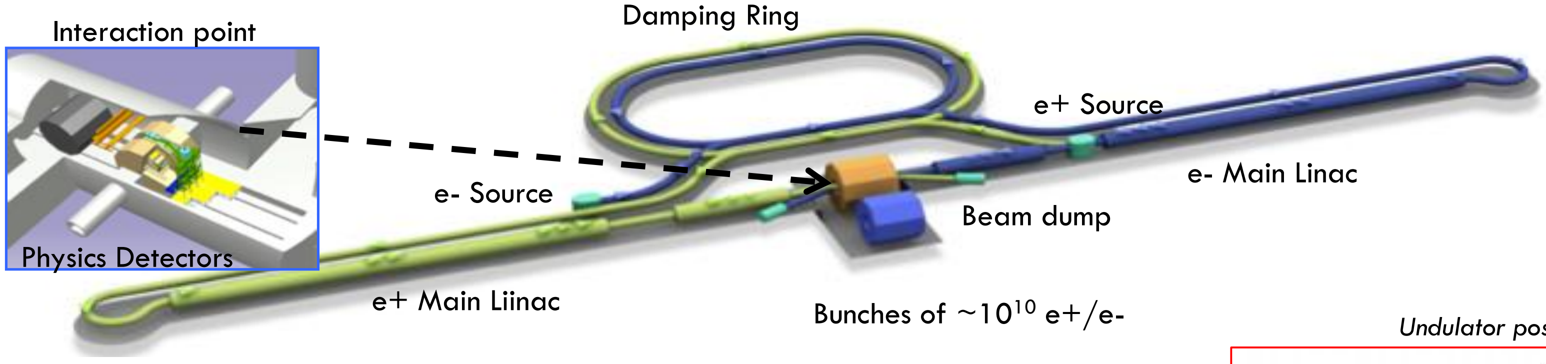
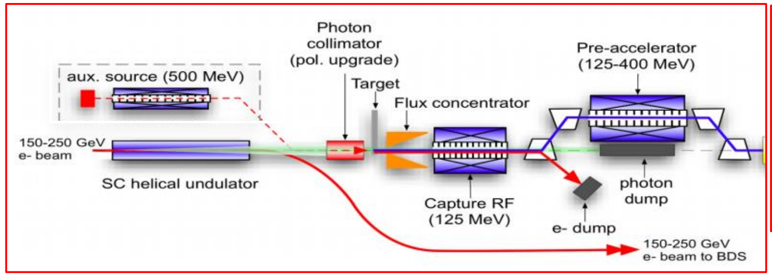
The ILC250 accelerator facility

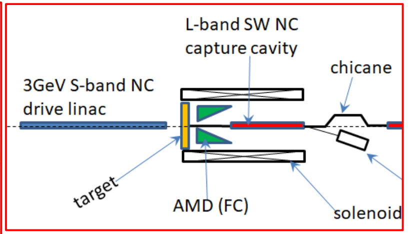


Item	Parameters
C.M. Energy	250 GeV
Length	20km
Luminosity	1.35 x10^{34} $cm^{-2}s^{-1}$
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	7.7 nm@250GeV
SRF Cavity G. Q_0	31.5 MV/m (35 MV/m) Q_0 = 1x10 ^{10}

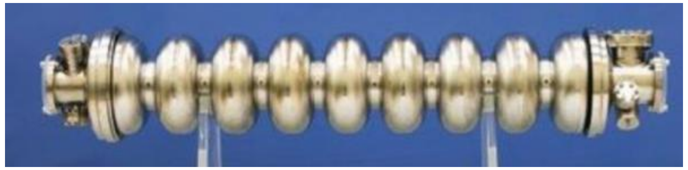
- Creating particles — Sources
  - polarized elections/positrons
- High quality beam. — Damping ring
  - low emittance beams
- Acceleration — Main linac
  - superconducting radio frequency (SRF)
- Collide them — Final focus
  - nano-meter beams
- Go to — Beam dumps

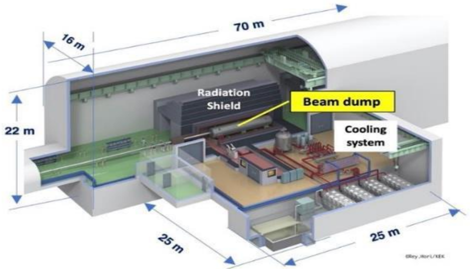
Undulator positron source





Electron driven positron source





IDT organization

ICFA

ILC International Development Team

Executive Board

Americas Liaison	Andrew Lankford (UC Irvine)
Working Group 2 Chair	Shinichiro Michizono (KEK)
Working Group 3 Chair	Jenny List (DESY)
Executive Board Chair and Working Group 1 Chair	Tatsuya Nakada (EPFL)
KEK Liaison	Yasuhiro Okada (KEK)
Europe Liaison	Steinar Stapnes (CERN)
Asia-Pacific Liaison	Geoffrey Taylor (U. Melbourne)

