Report of EPPSU2019 at Granada

K. Yokoya

CLIC-ILC Positron Meeting, May 22, 2019

	13 (Mon)	14 (Tue)	15 (Wed)	16 (Thu)
AM 9:00-13:30	Plenary	Parallel BSM Strong Neutrino Instrument. &Computing	Parallel BSM Strong Neutrino Instrument. &Computing	Plenary Summaries
PM 15:00-19:30	Parallel EW Flavor DM Accelerator	Parallel EW Flavor DM Accelerator	Plenary Americas Asia etc. Acc. summary	Plenary Summaries Closeout

Relevant Talks: Plenary

- Monday
  - Implementation of the 2013 European Strategy Update (Fabiola Gianotti)
  - State of the art and challenges in accelerator technology – Past and present (Akira Yamamoto)
  - Future – Path to very high energies (Vladimir Shiltsev)
- Wednesday
  - Perspective on the European Strategy from the Americas (Young-Kee Kim)
  - Perspective on the European Strategy from Asia (Geoffrey Taylor)
  - Overview of National Inputs to the Strategy Update (Siegfried Bethke)
  - Accelerator Summary (Caterina Biscari, Lenny Rivkin)

Parallel Session: Accelerator Science

- Monday
  - LHC future (Lucio Rossi)
  - Future Circular Colliders (Michael Benedikt)
  - Future Linear Colliders (Steinar Stapnes)
  - Overview and Technological Challenges of proposed Higgs Factories (Daniel Schulte)
- Tuesday
  - Muon collider (Daniel Schulte)
  - Future Accelerator Based Neutrino Beams (Vladimir Shiltsev)
  - Energy efficiency of HEP infrastructures (Erk Jensen)
  - Current plasma acceleration projects (Edda Gschwendtner)
  - Challenges of plasma acceleration (Wim Leemans)
  - Physics beyond Colliders (Mike Lamont)

Implementation of the 2013 European Strategy Update (Fabiola Gianotti)

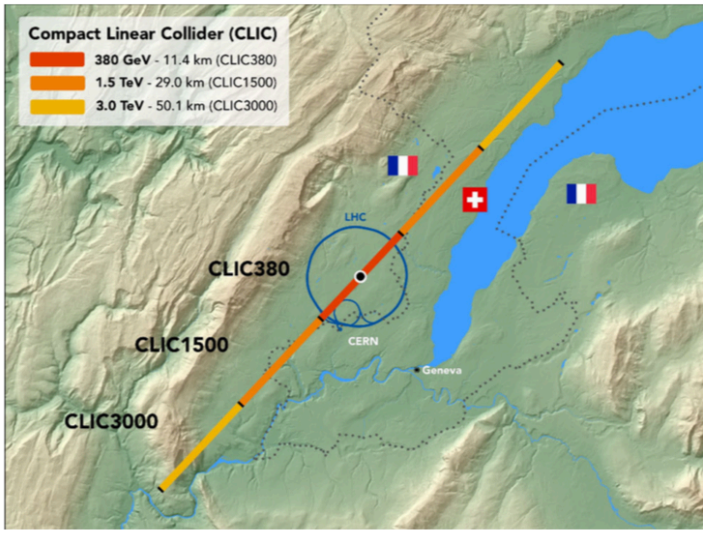
- Review the ESPP 2013 “recommendations” and the implementation
  a. b. General issues
  b. LHC, HL-LHC
  c. Design studies of large-scale projects (FCC, CLIC, AWAKE)
  d. ILC

     Latest news on ILC in Japan
     - MEXT’s view in regard to ILC project, Executive Summary, March 7 2019
     - Master Plan of SCJ (Scientific Council of Japan) to be officially released May 2020
  e. Neutrino

etc.

CLIC: multi-TeV e+e- linear collider

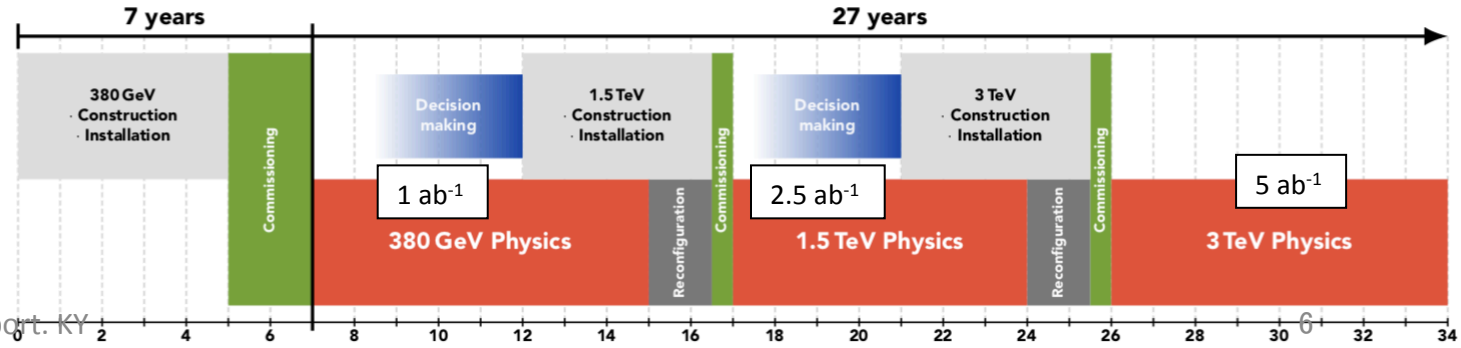
Parameter	Unit	Stage 1	Stage 2	Stage 3
√s	GeV	380	1500	3000
Tunnel length	km	11	29	50
Gradient	MV/m	72	72/100	72/100
Luminosity (above 99% of √s)	10^{34} cm^{-2}s^{-1}	1.5 0.9	3.7 1.4	5.9 2
Beam size at IP (σ_y/σ_x)	nm	2.9/149	1.5/60	1/40
Annual energy consumption CERN today: 1.2 TWh	TWh	0.8	1.7	2.8
Power consumption	MW	170	370	590
Construction cost	BCH	5.9	+5.1	+7.3



