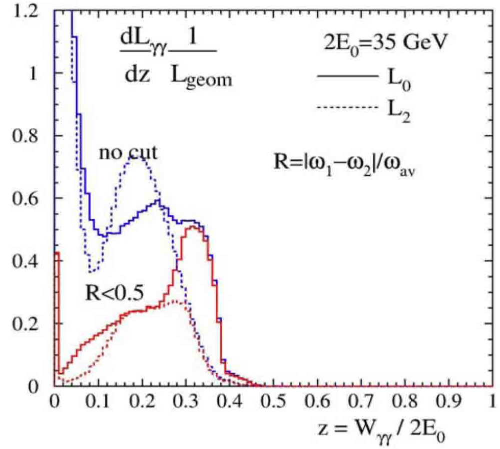
γγ collider based on European XFEL as a prototype of PLC at ILC

Valery Telnov

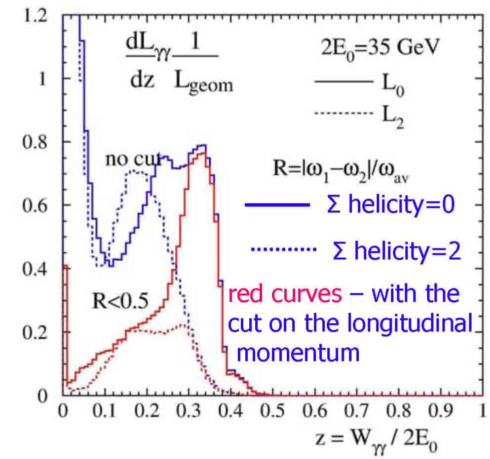
European XFEL: e-beams 17.5 GeV + laser 0.5 μm = γγ collider ($W_{\gamma\gamma}$ <12 GeV)

E_0, GeV	17.5 (23)
$N/10^{10}$	0.62
f, kHz	15
σ_z, μm	70
$\varepsilon_{nx}/\varepsilon_{ny}$, mm mrad	1.4/1.4
β_x/β_y, μm	70/70
σ_x/σ_y, nm	53/53
laser λ, μm (x≈0.65)	0.5 (1)
laser flash energy, J	3 (ξ^2=0.05)
f#, τ, ps	27, 2
crossing angle, mrad	~30
b, (CP-IP dist.), mm	1.8
L_{ee}, 10^{33}	1.6
$L_{\gamma\gamma}(z>0.5z_m)$, 10^{33}	0.21
$W_{\gamma\gamma}$(peak), GeV	12

Unpolarized electrons, P_c=-1

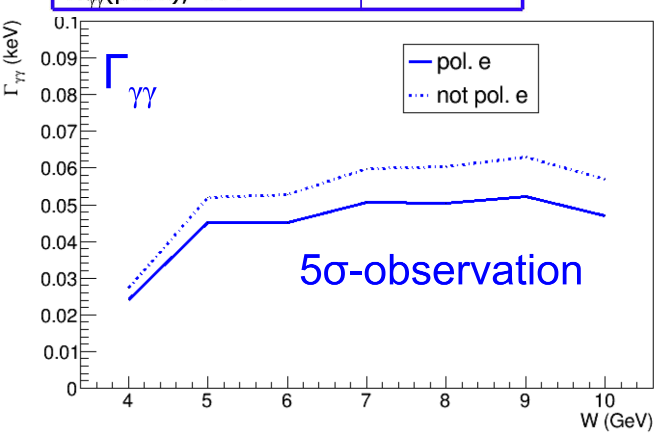


Polarized electrons, $2\lambda_e P_c$=-0.85



L_{ge}

Two real photons will produce resonance states with Q=0, C=+,
J^P= 0^+, 0^-, 2^+, 2^-, 3^+, 4^+, 4^-, 5^+ … $(\text{even})^\pm$, $(\text{odd} \neq 1)^+$
2=quark, 4-quark (or molecule) states, glueballs and ???



Observation limit is much lower than $\Gamma_{\gamma\gamma}$ width of $q\bar{q}$ ground states:

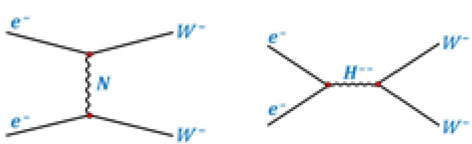
η_c(1S),M=2.98 GeV $\Gamma_{\gamma\gamma}$~5 keV
η_b(1S),M=9.4 GeV $\Gamma_{\gamma\gamma}$~0.5 keV (not measured)

Potential BSM search in e-e- collisions at the ILC

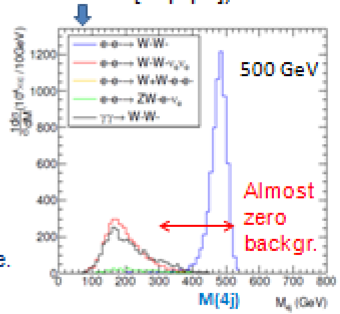
Alexey Drutskoy
(LPI, Moscow)

Search for heavy Majorana neutrino effect

Possibility to search for heavy Majorana neutrino mediation effect has been discussed in many papers (see for example arXiv:1610:02618 [hep-ph]).



Majorana neutrino exchange *H^{--} exchange ($H^{--} \to \mu^-\mu^-$)*



Potentially H^{--} exchange can result in same final state.

Heavy Majorana neutrinos naturally appear in frame of seesaw mechanism.

Best way to search for $e^-e^- \to W^-W^-$ process is to test mass of 4-jets. Backgrounds are located in lower mass region and can be additionally suppressed: right-handed

e-e- is useful for

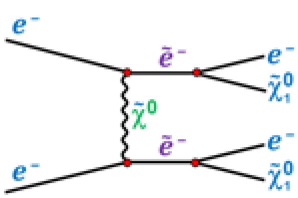
1) Majarano neutrino
2) Selectron
3) Charged H bosons

(and not only)

three e-e- workshop organized by C. Heusch in ~2000

Search for SUSY selectrons production

Search for SUSY selectrons was discussed in many papers (arXiv:0808.2410, arXiv:0307001)



$\boxed{e^-e^- \to e^-e^-\tilde{\chi}^0\,\tilde{\chi}^0}$

Processes with Majorana neutralino exchange:

$$e^-_L e^-_L \to \tilde{e}^-_L \tilde{e}^-_L\,, \quad e^-_R e^-_R \to \tilde{e}^-_R \tilde{e}^-_R$$
$$e^-_L e^-_R \to \tilde{e}^-_L \tilde{e}^-_R\,.$$

Only last process can come via Dirac neutralino exchange.