Working Group 1
Pre-Lab Setup

Working Group 2
Accelerator

Working Group 3
Physics & Detectors

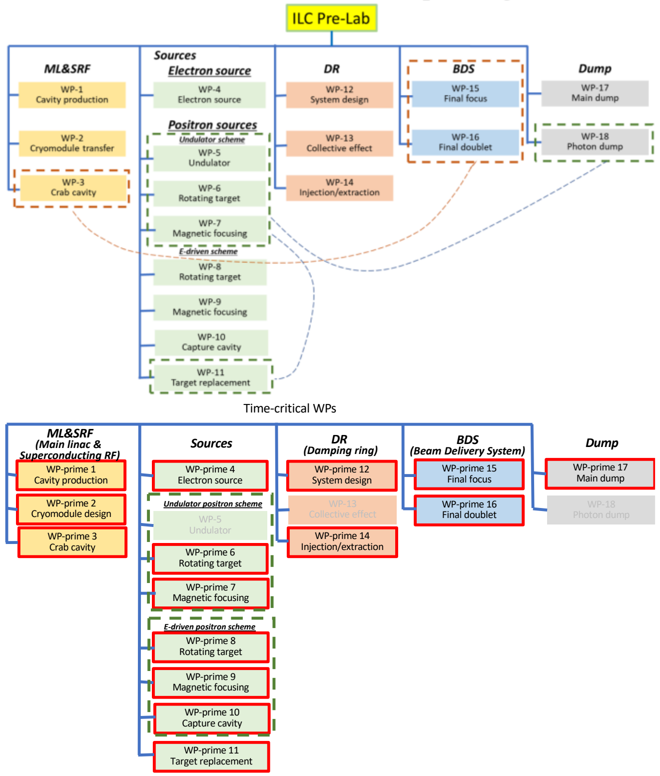
Recent developments – I

The initial planning for the ILC preparation phase (2022-2026) – see upper figure - leading to a complete Engineering Design as needed for construction was reviewed by a MEXT appointed committee and deemed premature, referring to that the prospects for an international sharing for ILC are not clear.

However increased support for technical developments was indicated as possible.

A result a subset of the technical activities of the full preparation phase programme have been identified as critical. We call this an **ILC Technology Network (ITN) -** see lower figure, and this presentation (briefly) summarized this work, with a European focus.

The goal is that in parallel with starting with these technical activities international discussion can proceed and open for addressing the Engineering Design in full, such that the changes in the ILC timescale are not too large overall.



Reducing the number of WPs
and reducing the size of the WPs:
From 60 M$ to 15 M$
From 360 FTEy to 112 FTEy

P1 P2 P3 P4 C1 C2 C3 C4 C5 C6 …

Previous: Pre-lab ~4 years | Construction ~10 year

Y1 Y2 Y3/P1? Y4/P2? C1 C2 C3 C4 C5 C6 …

Now: Time critical WPs ~4 years
Pre-lab 3~4 years | Construction ~10 year

Recent developments – II

Indeed, further negotiation with MEXT during 2022 have been productive and a budget request has been submitted to the Ministry of Finance for the ITN work (announces as):

MEXT submitted its budget request for 2023 Japanese Fiscal Year
*to the Ministry of Finance, which includes the KEK funding available for the ILC R&D, 9.7 Oku-yen**.
This is a factor of two increase compared to the 2022 budget level.
The next step is the budget plan of the Ministry of Finance to the Diet, which should be released in December.

If this budget request is successful it will enable, with international support, the ITN work. The request is for one year, but the funding can normally be expected to continue in the following years. The various ITN activities presented are foreseen to take 2-4 years.

*This request also includes local infrastructure investments at KEK, e.g for SRC and ATF, in addition to the funds directly needed for the ITN programme mentioned on previous slide

IDT-WG2

The initial plan for the ILC preparation phase activities, and the subset currently emphasised in the ITN have been worked out by the IDT-WG2.

The WG2 group has important European involvement.

IDT WG2
Shin Michizono (Chair)
Benno List (Deputy)

ML&SRF group

Yasuchika Yamamoto	***KEK***
Sergey Belomestnykh	**FNAL**
Nuria Catalan	CERN
Enrico Cenni	**CEA**
Dimitri Delikaris	CERN
Luis Garcia Tabares	CIEMAT
Rongli Geng	ORNL
Hitoshi Hayano	KEK
Bob Laxdal	Triumf
Matthias Liepe	Cornell
Peter McIntosh	**STFC**
Laura Monaco	**INFN Milano**
Olivier Napoly	CEA
Sam Posen	FNAL
Robert Rimmer	JLAB
Roger Ruber	JLAB
Marc C. Ross	SLAC
Kensei Umemori	KEK
Hans Weise	DESY
Akira Yamamoto	**KEK**

DR/BDS/Dump group

Toshiyuki Okugi	***KEK***
Karsten Buesser	DESY
Philip Burrows	**U. Oxford**
Angeles Faus-Golfe	**LAL**
Andrea Latina	CERN
Kiyoshi Kubo	KEK
Jenny List	DESY
Thomas Markiewicz	SLAC
Brett Parker	BNL
Ivan Podadera	CIEMAT
David L. Rubin	**Cornell**
Nikolay Solyak	FNAL
Nobuhiro Terunuma	**KEK**
Glen White	**SLAC**
Kaoru Yokoya	KEK
Mikhail Zobov	INFN LNF

Dump sub-group

Nobuhiro Terunuma	***KEK***
Toshiyuki Okugi	KEK

Crab sub-group

Peter McIntosh	***STFC***
Yasuchika Yamamoto	KEK

Sources group

Kaoru Yokoya	***KEK***
m Clarke	STFC
Steffen Doebert	CERN
Joe Grames	**JLAB**
Hitoshi Hayano	KEK
Masao Kuriki	**U. Hiroshima**
Benno List	DESY
Jenny List	DESY
Gudrid Moortgat-Pick	**U. Hamburg**
Tsunehiko Omori	KEK
Sabine Riemann	DESY
Peter Sievers	CERN -retired
Tohru Takahashi	U. Hiroshima

Civil engineering group

Nobuhiro Terunuma	***KEK***
John Andrew Osborne	CERN
Tomoyuki Sanuki	U. Tohoku

WG3 Organisation and mandates

Chair: Jenny List (DESY/CERN) with Deputies: Roman Pöschl (IJCLab), Michael Peskin (SLAC), Daniel Jeans (KEK), Jinlong Zhang (ANL)

Coordinator and Deputy coordinator(s)

Steering Group

Subgroup conveners, Coordinator and Deputy Coordinator(s)

Andy White (UT Arlington), Ties Behnke (DESY), Yuanning Gao (Peking), Frank Simon (MPP), Jim Brau (Oregon), Keisuke Fujii (KEK), Phil Burrows (Oxford), Francesco Forti (INFN), Filip Zarnecki (Warsaw), Patty McBride (Fermilab), Mihoko Nojiri (KEK), Timothy Nelson (SLAC), Kajari Mazumdar (Mumbai), Phillip Urquijo (Melbourne), Dmitri Denisov (Brookhaven), Hitoshi Murayama (Berkley/Tokyo), Claude Vallee (Marseille), Shoji Asai (Tokyo)