Since last ESPP: development of key technologies, progress towards demonstration of design parameters:

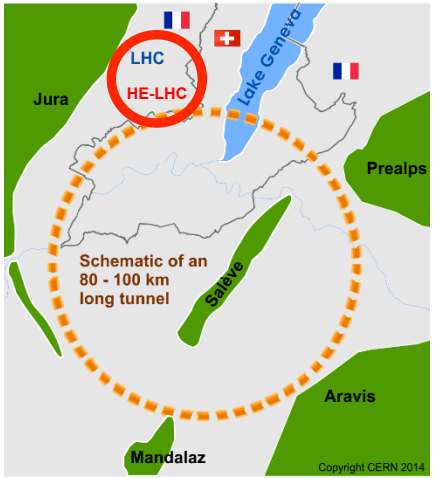
- ❑ 100 MV/m accelerating structures with low breakdown rate
- ❑ two-beam acceleration scheme demonstrated (CTF3) up to 145 MV/m
- ❑ R&D on alignment and vibration stabilization systems
- ❑ reduction of energy consumption (optimisation ongoing for 1.5 and 3 TeV) and cost

Technically:
construction could start in ~2026 (TDR in 2025)
→ start operation at √s=380 GeV in ~2035



FCC: Future Circular Collider

	√s	L /IP ($cm^{-2} s^{-1}$)	Int. L /IP(ab^{-1})	Comments
e^+e^- FCC-ee	~90 GeV Z 160 WW 240 H ~365 top	230 x10^{34} 28 8.5 1.5	75 ab^{-1} 5 2.5 0.8	2 experiments Total ~ 15 years of operation
pp FCC-hh	100 TeV	5 x 10^{34} 30	2.5 ab^{-1} 15	2+2 experiments Total ~ 25 years of operation
PbPb FCC-hh	$\sqrt{s_{NN}}$ = 39 TeV	3 x 10^{29}	65 nb^{-1}/run	1 run = 1 month operation
ep Fcc-eh	3.5 TeV	1.5 10^{34}	2 ab^{-1}	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
e-Pb Fcc-eh	$\sqrt{s_{eN}}$ = 2.2 TeV	0.5 10^{34}	1 fb^{-1}	60 GeV e- from ERL Concurrent operation with PbPb



Also studied: HE-LHC: √s=27 TeV using FCC-hh
16 T magnets in LHC tunnel; L~1.6x10^{35} → 15 ab^{-1} for 20 years operation

Parameter	Unit	FCC-ee	FCC-hh
Annual energy consumption CERN today: 1.2 TWh	TWh	1.9	4
Power consumption	MW	~300	550
Construction cost (tunnel included)	BCH	11.6	17 if after FCC-ee; otherwise 24

Preliminary, purely technical schedule for integrated programme (FCC-ee followed by FCC-hh), assuming green light to preparation work in 2020.

8 years preparation	10 years tunnel and FCC-ee construction	**15 years FCC-ee operation**	11 years preparation for FCC-hh and installation	**25 years FCC-hh operation pp/PbPb/eh**
2020-2028		**2038-2053**		**2064-2090**

High-priority large-scale scientific projects (3)

e) There is a strong scientific case for an electron-positron collider, …
The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome … *Europe looks forward to a proposal from Japan to discuss a possible participation.*

Since the last ESPP, in Europe and at CERN:

- ILC-related activities continued, in particular building upon synergies with CLIC:
  -- accelerators (beam dynamics, damping rings, beam delivery system, etc.)
  -- detector design and R&D (e.g. Linear Collider Detector group at CERN and many efforts in European countries).
- CERN-KEK cooperation agreements (e.g. accelerator studies at ATF KEK)

- CERN's help for civil engineering and geological studies of tunnel layout in Japan

- "Preparation plan for European participation in the ILC", describing possible scientific and industrial contributions of Europe to the ILC over a four-year preparatory phase, prepared by E-JADE (Europe-Japan Accelerator Development Exchange Programme, H2020)
  https://ilchome.web.cern.ch/sites/ilchome.web.cern.ch/files/ILC-EIPP.E-JADE.v2.12.20180703.pdf

Perspective on the European Strategy from the Americas (YongKee Kim)

- Surveyed the status of US, Canada and Latin America
- ILC-related matters:
  - P5 report (2014) based on Snowmass-on-Mississippi (2013)
  - It's implementation as of 2019
    - ILC: cost reduction R&D while waiting for decision from Japan
  - Next collider options (see next page)
    - Emphasized ILC

Next Options

YongKee Kim

ILC

Statement by American Linear Collider Committee (US+Canada)

ALCC stance vis-a-vis discussions concerning the International Linear Collider in the context of the European Strategy for Particle Physics (2020) ALCC, March 27, 2019

The Americas Linear Collider Committee supports the ICFA position confirming the international consensus that *"the highest priority for the next global machine is a 'Higgs Factory' capable of precision studies of the Higgs boson."* We remain convinced that the ILC best meets all of the requirements needed to probe detailed properties of the Higgs boson. The ILC has the potential for a future upgrade in energy, can sustain beam polarizations that increase its ability to do precision measurements, and is the most technically mature proposal for an electron-positron collider now available.

The recent statement by MEXT in Japan stated that further consideration by the Science Council of Japan and intergovernmental discussions are necessary before Japan would be in a position to make a bid to host the ILC. Unfortunately, this does not fit naturally into the timetable for finalizing the European Strategy recommendation. On the other hand, it appears that high-level interactions between the U.S. DOE and the Japanese principals, government and DIET, continue to be positive. We understand that the DOE remains interested in discussing with senior Japanese officials about ILC and the possibility of hosting it in Japan.

The ALCC is supportive of any electron-positron project that can distinguish the Standard Model from new physics models through precision measurements of the Higgs production and decay couplings. However, given the strengths of the ILC noted above and the recent progress in obtaining support for it within Japan, we urge that the European Strategy group support the completion of the process underway in Japan to decide on a bid to host the ILC.