$\tilde{e}^-$ has electron lepton number

Signal signature: 2 back-to-back e^-, large missing P_T, 20 < M(e^-e^-) <100 GeV.

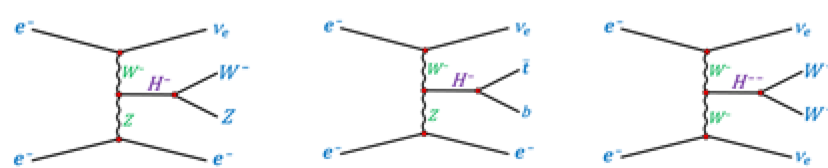
Dominant background coming from $e^-e^- \to \nu_e \nu_e W^-(e\nu_e) W^-(e\nu_e)$ process can be suppressed using right-handed electron beams. Background should be small. Other potential backgrounds?

Neutralino with lepton flavor violation is also discussed: $e^-e^- \to e^-\mu^-\tilde{\chi}^0\,\tilde{\chi}^0$

Search for charged Higgs bosons H^- and H^{--}

Charged Higgs bosons appear in Higgs doublet and Higgs triplet models. Using data collected in e^-e^- collisions, Higgs triplet model can be tested. This model has very attractive features, can explain many BSM effects, such as neutrino mass, right-handed neutrino, dark matter. Unfortunately data taken in e^-e^- collisions will not be sensitive to 2HDM models.

Left-handed polarized electron beams should be used, $\mathcal{L}_{int}$~100 fb^{-1}.



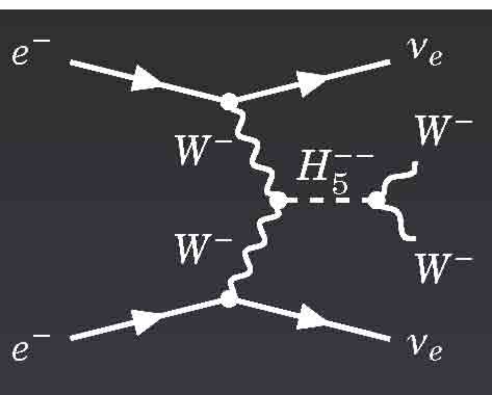
Signal cross sections are expected to be ~(1-10) fb in wide mass interval. Final states are 4-jets. Detector resolution of 4-jet mass is roughly 10-15 GeV. Backgrounds are larger, but still acceptable (detailed studies are required).

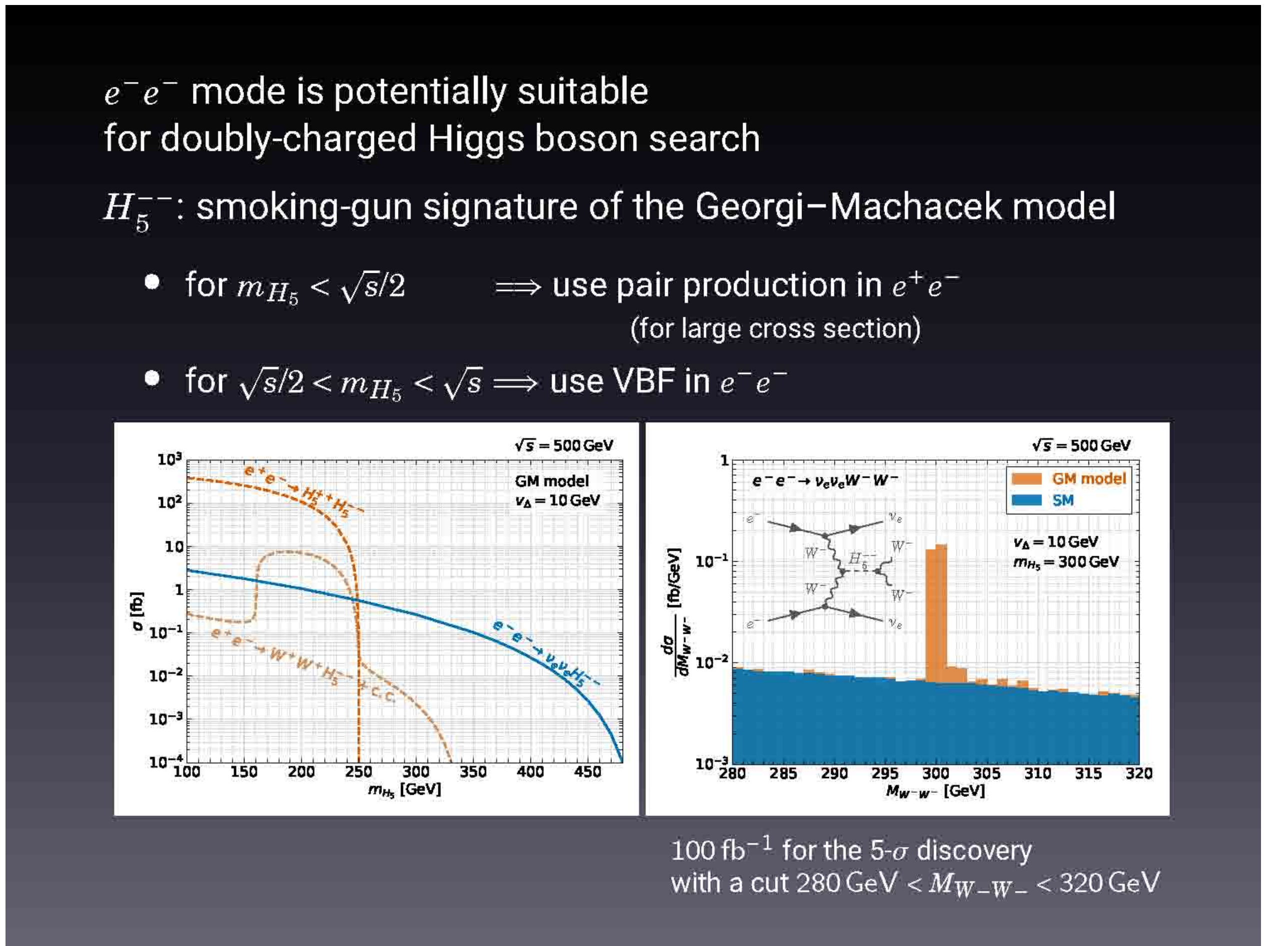
Doubly-charged Higgs boson production at electron-electron colliders in the Georgi-Machacek model. Takihira Ueda

The e-e- mode is potentially suitable for doubly-charged Higgs boson search.