Speaker's bureau

Kiyotomo Kawagoe (Kyushu),
Carsten Hensel (Rio de Janeiro),
Ivanka Božović Jelisavčić (Belgrade)

Interface with machine

Coordinate the interactions between the accelerator and facility infrastructure planning and the needs of the experiments

Karsten Buesser (DESY), Yasuhiro Sugimoto (KEK), Roman Poeschl (IJCLab), Tom Markiewicz (SLAC)

Detector and technology R&D

Provide a forum for discussion and coordination of the detector and technology R&D for the future experimental programme

Marcel Vos (Valencia), Katja Krueger (DESY) Jinlong Zhang (ANL), Shinya Narita (Iwate)

Software and computing

Promote and provide coordination of the software development and computing planning

Frank Gaede (DESY), Jan Strube (PNNL) Daniel Jeans (KEK)

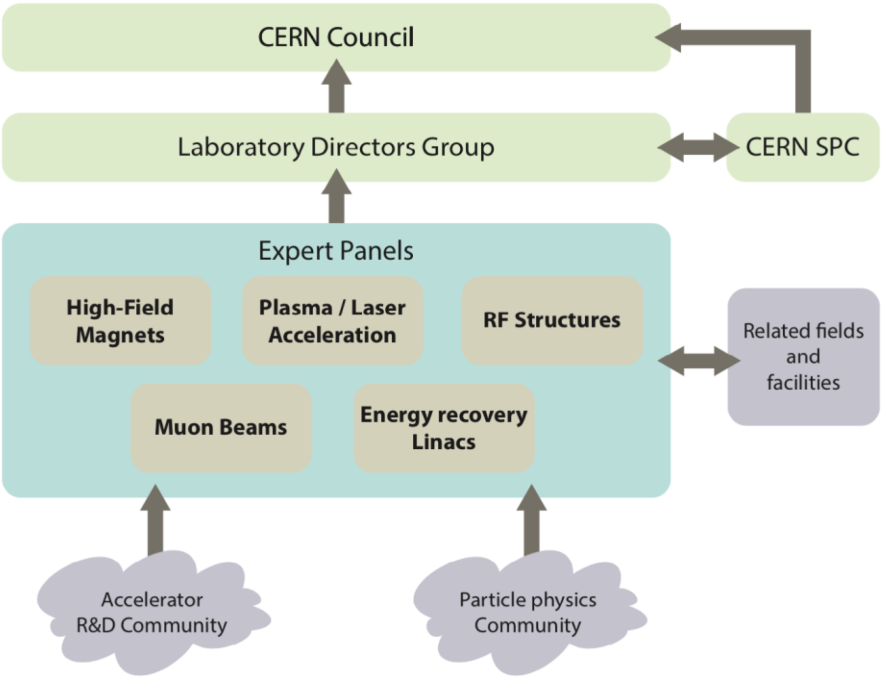
Physics potential and opportunity

Encourage and develop ideas for exploiting the physics potential of the ILC collider and by use of the beams available for more specialised experiments

Michael Peskin (SLAC), Junping Tian (Tokyo) Aidan Robson (Glasgow)

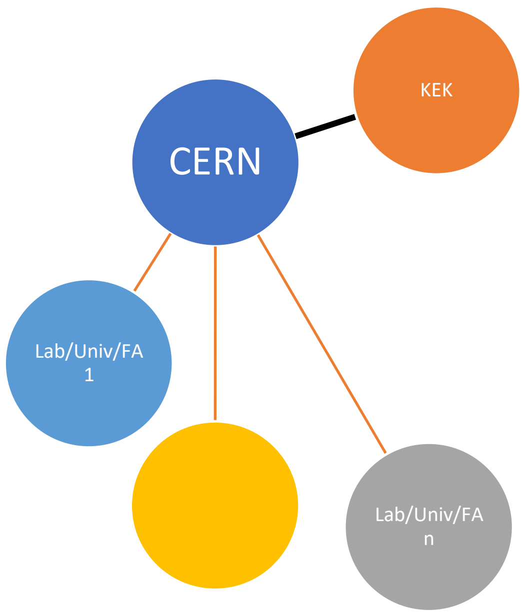
European process and LDG interactions

- Mails sent to many of you during the summer to update you on the points mentioned in the slides above, called “Recent developments”.
- A model for European participation also discussed over the summer, in particular in a series of ILC Europe meetings (covering all aspects of European ILC activities): LINK. The operation model has also been discussed with KEK and in the ILC IDT.
- In parallel discussions took place between Fabiola Gianotti, Masanori Yamauchi, Tatsuya Nakada and myself on a contribution to the material cost from KEK, to enable the start of the European programme and the following activities.
- Meeting with Fabiola Gianotti and Mike Lamont end of August concerning the European planning and CERN’s role, concluded that a report in the LDG meetings would be useful (hence the presentation today).
- Reminder: ITN is not only relevant for ILC, it is also – in shorter term - relevant for our R&D planning and for many European labs and industries technology expertise and interests (and also other projects related the technologies pursued)



European Organisation of such programme

- CERN plays coordinating role
- KEK contribution to the material cost is essential
- Main contract for flow of funds between CERN and KEK*
  - CERN-KEK ILC IDT agreement already extended by 2 years
  - Amendments/modifications would be needed for ITN
- Subsequent contracts* – similar to what is done for other studies for future colliders – between CERN and European Labs in the cases where money flow is needed (limited number)
- Establish a distributed Project Office, administratively anchored to CERN, to follow up the work.
- Aim to involve CERN personnel, fellows, PJAS within the current LC resource planning at CERN (in many cases using long term collaborative links and common studies between CLIC and ILC)



*Additional collaboration agreements between KEK and FA/countries might be very beneficially, where these activities are recognised directly

The European activities, and resources

European presentation of ILC studies, distributed on five main activity areas:

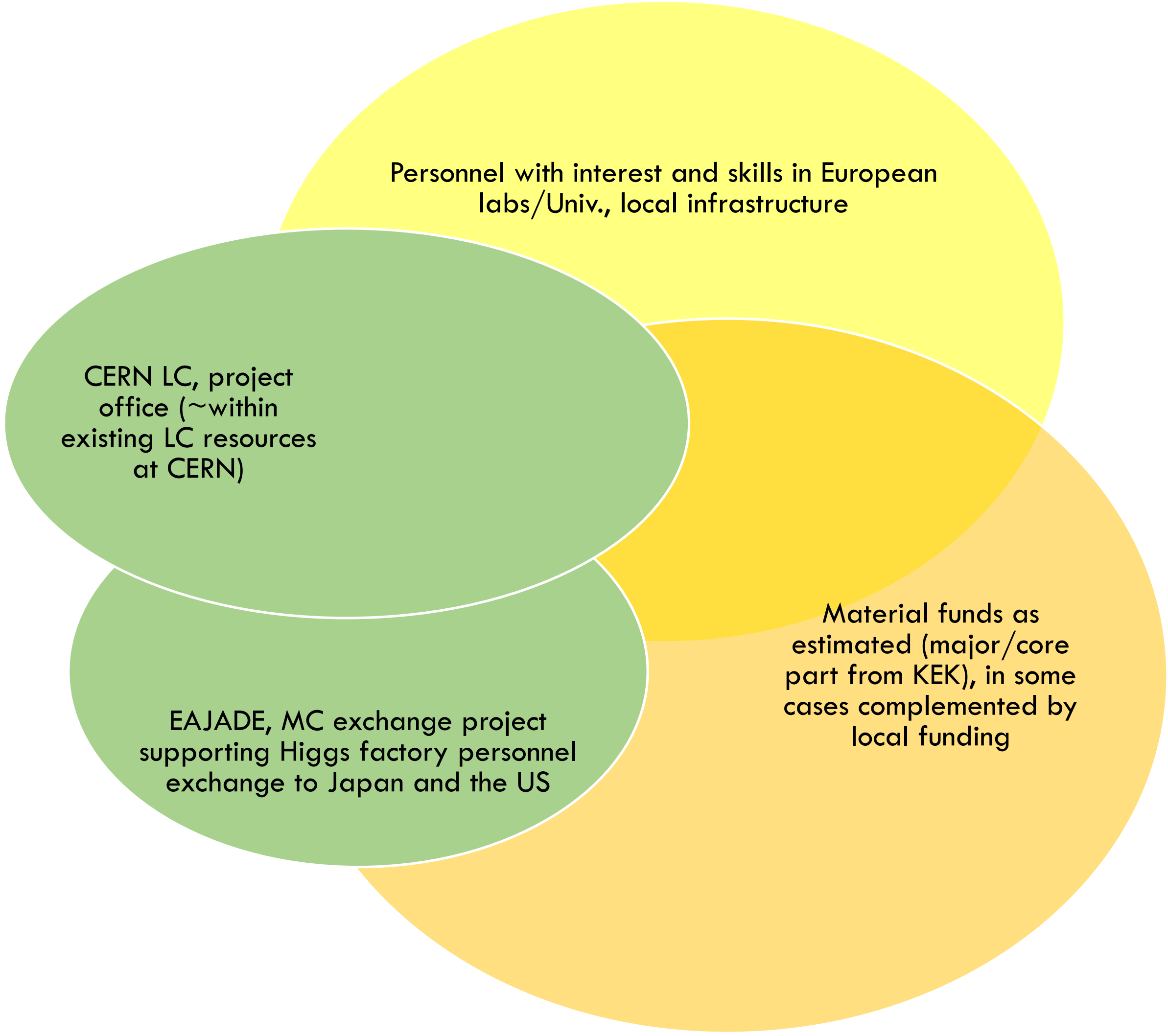
A1 with three SC RF related tasks
- SRF: Cavities, Module, Crab-cavities
- Might want to split into 3 separate WPs

A2 Sources
- Concentrate on undulator positron scheme, consult on conventual one (used by CLIC and FCC-ee)

A3 Damping Ring including kickers
- Low Emittance Ring community

A4 ATF activities for final focus and nanobeams
- Groups active in ATF (including new ones)

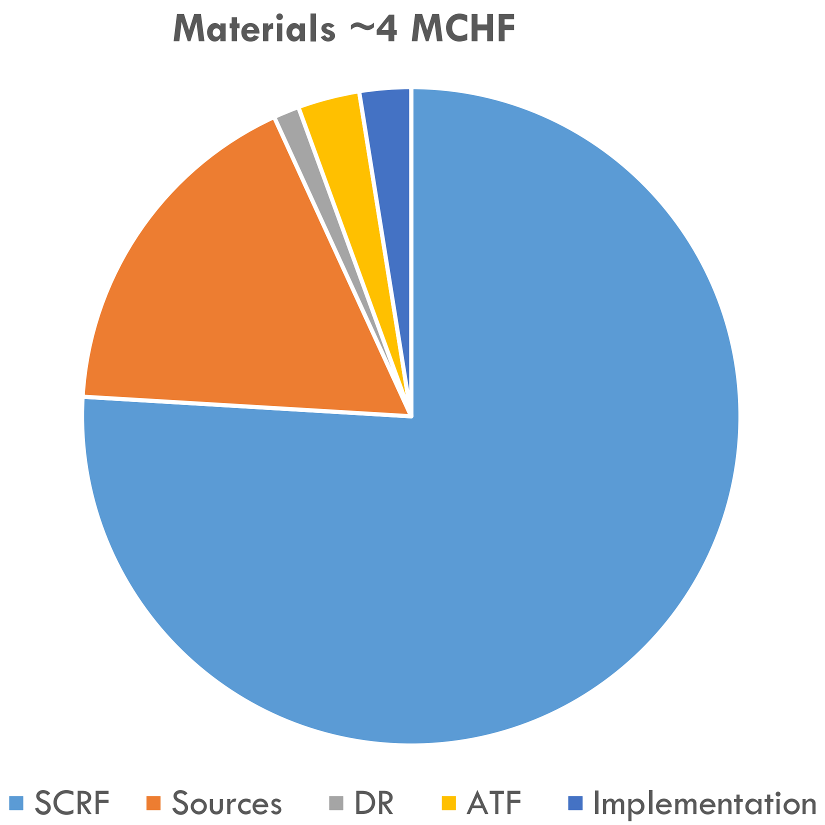
A5 Implementation including Project Office
- Dump, CE, Cryo, Sustainability, MDI, others (many of these are continuations of on-going collaborative activities)