CLIC

- CLIC and normal conducting high-gradient activities
- O(200) signatories for CDR
- Detector design and R&D
- Ongoing studies on physics potential

FCC-ee, ep, pp

- Deep expertise in accelerator technologies including high field magnets and SCRF
- O(500) engaged; O(100) co-authored European Strategy Documents
- Ongoing studies on physics potential and detector design
- Long and productive cooperation on joint projects in US and at CERN

CEPC

- Pre-CDR & CDR on arXiv with international contributions
- O(100) participated
- Detector design and R&D

Perspective on the European Strategy from Asia (Geoffrey Taylor)

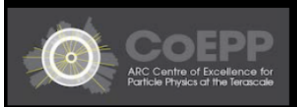
- Survey of all Asian activities on HEP
- With emphasis both on ILC and CEPC
- "No feasibility issue is known for any of the proposed higgs factories CLIC, ILC, FCC-ee and CEPC"
- e+e- Lumi Comparison
  - Apparently significant difference at the overlap region (~250GeV) quite a range of luminosities
  - (but) differences should not be taken too seriously at this stage!
- Described the recent ILC situation in Japan
  - March 2019:
    - MEXT presented its view to the LCB meeting in Tokyo
    - ILC Federation of Diet Members message of support
    - MEXT and KEK released their action plans.
    - ICFA made clear that other options being considered at EPPSU2019
  - SCJ Master Plan
    - SCJ represents all sciences but Not policy making nor budgetary authority
  - MEXT
    - ILC proposal submitted with recommendation letter from Barry Barish
    - Results of this evaluation will be publicist February 2020 (informally late 2019?)
  - Active political work continues
  - International WG initiated by KEK, MEXT
    - Update ILC-PIP
    - Will report to MEXT September 2019

Jeff Taylor

But can CERN/Europe Rely on Asia?

ILC:

- *It has taken a long time to get this far*
  - *(SLC), NLC, GLC, JLC ….*
- *But finally ILC - International Linear Collider*
  - ILC250 as first phase
  - Japan as Host, with strong participation by all regions
- *So why so hard?*
  - $8B pricetag with about half from Japan
    - Very big additional national investment in HEP
  - "Zero Sum Gamers" (non-HEP scientists) in Japan (… but remember the SSC)
  - Process, cultural differences: perhaps our expectation of the process unrealistic
- *Are we there yet?*
  - No! but Very Positive Signals
  - Still hoping for international negotiations to start soon, construction from 2023-24



Geoffrey Taylor "Perspective on the European Strategy from Asia", EPPSU2019, Granada 32

Asian Perspective

- CepC represents additional resources to our field.
  - *~$6B additional resource is very significant.*
- Possible to have CepC operational by early to mid-2030?
  - *Considerably ahead of FCC(ee)*
- China wishes to achieve international status with large scientific projects
  - *We should try very hard to gain from this strategy.*
- Circular and Linear Solution to (initial) higgs factory have different development strengths
  - *Complementary solutions*

Geoffrey

But can CERN/Europe Rely on Asia?

- CepC
  - *Approval process will be internal but needs International (moral) support*
    - ICFA support for potential international facility
- But clear advantages
  - *Considerable hosting cost moved to China*
  - *Additional staff and students for the field*
- China will depend upon international involvement
  - *IAC for CepC/SppC has been operating for several years*

Overview of National Inputs to the Strategy Update (Siegfried Bethke)

- Summarized the inputs to European Strategy Update
- Nation-wise “score” (next page)
  - highest priority for a (general) e+e- collider as next big project : total score of 13,67 out of 15 max.
  - score of 3,00 for upgradeability to include ttbar and/or explicitly for FCC-ee
  - score of 6,83 for upgradeability to include HH or ttH and/or explicitly for linear colliders (i.e. ILC+ or CLIC)

summary of national priorities and interests:

country	item #	e+e- e-w,H,.. (ILC, ...)	e+e- incl. ttbar (FCC-ee)	e+e- incl. HH (ILC+,CLIC)	hh beyond LHC	hh he-LHC	hh FCC	eh	accel. R&D	R&D magnets FCC,he-LHC	R&D novel PWA,μ+μ-	non-accelerator (DM,ndbd)	neutrino physics	intensity frontier	nuclear (FAIR,EIC...)	astro-particle
A	108	1			3				2			√			√	√
B	122	1														
CH	142	1	1		3		3		2	2	3		√	√	√	√
CZ	88	3		3	2	2	2		1	1	1		√		4	
D	33	1		1	3	3	3		2	2	2	4	√	√	√	√
DK	61	3	3		3		3		2	2	2	1	√	√	√	√
E	31	1	3	1	3	3	3		2	2	4		√		√	√
F	15,116,155	1	√	√	3		3	√	2	2	√	√	√	√	√	√
FIN	55	1		1									√		√	√
I	26,138	1	1		3		3		2	2	2	√	√	√		√
IL	34	√			√							√	√	√		
N	43	1		1					3		3	√			√	√
NL	166	1	3	2	3		3		2	2	3	√	√	√		√
PL	125	1	√	√					2							
RO	73												√	√		
S	127	1		1					2	2	√	√	√	3		√
SLO	78															
UK	134,144	1		1	2		2	2	3	3	√	√	√		√	
total score:		13,67	3	6,83	3,67	1,17	3,33	0,5	6,67	5,33	3,75					

1...4: priority 1 to priority 4;
√: mentioned without (clear) assignment of priority
total score: =Σ(1/priority) where given; √ not counted

S. Bethke

non-member coutries

country	item #	e+e- e-w,H,.. (ILC, ...)	e+e- incl. ttbar (FCC-ee)	e+e- incl. HH (ILC+,CLIC)	hh beyond LHC	hh he-LHC	hh FCC	eh	accel. R&D	R&D magnets FCC,he-LHC	R&D novel PWA,μ+μ-	non-accelerator (DM,ndbd)	neutrino physics	intensity frontier	nuclear (FAIR,EIC,...)	astro-particle
CDN	157	√	√	√	√	√	√					√	√			
J	63	1							4			3	2			
RUS	40								√			√	√	√	√	√
USA	149;150	√	√	√	√	√	√		√	√	√	√	√	√		√
total score:																