We considered H_5^{--} Higgs boson production, which is a smoking-gun signature of the Georgi-Machacek model. If the mass of H_5 Higgs bosons is less than half of the center-of-mass energy, then the pair production in e+ e- collisions is useful. If this is not the case, the vector-boson-fusion process in e-e- collisions is useful. Although the signal strengths depend on the model parameters, 100 fb^{-1} is sufficient for the discovery with the center-of-mass energy 500 GeV and a certain parameter set that is still allowed by the current constraints.

e-e- is needed when $H_5 > 0.5(2E_0)$



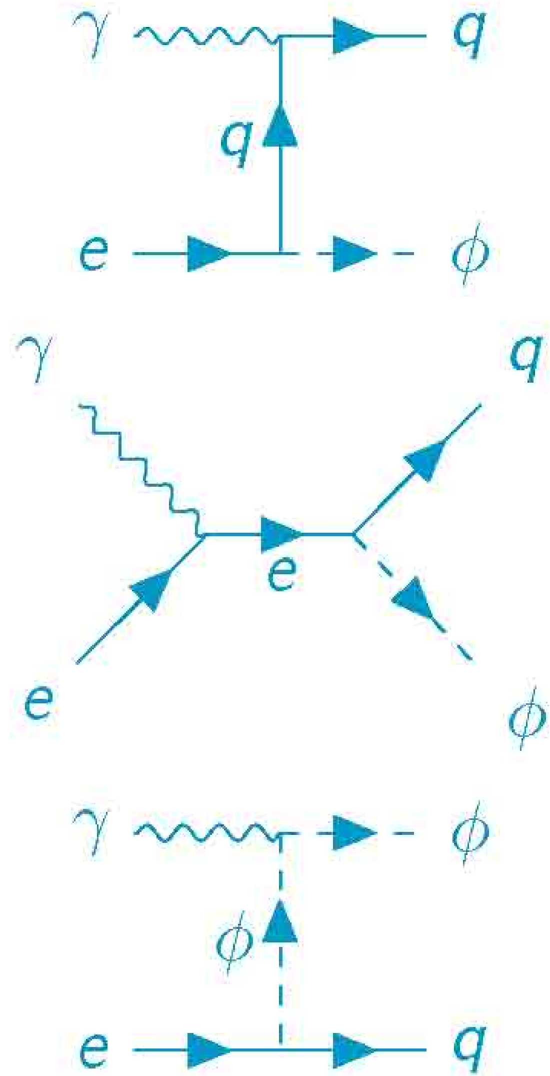


Leptoquarks and Zeros of Amplitude at $e^-\gamma$ Collider

Anirban Karar

$e\gamma \rightarrow q\phi$

Though leptoquarks have gained much attention in recent time due to their ability to explain various flavour anomalies, their existence is not confirmed yet experimentally. But, we find that zeros of single photon tree level amplitude have the potential to provide information about leptoquarks (if any) at electron-photon collider. It is a well known fact that the tree-level single photon amplitudes for various electroweak processes vanish at certain regions of phase space depending on the electric charges and four-momenta of the external particles. On the other hand, using the technique of laser-backscattering, one electron-positron collider can be transformed to an electron-photon collision machine. A small number of SM backgrounds would keep the signal very clean in this collider. We have used a PYTHIA based simulation for production of leptoquark associated with a quark at electron-photon collider to obtain the results which are very encouraging

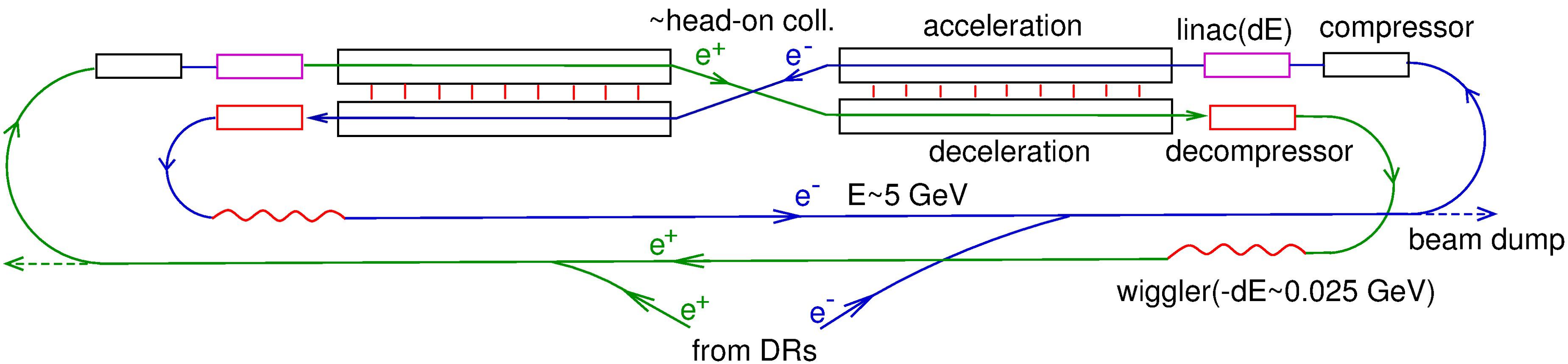


A high-huminosity SC e+e- twin LC with energy recovery and multiple use of bunches (ERLC)

(this talk was given at the Green ILC session)

Valery Telnov

To avoid parasitic collisions in SC linacs a twin (dual) LC is proposed (arXiv:2105.11015)



Such ERLC collider can work with a duty cycle or in continuous CW mode.