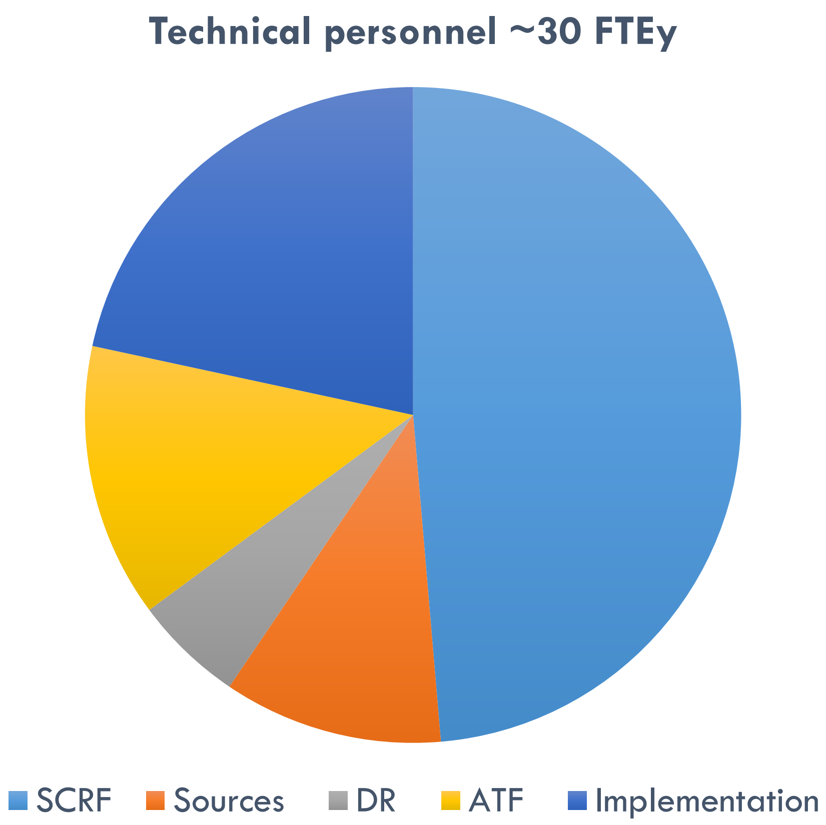
EAJADE: Information at LINK

Resource estimate (core)

Estimated material funds 4 MCHF over 4 years



Top-down estimate of technical personnel purely for ITN deliverables ~30 FTY year



This rests of basis of technical expertise, infrastructure and technology in the European labs/Universities/Industries which are not included in this resource overview, plus the scientific community, including students, involved in ILC related studies.

A1: SRF Cavities and Cryomodule design

(Global Industrial Production Readiness)

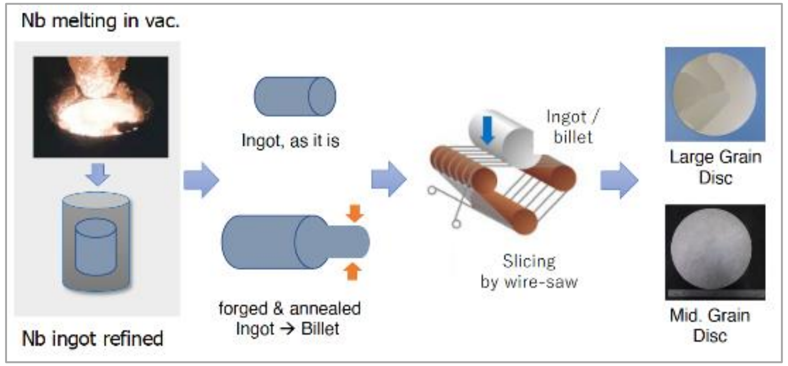
- Research with single-cell cavities to establish the best production process
  - Advanced Nb sheet production method
  - Advanced surface treatment recipe
- Globally common design compatible with High Pressure Gas Safety (HPGS) regulation
- 24 nine-cell cavities are to be developed for industrial-production readiness
  - 8 cavities (4 / batch) in each region
  - Production process optimized in each region encouraged
- RF performance/success yield to be examined (at least including 2nd pass)
  - 3rd pass to be examined if effective

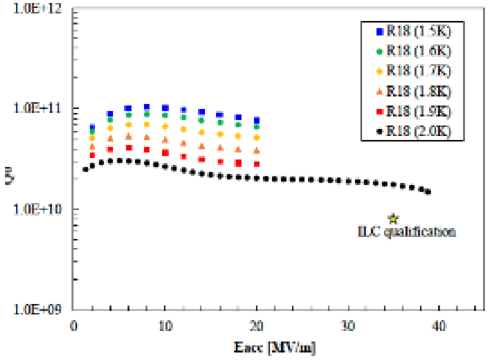
Production process

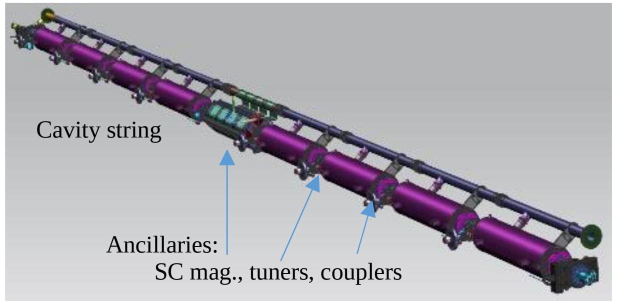
	# of cavities to be produced		
	Americas	Europe	JP/Asia
single-cell	2	2	2
nine-cell	8	8	8 (+ 12)

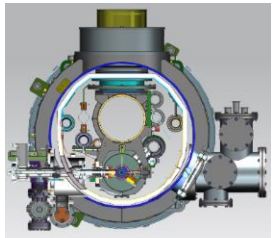
Material/Sub-component
↓
QA of Material/Sub-C
↓
Cavity Production
↓
Surface Process
↓
Vertical Test = Cavity RF Test

- Unify cryomodule (CM) design with ancillaries, based on globally common drawings and data-base, and
- Establish globally compatible safety design base to be approved by HPGS regulations individually authorized in each region, most likely referring ASME guidelines.