A comment by audience:
This is just a snapshot before March (MEXT/LCB)

Accelerator Technologies – Past and Present (Akira Yamamoto)

- SRF and SC magnet technology past and present
- Magnet: next page
  - HL-LHC　5.5m 11T dipole initial test fine
  - NbTi → Nb_3Sn, MgB_2
  - 14-16 Tesla magnet for mass production is very far
    - Mechanical Constrain
    - Cost (compared with NbTi , Nb3Sn x5-10, HTS x30-100)
- Lucio Rossi confirms this view (after next)

A. Yamamoto

Personal Prospect (2/2)

- Nb_3Sn superconducting magnet technology for hadron colliders, still requires **step-by-step** development to reach **14, 15, and 16 T**.
- It would require the following **time-line** (in my personal view):
  - **Nb_3Sn, 12~14 T:** 5~10 years for short-model R&D, and the following 5~10 years for prototype/ pre-series with industry. It will result in **10 – 20 yrs** for the construction to start,
  - **Nb_3Sn, 14~16 T:** 10-15 years for short-model R&D, and the following 10 ~ 15 years for protype/ pre-series with industry. It will result in **20 – 30 yrs** for the construction to start, (consistently to the FCC-integral time line).
  - **NbTi , 8~9 T:** proven by LHC and **Nb_3Sn, 10 ~ 11 T** being demonstrated. It may be feasible for the construction to begin in > ~ 5 years.
- **Continuing R&D effort** for high-field magnet, present to future, should be critically **important**, to realize highest energy frontier hadron accelerators in future.

Conclusions

L. Rossi

- HiLumi will allow LHC to continue to produce top class HEP till 2035-2040; it is technology drivers and buys time for next project
- A HE-LHC of 27 TeV (16 T dipoles) is probably for 2050…
- **A new HEP hadron collider to start in 2040 can be – with realism – a LHC1.5 @ 21 TeV, based on 12 T magnets of HiLumi technology and SC.** If treated as un upgrade (and not as a full new project, may save time&money (cryogenics and T.I. …)
- The LHeC machine may be a mid-size project to fill the gap to a very large project (like FCC-hh) **or a very appealing complement** in case of:
  - LHC used as Injector for FCC-hh (today baseline of FCC study)
  - LHC1.5 at 10.5 TeV/beam (from 2040)
  - HE-LHC at 13.5 TeV/beam (from 2050)

Future – Path to very high energies (Vladimir Shiltsev)

- Circular (lepton, hadron), Linear, μ+μ- , and plasma
- Compared by 3 factors: next page
  1. Technology Readiness
  2. Energy Efficiency
  3. Cost
- For Plasma colliders, the key issues to study are:
  - acceleration of positrons
  - Staging efficiency
  - emittance control vs scatter
  - beamstrahlung
  - HP lasers / HP operation
  - power efficiency

F1: Technology Readiness

Green - TDR

Yellow - CDR

Red - R&D

F2: Energy Efficiency

Green : 100-200 MW

Yellow : 200-400 MW

Red : > 400 MW

F3: Cost

Green : < LHC

Yellow : 1-2 x LHC

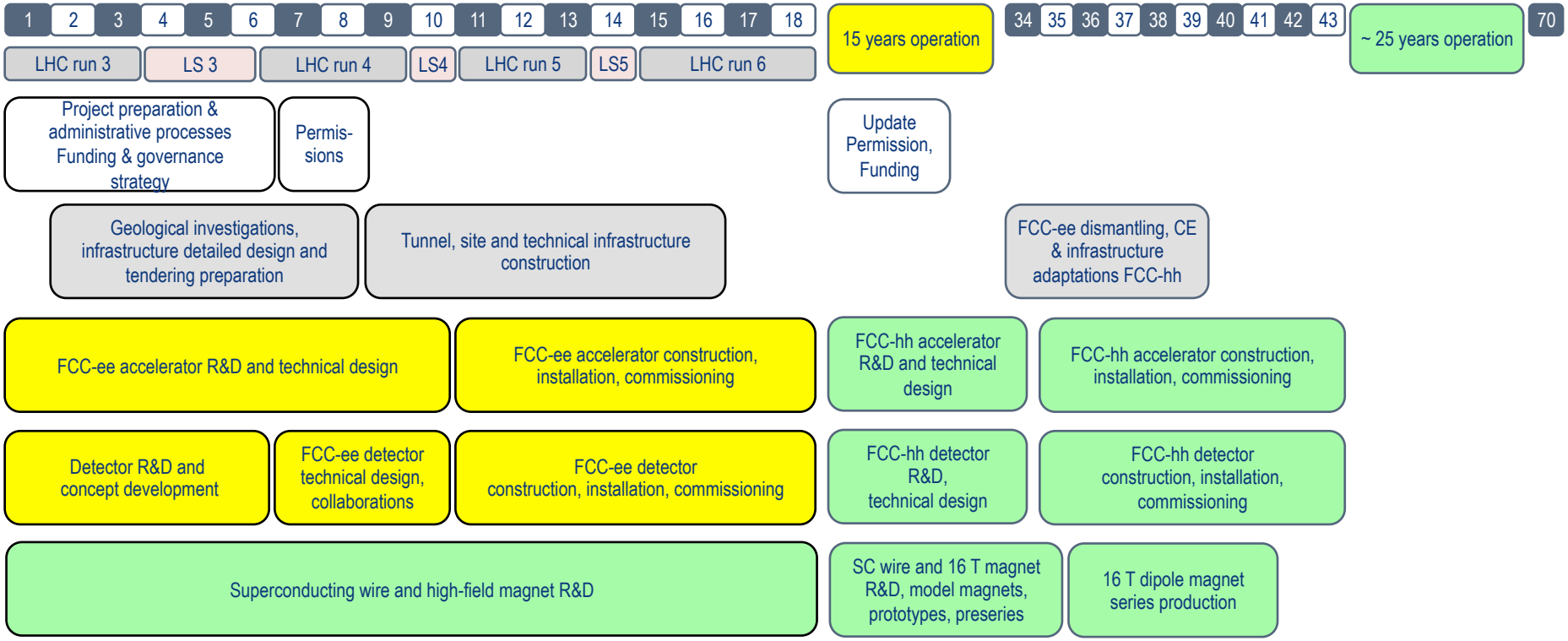
Red : > 2x LHC

Higgs Factories	Readiness	Power-Eff.	Cost
ee Linear *250 GeV*			
ee Rings *240GeV/tt*			
μμ Collider *125 GeV*			*
Highest Energy			
ee Linear *1-3TeV*			
pp Rings *HE-LHC*			
FCC-hh/SppC			
μμ Coll. *3-14 TeV*			*