Main power is used for removal of heat due to RF and HOM losses.

The power required for continuous operation in the case of Nb cavities at 1.8 K is larger than acceptable by a factor of 3.

More promising are SC cavities working at 4.5 K, such as cavities covered by thin layers Nb^3Sn (or some other).

Collision effects limiting luminosity

BI 1) Beam Instability (the turn shift) $$\xi_y = \frac{N r_e \sigma_z}{2\pi\gamma\sigma_x\sigma_y} \le 0.1 \quad (\text{for } \beta_y \approx \sigma_z)$$

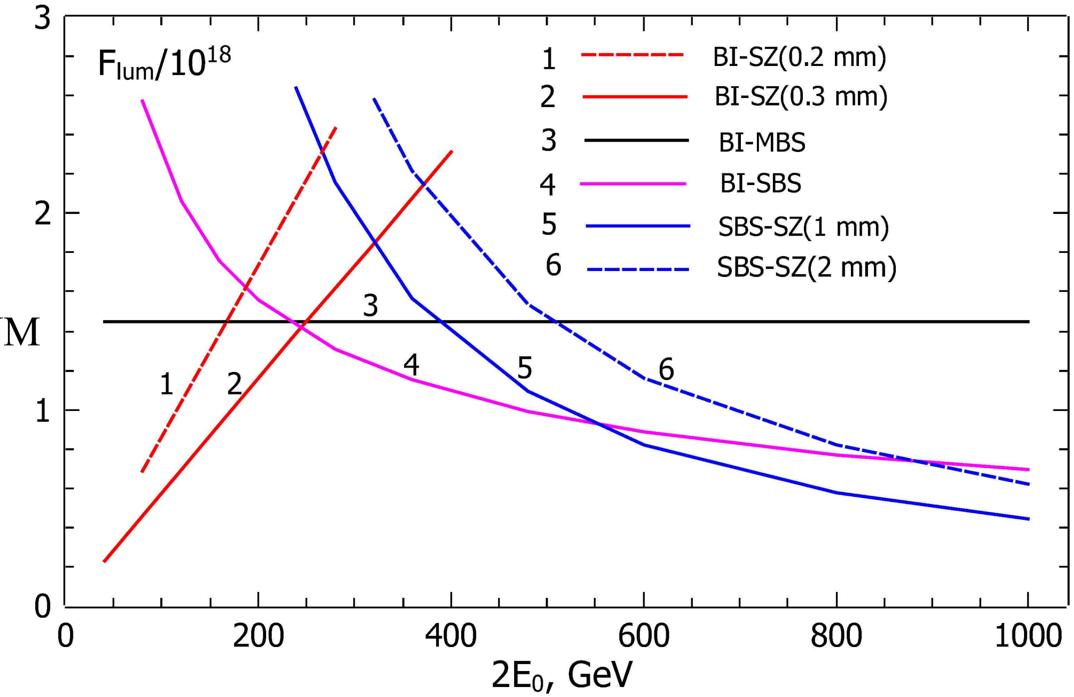
MBS 2) Beam energy spread at the IP due to multiple beamstrahlung $$\frac{N^3}{\sigma_x^3\sigma_z^2} < \frac{8\cdot10^{-3}}{r_e^5\gamma^2}\left(\frac{\sigma_E}{E_0}\right)^2 \frac{\delta E}{E}$$

rel. energy loss in wigglers ~1/200

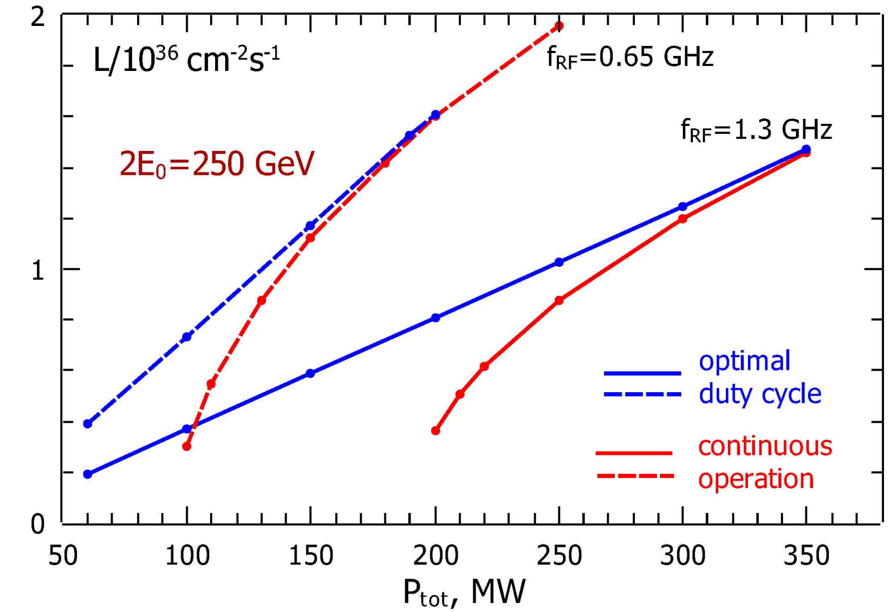
SBS 3) Beam life time due to tails in single beamstrahlung (>1.5×10^6 collisions, ~5 min) $$\frac{N}{\sigma_x\sigma_z} < \frac{7.9}{\gamma^2 r_e^2 \Lambda}, \quad \Lambda \approx \ln\frac{120}{E_0/125},$$