Group involved on European side in discussions of the programme:
CEA, INFN Milano primarily
Also potentially: IJClab, DESY, STFC/Daresbury+Lancaster, CERN, Uppsala, ...
CIEMAT (for SC magnet)

SCRF (Grad, Q) is a priority for most future high energy accelerators, and also beyond HEP

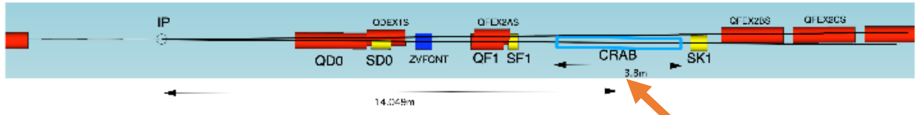
A1: Crab Cavity Development with down-selection

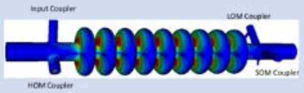
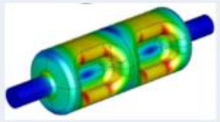
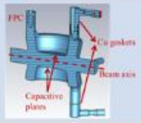
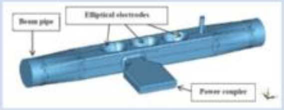
:

- RF property simulation to optimize cavity design
- Pre-down-selection to choose two primary candidates
- Development and evaluation of two prototype cavities
- Demonstration of synchronized operation with two prototypes
- Down-selection to choose final cavity design
- Cryomodule design based on final cavity design

Item	Recent specification (after TDR)
Beam energy	125 GeV (e^-)
Crossing angle	14 mrad
Installation site	14 m from IP
RF repetition rate	5 Hz
Bunch train length	727 μsec
Bunch spacing	554 nsec
Operational temperature	2.0 K (?)
Cavity frequency	1.3/2.6/3.9 GHz
Total kick voltage	1.845/0.923/0.615 MV
Relative RF phase jitter	0.069 deg rms (49 fs rms)

two beamline distance
14.049m x 0.014rad = **197mm**



Elliptical/Racetrack (3.9 GHz)	Lanc. Univ.	
RF Dipole (RFD)	ODU	
Double Quarter Wave (DQW)	CERN	
Wide Open Waveguide (WOW)	BNL	
Quasi-waveguide MultIcell Resonator (QMIR)	FNAL	

Group involved on European side in discussions of the programme: **STFC/Daresbury and Lancaster Univ, and CERN**

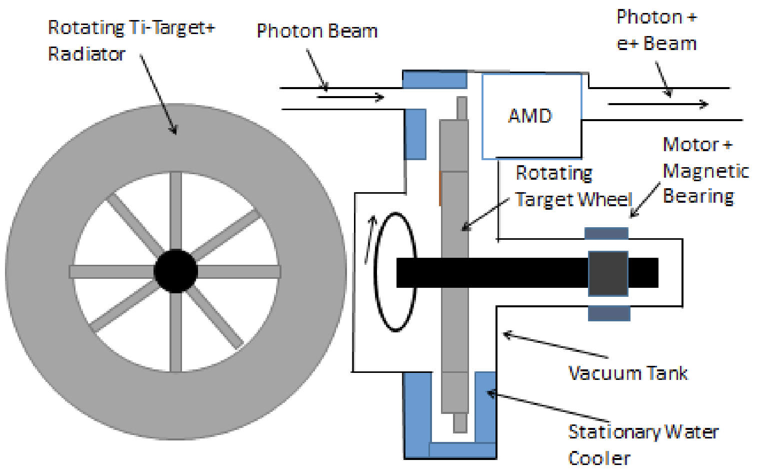
Links to general studies of crab cavity solutions:
(among others for HL-LHC, EIC and Elettra2.0)

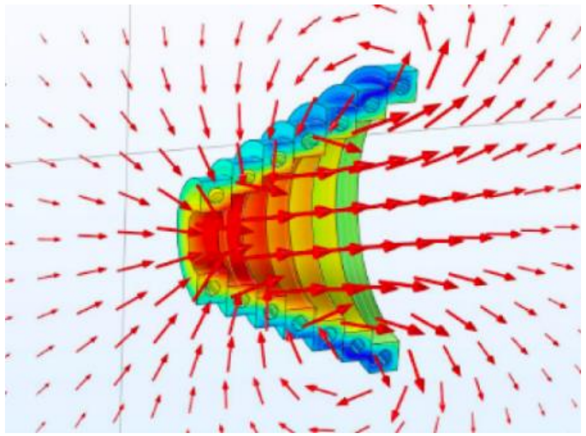
A2: Positron Source - Rotating Target and Focusing System for Undulator Scheme

- Target specification
  - Titanium alloy, 7mm thick (0.2 X_0), diameter 1m
  - Rotating at 2000 rpm (≙ ~33 Hz) in vacuum
  - Photon power ~60 kW, deposited power in target about 2 kW, efficient power/e+
  - Radiation cooling
  - Magnetic bearings, widely used for Fermi choppers (ESS etc.), vacuum pumps and fast rotating masses
- R&D to be done as WP-prime
  - Detailed simulations in close contact with OMD design on-going
  - Design finalization, laboratory test of mock-up design (in the first 2 years)
  - Magnetic bearings: technical specifications done, ready for feasibility study, engineering design, test (in the remaining years)