Future Circular Colliders (M. Benedikt)

- Included SuperKEKB, Super Tau-Charm (BINP, HIEPA), electron-ion (BNL-eRHIC, JLAB-JLEIC), HL-LHC, FCCee/FCChh/CEPC/SppC/, and electron-hadron (FCCeh, CEPC-SppC)
- In the Summary
  - Circular lepton colliders: All key technologies and concepts are available
  - Future hadron colliders are based on high-field Nb3Sn and/or HTS magnets, whose development represents a challenging R&D requiring long-term planning and funding.
  - Lepton (FCCee, FCCeh, CEPC) to Hadron (FCChh, SppC) is a very powerful and attractive long-term options for HEP

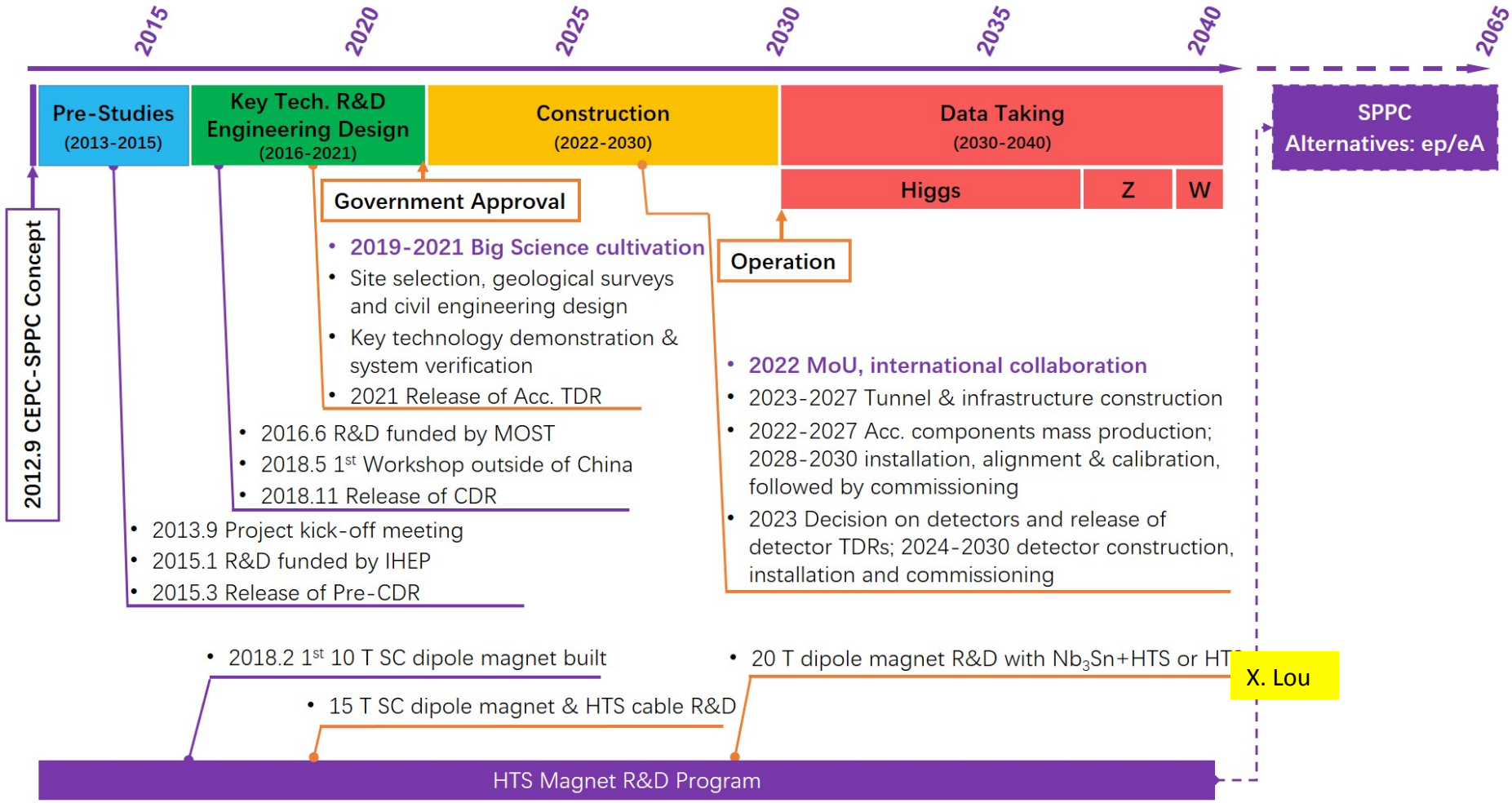
FCC integrated project technical schedule



FCC integrated project plan is fully integrated with HL-LHC exploitation and provides for seamless further continuation of HEP in Europe.