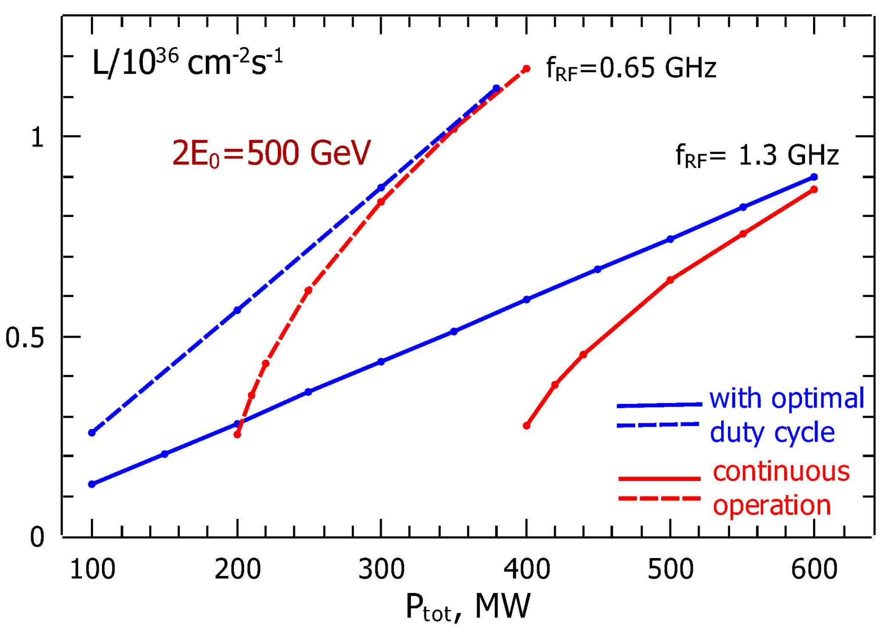
SZ 4) Bunch length $$\sigma_{z,\min} < \sigma_z < \sigma_{z,\max}$$

$$L = Nf \times F_{\mathrm{LUM}}$$



Parameters of ERLC at E=250 and 500 GeV





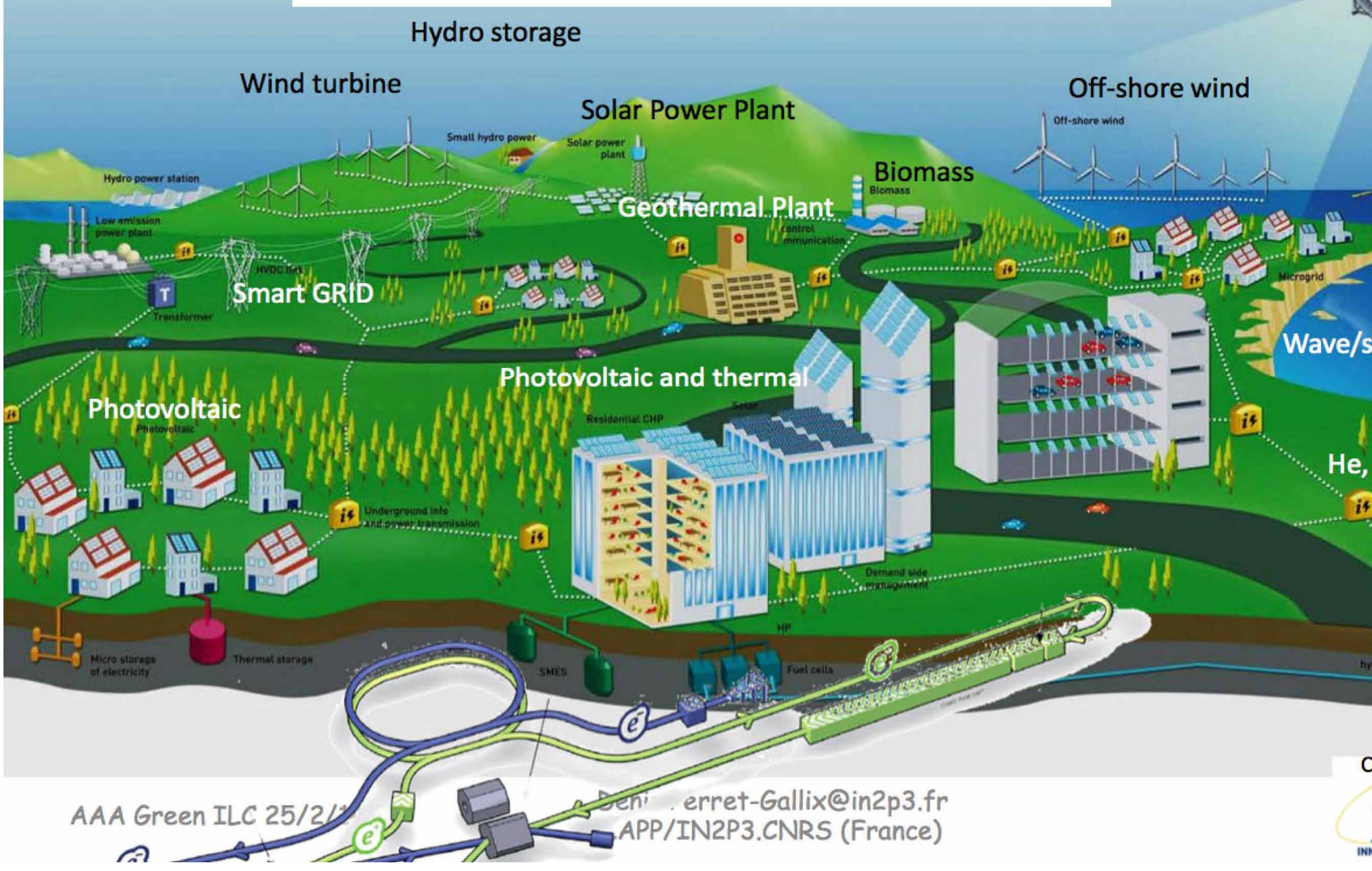
	unit	ERLC pulsed	ERLC contin.	ERLC pulsed	ERLC contin.
Energy $2E_0$	GeV	250	250	500	500
Luminosity $\mathcal{L}_{\rm tot}$	$10^{36}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$	0.73	1.	0.41	0.61
Duty cycle, DC		0.53	1	0.4	1
Accel. gradient, G	MV/m	20	20	20	20
Cavity quality, Q	10^{10}	3	3	3	3
Length $L_{\rm act}/L_{\rm tot}$	km	12.5/30	12.5/30	25/50	25/50
P (wall)	MW	100	140	150	250
N per bunch	10^9	1.5	1.1	1.6	0.97
Bunch distance	m	0.46	0.46	0.46	0.46
Rep. rate, f	Hz	$3.4\cdot10^8$	$6.5\cdot10^8$	$2.6\cdot10^8$	$6.5\cdot10^8$
Norm. emit., $\epsilon_{x,n}$	10^{-6} m	10	10	10	10
Norm. emit., $\epsilon_{y,n}$	10^{-6} m	0.035	0.035	0.035	0.035
β_x^* at IP	cm	4.8	2.6	16	6
β_y at IP	cm	0.03	0.03	0.09	0.09
σ_x at IP	μm	1.4	1.04	1.8	1.1
σ_y at IP	nm	6.2	6.2	7.4	7.4
σ_z at IP	cm	0.031	0.031	0.09	0.09
$(\sigma_E/E_0)_{\rm BS}$ at IP	%	0.2	0.2	0.1	0.1

ILC center futuristic view

Green-ILC

ILC Workshop on Potential Experiments (ILCX2021)

ILCX2021 ILC Workshop on Potential Experiments



Green-ILC session

Room#1, 13:00 – 15:00 W-1 session, 15:30 – 17:30 W-2 session on 28th (Thu.) Oct.