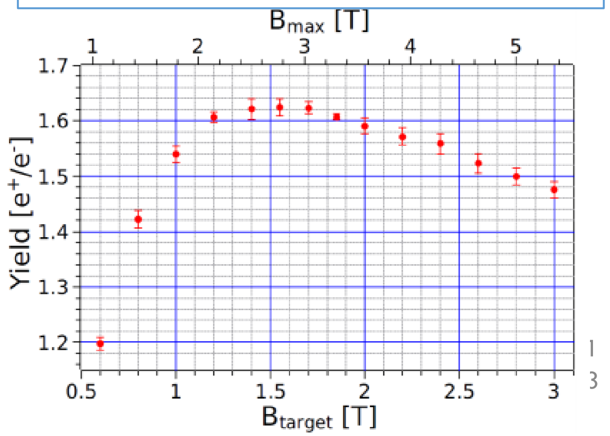
- A priority item for the undulator scheme is the magnetic focusing system (OMD) right after the target
- The mature candidate is a pulsed solenoid (PS)
- R&D items to be done as WP-prime
  - Detailed simulations (almost finished)
  - Ready for engineering design for a prototype PS
  - Field measurements with 1kA (pulsed and DC) and with 50kA both in a single pulse mode and finally in a 5ms pulsed mode at 5 Hz
  - Prototype of plasma lens as OMD (funded study on-going), example for application of new technology for the ILC
- Undulators are very popular photon sources, possible synergies

Principal Layout: Ti-Wheel with a Diameter of 1.0 m, rotating at 100 m/s, 2000 rpm.





Yield versus field on the target

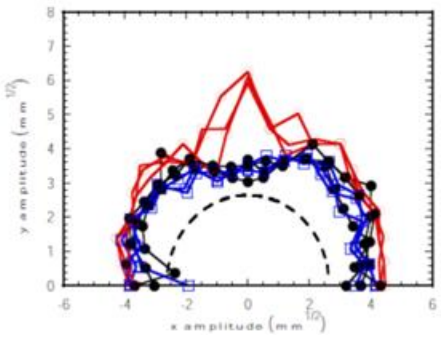


Group involved on European side in discussions of the programme:
Univ. of Hamburg, CERN, DESY, HZ Dresden-Rossendorf, SKF Jülich and possibly ESS-Bilbao.
For polarized positrons, providing physics advantages, linking also to FEL/undulators studies.

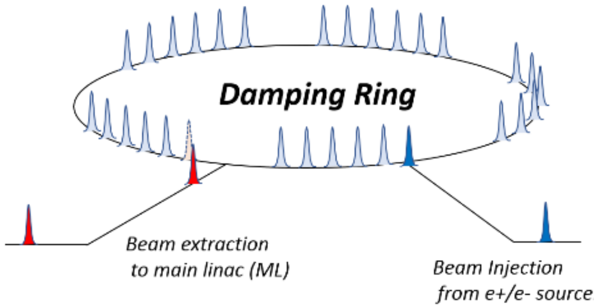
A3: Damping Ring optimization and injection/extraction

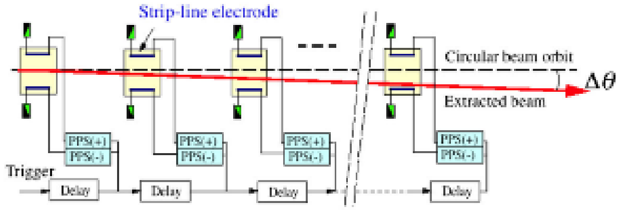
- The ILC damping ring (DR) is required to satisfy the low emittance and the large dynamic aperture simultaneously.
- The ILC DR will be further improved by incorporating the findings of the latest light source design. Increasing the dynamic aperture is also important in the design of DR.
- By quantitatively evaluating the effect of fringe field to the dynamic aperture of magnets in ILC DR, the method for evaluating fringe field to the dynamic aperture in accelerator design will be established and the design of ILC DR will be optimized.

- A fast kicker system using a semiconductor pulse power supply with nanosecond response was confirmed as proof of principle at KEK's ATF about 10 years ago.
- Semiconductor technology has been evolving, and it is now possible to advance nanosecond response beam injection/excitation systems using the recent semiconductor technology.
- The technical evaluation of the fast kicker power supply using the recent semiconductor technologies.
- The evaluation of fast pulsed power supply technology will contribute not only to the fast kicker system but also to the performance and reliability of nanosecond-scale beam control technology and its application to a wide range of accelerator systems.



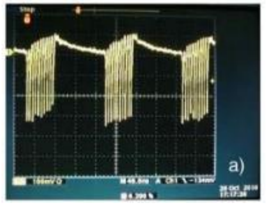
ILC fast injection/extraction system



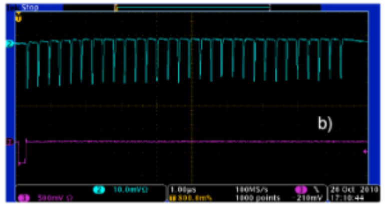


Beam extraction test at KEK ATF

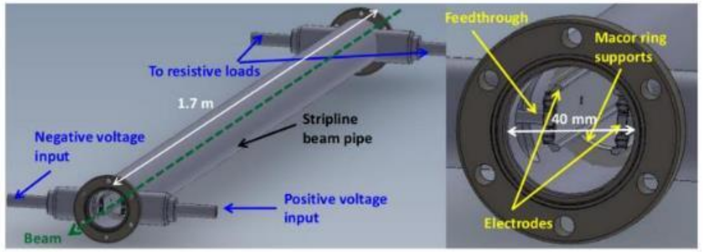
Stored beam in DR



Extracted beam from DR



Beam injection/extraction system for CLIC damping ring

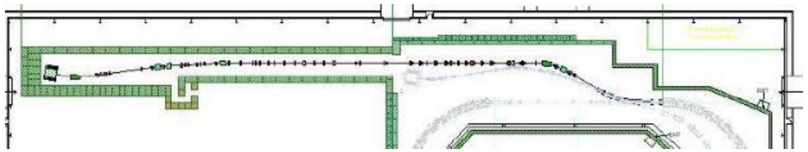


Many group can find this interesting and have capabilities to do it, there is a large and well organised low emittance ring community in Europe – and many also experience with similar studies for CLIC and FCC-ee.