CEPC-SppC timeline

CEPC Project Timeline



Linear Colliders (S, Stapnes)

Summary

- CLIC and ILC have both submitted very complete proposals for implementation of a LC being ready for start up ~2035
  - One is focused on being hosted by and at CERN, the other hosted in Japan
  - In both cases promoted and set up as international projects

- The main accelerator technologies have been demonstrated
- The cost and implementation time are similar to LHC
- The physics case is broad and profound, and being further developed
- The detector concept and detector technologies R&D are advanced

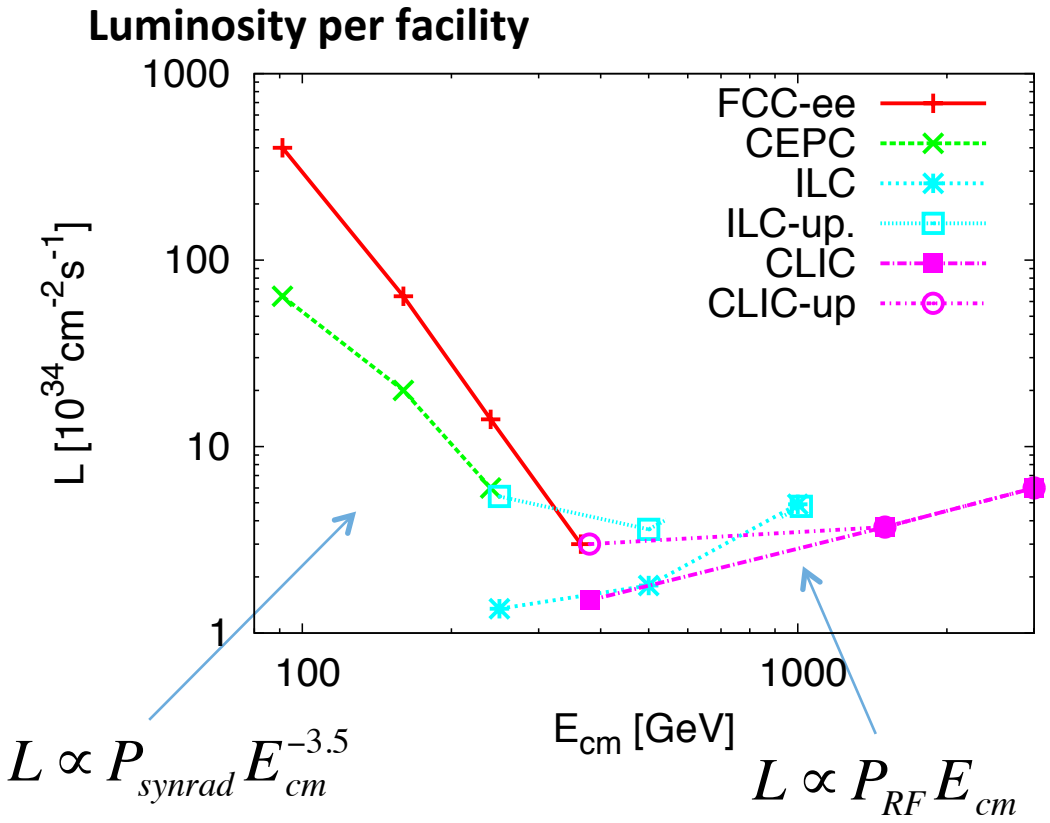
- Implementing a LC now provides a very attractive, implementable way forward, with a good match between scientific progress and further technology development – not only for LC technologies ..

Higgs Factories (D. Schulte)

- Comparison of
  - Lepton Colliders
    - LC: ILC, CLIC
    - CC: FCCee, CEPC
  - Hadron Colliders
    - LHC, HL-LHC, HE-LHC, FCChh, SppC
  - Lepton-hadron
    - LHeC,FCCeh
  - Far future : muon, plasma
  - “Low-field” magnet in FCC tunnel

Luminosity

D. Schulte



Energy dependence:

At low energies circular colliders trump
- Reduction at high energy due to synchrotron radiation

At high energies linear colliders excel
- Luminosity per beam power roughly constant

Note: The typical higgs factory energies are close to the cross over in luminosity
Linear collider have polarised beams (80% e^-, ILC also 30% e^+)
The picture is much clearer at lower or higher energies

Luminosity Challenge

D. Schulte

Luminosity cannot be fully demonstrated before the project implementation

- Luminosity is a feature of the facility not the individual technologies
- Have to rely on experiences, theory and simulations

FCC-ee and CEPC are based on experience from LEP, DAPHNE, KEKB, PEP II, superKEKB, …

- Gives confidence that we understand performance challenges
- New beam physics occurs in the designs,
  - e.g. beamstrahlung is unique feature of FCC-ee and CEPC
    - Identified and anticipated in the design, should be able to trust simulations
- The technologies required are improved versions of those from other facilities

Linear colliders are based on experiences from SLC, FELs, light sources, …

- Gives confidence that we understand the performance challenges
- Gives us confidence that we can do better than SLC
- Still performance goal more ambitious, e.g. beam size of nm scale
  - Creates additional challenges and requires additional technologies, e.g. stabilisation
- A part of the technologies are improved versions of those from other facilities
- Some had to be purpose-developed for linear colliders

All studies prioritised their work because of limited resources

- Depending on your preference you will see holes in any of them that you find are unacceptable
- Or you will be convinced that this very issue is a mere detail …