Green-ILC session / W-1 / Room #1,
13:00 - 15:00 (JST)
==========================

13:00 - 13:30 (JST)
Prof. Masakazu Yoshioka
Basic policy of Green ILC activities at Kitakami ILC candidate site

13:30 - 14:00 (JST)
Prof. Valery Telnov
A high-luminosity SC e+e- collider with energy recovery and multiple use of beams

14:00 - 14:30 (JST)
Takeyoshi Goto
Development of hydrofluoric acid-free EP treatment of Nb cavities at KEK

14:30 - 15:00 (JST)
Discussions

15:00 – 15:30 (JST) Break

Green-ILC session / W-2 / Room #1
15:30 - 17:30 (JST)
==========================

15:30 - 15:50 (JST)
John Andrew Osborne
Tunnel Heat Recovery - Green ILC

15:50 - 16:10 (JST)
Benno List
Sustainability issues

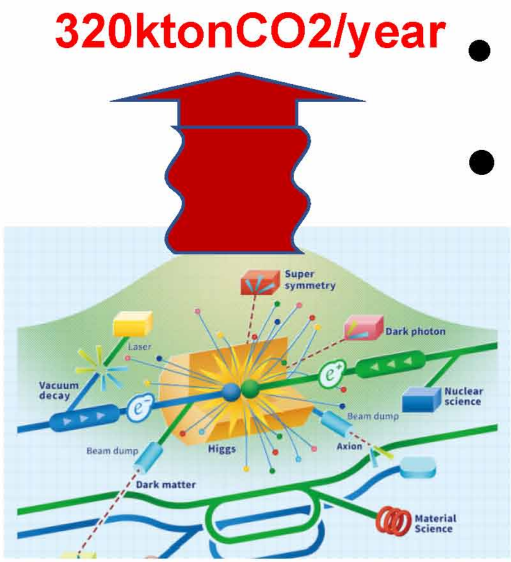
16:10 - 16:30 (JST)
Mr Riichiro Kobana
RF power system of ILC by all solid-state amplifiers.

16:30 - 16:55 (JST)
Igor Syratchev
High Efficiency Klystrons development.

16:55 - 17:30 (JST)
Discussions

Basic Policy of Green ILC at Kitakami ILC candidate site

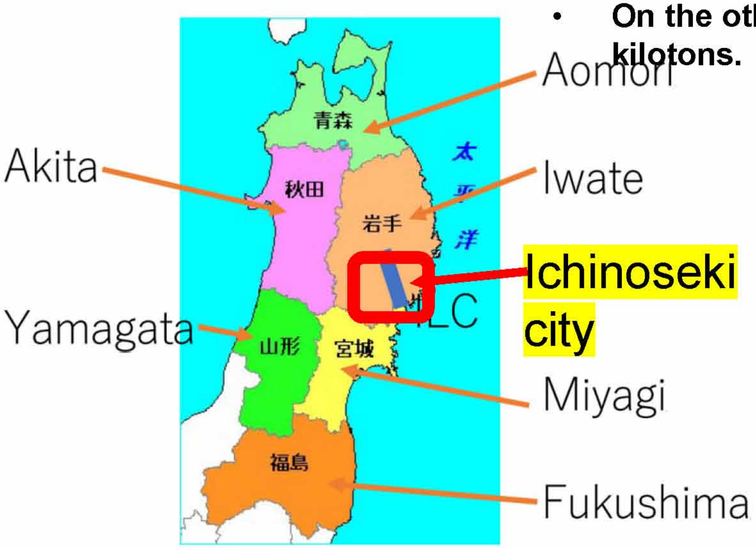
Masakazu Yoshioka (Iwate/Iwate Prefectural/Tohoku University)

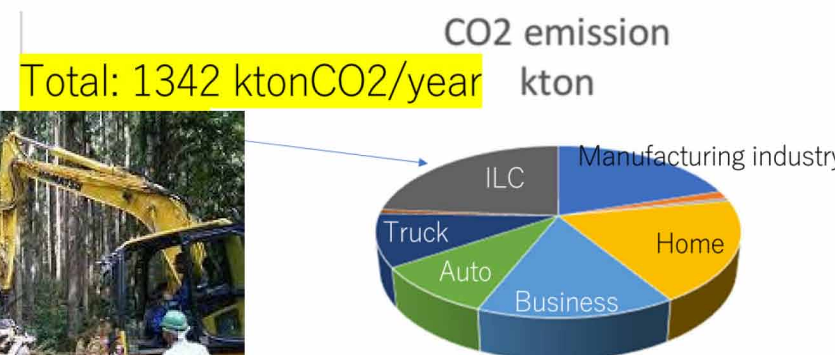


What I want to convey in this presentation

- The ILC is a facility that will produce many **important physical results**, but will also release **320 kilotons of CO2 per year.**
- There are three social responsibilities of a researcher
  1. ① Develop energy-saving technologies, and not only apply them to ILC, but also give them back to society.
  2. ② Cooperate in increasing the percentage of renewable energy in the region.
  3. ③ Forests are the only way to absorb CO2 in the region, and the ILC construction should be used as a trigger to contribute to the sound management of the local forestry industry.

- The annual CO2 emissions of Ichinoseki city are currently 1,022 kilotons of CO2, which will increase by 23.8% with the location of the ILC.
- On the other hand, the current amount of CO2 absorbed by the forest is only 300 kilotons.