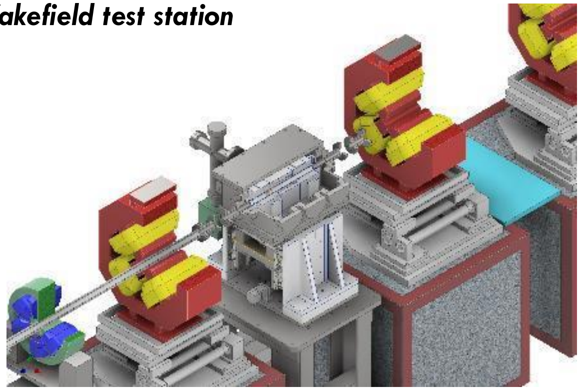
A4: ATF3 programme (final focus, nanobeams)

- ATF2 beamline is the only existing test accelerator in the world to test the final focus system (FFS) of linear colliders.
- The following 3 research topics are important topics to be pursued at the ATF.
  - wakefield mitigation
  - correction of higher-order aberration
  - training for ILC beam tuning
- The technical research at ATF2 beamline has proceeded, and should continue to be based on the ATF international collaboration, or its extension (welcome to new collaborators).

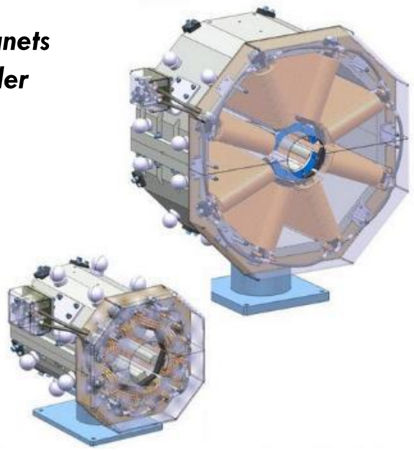
ATF2 beamline

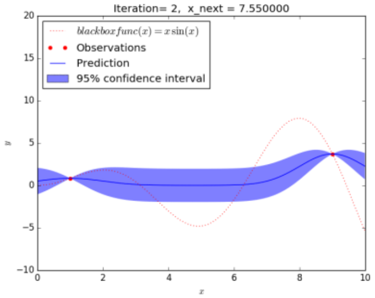


Wakefield test station



Octupole magnets for higher-order aberration





Maximum search algorithms to be applied to beam tuning (Machine Learning)

Very relevant studies for any linac and Higgs factory closely related to low emittances and nano beams, e.g. alignment, stabilisation, instrumentation, beam-dynamics, etc.

- Strong European leadership with several group from **France, UK, Spain, Germany and also CERN, also extensively used for PhD training**
- A future ATF3 programme has been defined and reviewed internationally, supported also by MC researcher exchange programmes as EJADE and EAJADE (LINK)

A5: Implementation studies

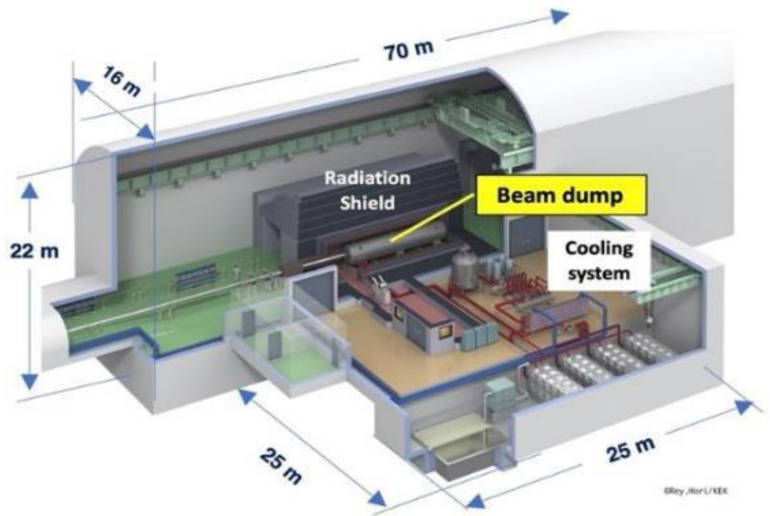
- Project Office to follow this effort, admin base CERN but can/should be distributed
  - Linking to EAJADE and communication efforts, and the KEK-CERN offices

- Continue existing collaborative efforts on CE and Cryo (CERN, DESY, KEK)
- Common studies CLIC/ILC on sustainability issue (ongoing), e.g. power, energy and running models, CO2 (sustainability is also an EAJADE WP).
  - the four activities above are all addressing optimisation of lum. to power, and/or power consumption directly for ILC
  - will also connect to green ILC studies in Tohoku within EAJADE (e.g. facility integration in local environment and infrastructure, carbon emission goals, power availability and sources)
- Connecting to ILC physics and detector developments, in particular MDI (also a focus of EAJADE)

- One of the ITN studies also belong to this activity:

◆ Finalize the engineering design of the main beam dump system

- Vortex water flow in the dump vessel
- Cooling water circulation and heat exchange
- Remote exchange of the beam window
- Countermeasure for failures / safety system



Involved: CERN, EAJADE community, ESS Bilbao for dumps. Many of these topics are related to exploiting communalities between EXFEL, HL-LHC or CLIC and ILC

Concluding words and next steps

- Initial planning in Europe for ITN is assuming a positive decision by the Japanese Ministry of Finance end of the year
- Contribution to the material cost from KEK starting next year crucial.
- With the two elements above in place we can move towards execution quickly.

- Maintain collaborative R&D with Japan and KEK with relevance for Linear Colliders under any circumstances, including ATF3 and EAJADE related exchanges of people (post Covid we can expect increased activity)

- The programme is very well aligned with European accelerator R&D priorities (for Higgs-factories and LDG roadmap), and builds on existing expertise, industrial capabilities and infrastructure – and a long history of technology developments for SC linacs and ILC in Europe
- Concerning the LDG accelerator roadmap, the primary – but not only – link is to RF (but also has R&D elements related to plasma, energy recovery, magnets and muons)