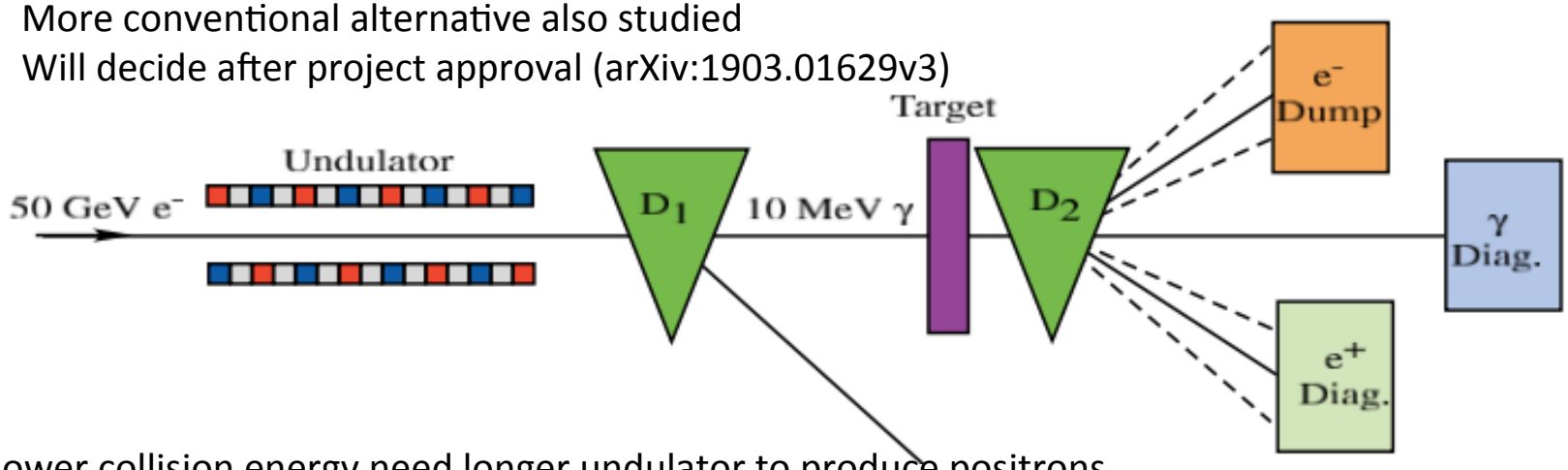
Polarisation

D. Schulte

Electron polarisation only in linear colliders
- 80%, SLC had 78% under difficult conditions
- Non-colliding bunches use transverse polarisation for energy measurements in FCC-ee

Positron polarisation of 30% in ILC
- not foreseen in CLIC, since not demanded by the physics study

ILC considers undulator-based positron source
- More conventional alternative also studied
- Will decide after project approval (arXiv:1903.01629v3)

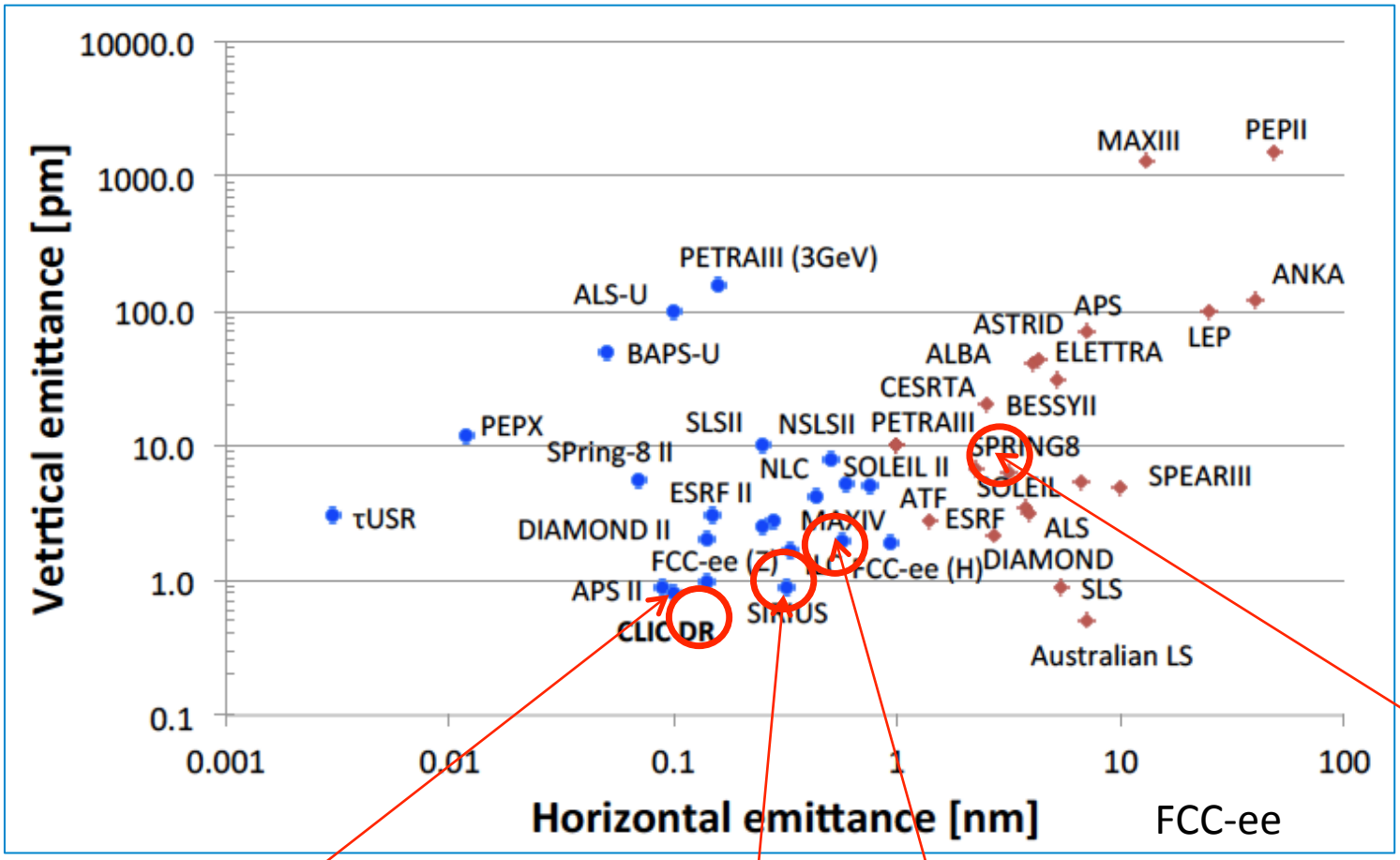


At lower collision energy need longer undulator to produce positrons
- More heat on the target
- More tails mitigated by thinner target
- Slightly reduced positron yield (1.36, goal has been 1.5), i.e. reduced margin
- Worst score in review: “Calculation study only. But no show stopper seen yet.“
- Conventional source should be fine
- Risk for luminosuty upgrades

It appears OK
But if it is essential
it has to be checked

Low Emittance Generation

D. Schulte



Small emittance is generated in collider ring for FCC-ee

Small emittance is generated in damping ring for linear colliders

Energy efficiency of HEP infrastructures (Erk Jensen)

- Quote from www.iea.org:

  Energy efficiency is one of the cornerstones of any strategy to guarantee sustainable and inclusive economic growth. It remains one of the most cost-effective ways to enhance security of energy supply, to boost competitiveness and welfare, and to reduce the environmental footprint of the energy system. Not only can the growth of carbon emissions be tempered by the more efficient use of energy but energy efficiency can also improve local pollution and contribute to reducing the millions of air-pollution related premature deaths each year, and keep consumers energy bills in check.