Development of hydrofluoric acid-free EP treatment of Nb cavities at KEK

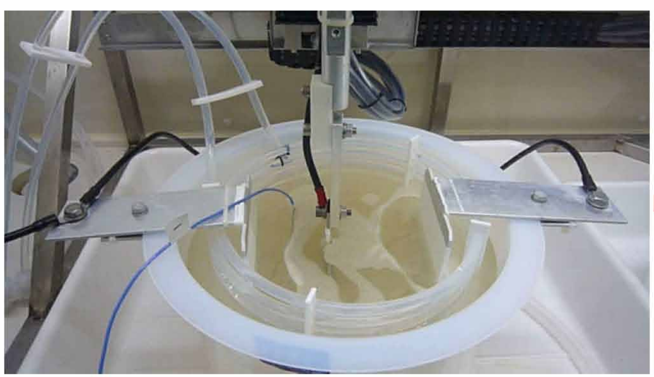
Takeyoshi Goto, Takayuki Saeki (KEK)

- Electrolytic polishing (EP) with HF electrolyte is an essential step in the surface treatment of Nb cavities.
- HF-EP is high cost due to the handling of HF electrolyte and the prevention of electrolyte leakage to the environment.
- We have been working on the establishment of the BP- and AC-EP methods as an HF-free EP. However, BP- and AC-EP methods were not energy efficient and took a long time to obtain flat Nb surface.
- Then, we just started to study the following new DC-EP methods.

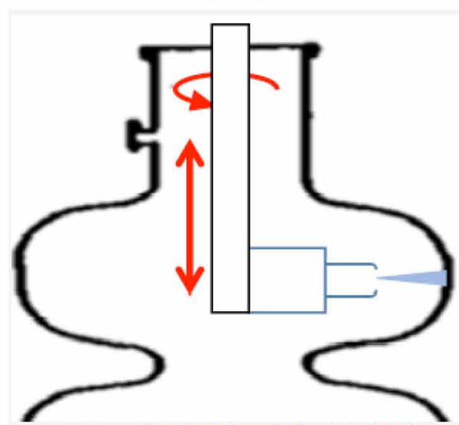
  1) DC-EP with new electrolytes (a)NaCl in ethylene glycol, b)alkali aqueous solution+EtOH)

  2) Plasma Jet EP for local grinding of Nb cavities

HF-EP



Jet



PEP

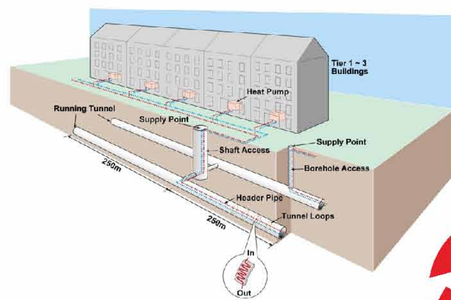
Thermal Heat Recovery – Green ILC

ARUP

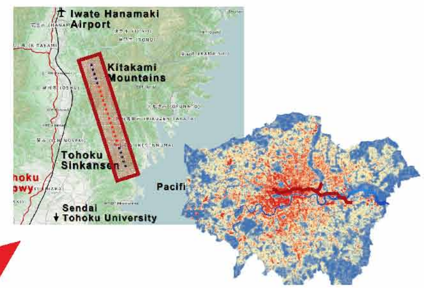
Summary

- Ground Source Heat Pump systems are well understood
- Thermal tunnel system design is well developed
- Tools & experiences can be applied to ILC
- ILC building requirements & heat distribution system needs further study
- Net Zero carbon and cost-effectiveness needs assessment
- This approach can be applied to ILC, CLIC and FCC

Proven Design & Technology

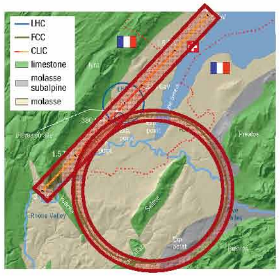


ILC - Heat demand and surface user mapping required



Green-ILC wider benefits: Energy transition, Net Zero and Circular Economy

Cross-applicability to CLIC / FCC



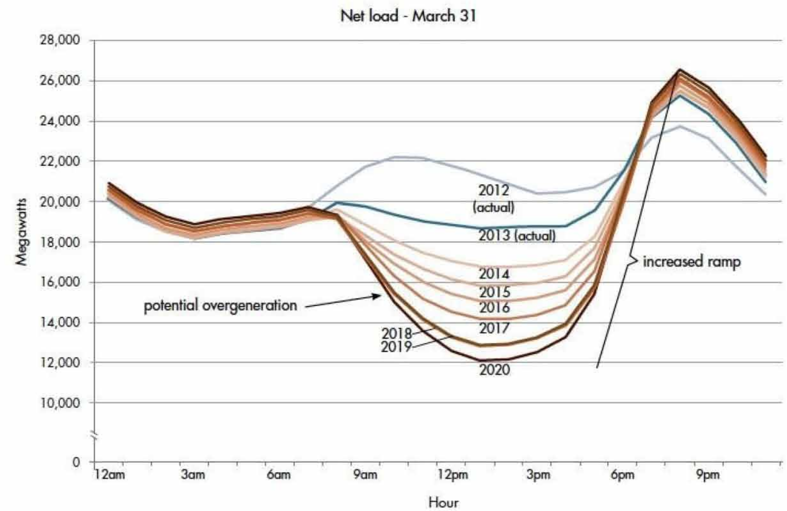
ilc international linear collider

CLIC

FUTURE CIRCULAR COLLIDER

ILC Sustainability Issues by Benno List (DESY)