  UN's "Sustainable Development Goal 7.3" is the measurable improvement (decrease) of global energy density, defined as primary energy supply per GDP.

- Particularly relevant since large colliders are quite gourmand for energy
- This is our duty (not option) to society, but also a necessity for acceptance!

Examples of improved efficiency of technical systems

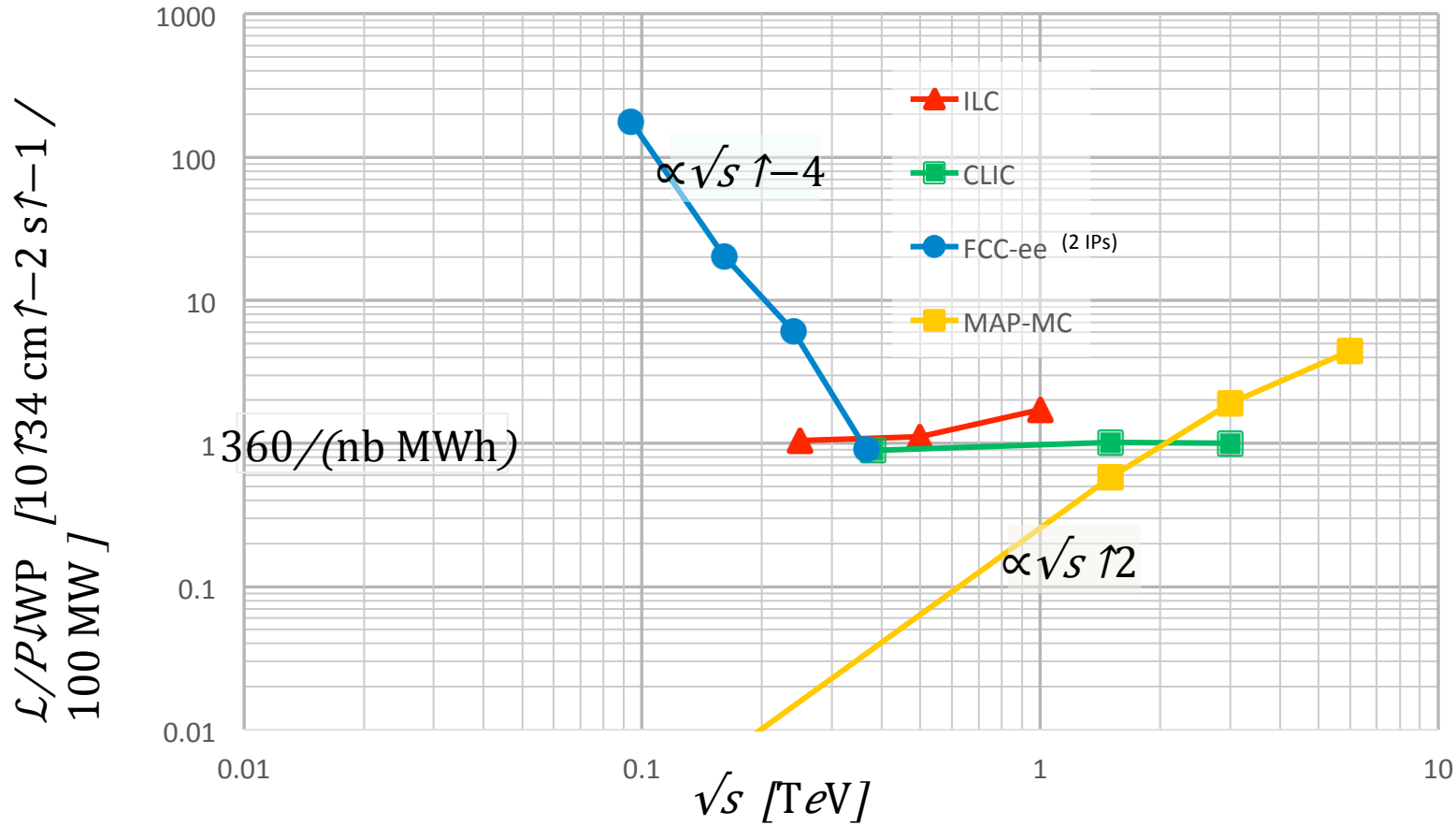
- Heat recovery
  - Thermal energy from LHC P8 at CERN is injected in a local “anergie” loop to nearby village
- Magnets
  - Superconducting
  - pulsed
  - permanent magnet (CLIC adjustable quadrupole, etc.)
- RF power generation
  - Hi efficiency klystron (aimed at 80% in FCCee)
- Cryogenics
  - NeHe (Nelium) refrigeration cycle (300K→40K)
- Beam energy recovery
  - Energy recovery linac (LHeC, FCCeh, etc)
- High-Performance Computing

Figure of merit for proposed lepton colliders

E. Jensen

Disclaimers:

1. This is not the only possible figure of merit
2. The presented numbers have different levels of confidence/optimism; they are still subject to optimisations



My Understandings/Impressions

- It's time for lepton colliders. Hadron collider is too far.
- Good support by the community to LC
- About Linear/Circular
  - The luminosity difference for E_{CM}<250GeV was not too much emphasized
    - Though, heard later that we must think about Z-pole
  - Energy extendibility is quite important
  - Comments in the final discussion time (not mine)
    - Asian participation (ILC/CEPC) is welcome for diversity of the community
    - Start digging 100km tunnel now is too risky. Must wait for technology.
    - Continuity ee→hh is important
- It may be very hard for the European Strategy to decide now something on large-scale colliders.
  - Need more info on ILC/CEPC