	500 TDR	250-A	250-A' w/R&D	250 2.5 Hz	250 2.5 Hz w/R&D	Standby (RF off)
Rep-Rate / Hz	5	5	5	2.5	2.5	0
Bunches / Pulse	1312	1312	1312	1312	1312	0
Lumi / 10^{34}	1.8	1.35	1.35	0.68	0.68	0
Gradient / MV/m	31.5	31.5	35	31.5	35	
Q_0/1E10	1.0	1.0	1.6	1.0	1.6	
ML E-gain / GeV	470	220	220	220	220	
ML Power / MW	107.1	50.1	49.3	30.1	29.1	10.0
e- Src / MW	4.9	4.9	4.9	5.6	4.9	5.6
e+ Src / MW	9.3	9.3	9.3	10.2	9.3	10.2
DR / MW	14.2	14.2	14.2	14.2	14.2	14.2
RTML / MW	10.4	10.4	10.4	10.4	10.4	10.4
BDS / MW	12.4	9.3	9.3	9.3	9.3	9.3
Dumps / MW	1.2	1.2	1.2	1.2	1.2	1.2
IR / MW	5.8	5.8	5.8	5.8	5.8	5.8
Campus / MW	2.7	2.7	2.7	2.7	2.7	2.7
Gen. Margin/MW	5.1	3.3	3.2	2.7	2.6	2.1
Total	**173**	**111**	**110**	**91**	**90**	**70**



- ILC sustainability increases with use of regenerative energy sources
- RES availability varies with season and time of day
- ILC can modulate power consumption according to RES availability
  -> Possible approaches:
  - Modulate beam power
  - Buffer energy – use pre-chilled water and/or liquid helium as buffer?

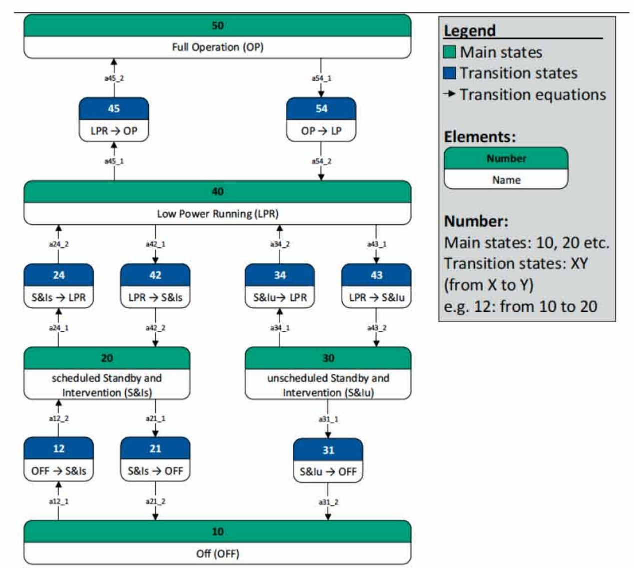


Figure 1-1: Schematic representation of the finite state machine

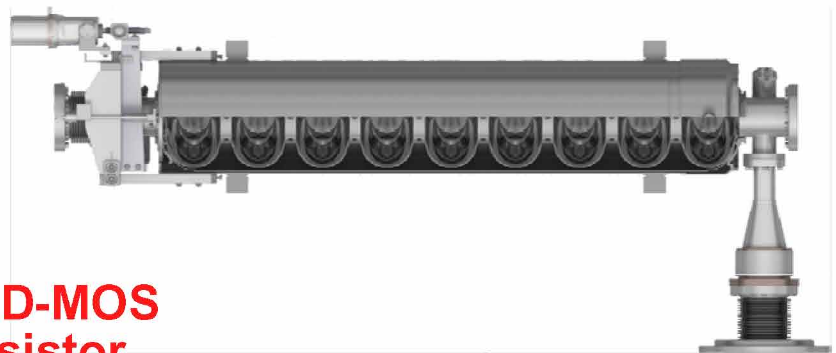
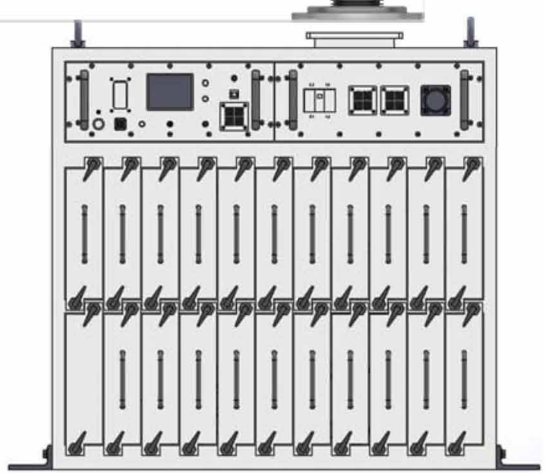
RF power system of ILC by all solid-state power amplifiers

by R. Kobana (R&K company)

You don't need any of the following below------------------------------
  Power for Heater, Power for Solenoid, Marx Generator, Waveguide Assy and complex components,
  Warm-up operation >>> Redundancy avoid Sudden Death.

No High Voltage is Less dangerous, High Mean Time between Failure (MTBF) and Short Mean Time to Repair (MTTR),

Quick Electrolytic capacitor PCB exchange, Affordable Cost for SSPA.

NXP LD-MOS
Transistor
For Long Pulse

R&K – SSPA
@1300MHz
＞200kW,
PW＞1.6m sec
@10pps max.

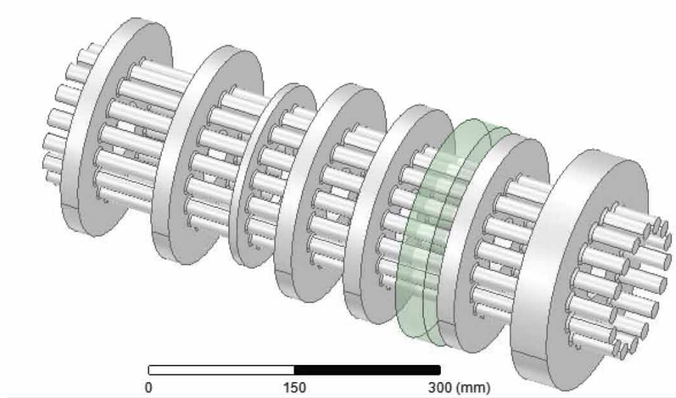
SSPA = Solid-State Power Amplifier

High Efficiency Klystrons Development by Igor Syratchev

Efficiency ~ 70%

High power L-band Multi Beam Klystrons (MBK). Commercial tubes.

Efficiency ~ 65%



High Efficiency 10 MW, 1.3 GHz, ILC TS MBK (scaled from TS CLIC MBK+2nd harmonic)

Efficiency ~ 85%