SuperKEKb and ILC Status and Prospects

M. Winter (IPHC/CNRS, Strasbourg)

Prospectives IN2P3 / IP2I Lyon / 12 mars 2020

Contents

SOURCES for SuperKEKb : EPPSU documents, "SuperKEKB: Challenges for the High Luminosity Frontier", https://conference-indico.kek.jp/indico/event/103/ – "SuperKEKB Design Report", https://kds.kek.jp/indico/event/15914/ – "Belle II TDR", http://www-superkekb.kek.jp/documents/B2TDR.pdf – "News from Belle II @ SuperKEKB", Talk by T.Browder at LP2019, https://docs.belle2.org/record/1630/files/BELLE2-TALK-CONF-2019-103.pdf

SOURCES for ILC : TDR & DBD, EPPSU documents, ESG roadmap LCWS-19 (Sendaï), ICFA statement (22.02.20), ILC European Action Plan (ILC-EIPP.E-JADE.v2.12.20180703

SuperKEKb

Laboratoires impliqués: CPPM, IJCLab, IPHC

SuperKEKB, the first new collider in particle physics since the LHC in 2008 (electron-positron $\left(e^{+}e^{-}\right)$ rather than proton-proton (p-p)

Phase 1

Background, Optics commissioning

Feb - June **2016**

Brand new 3 km positron ring

Phase 2: Pilot run

Superconducting Final Focus

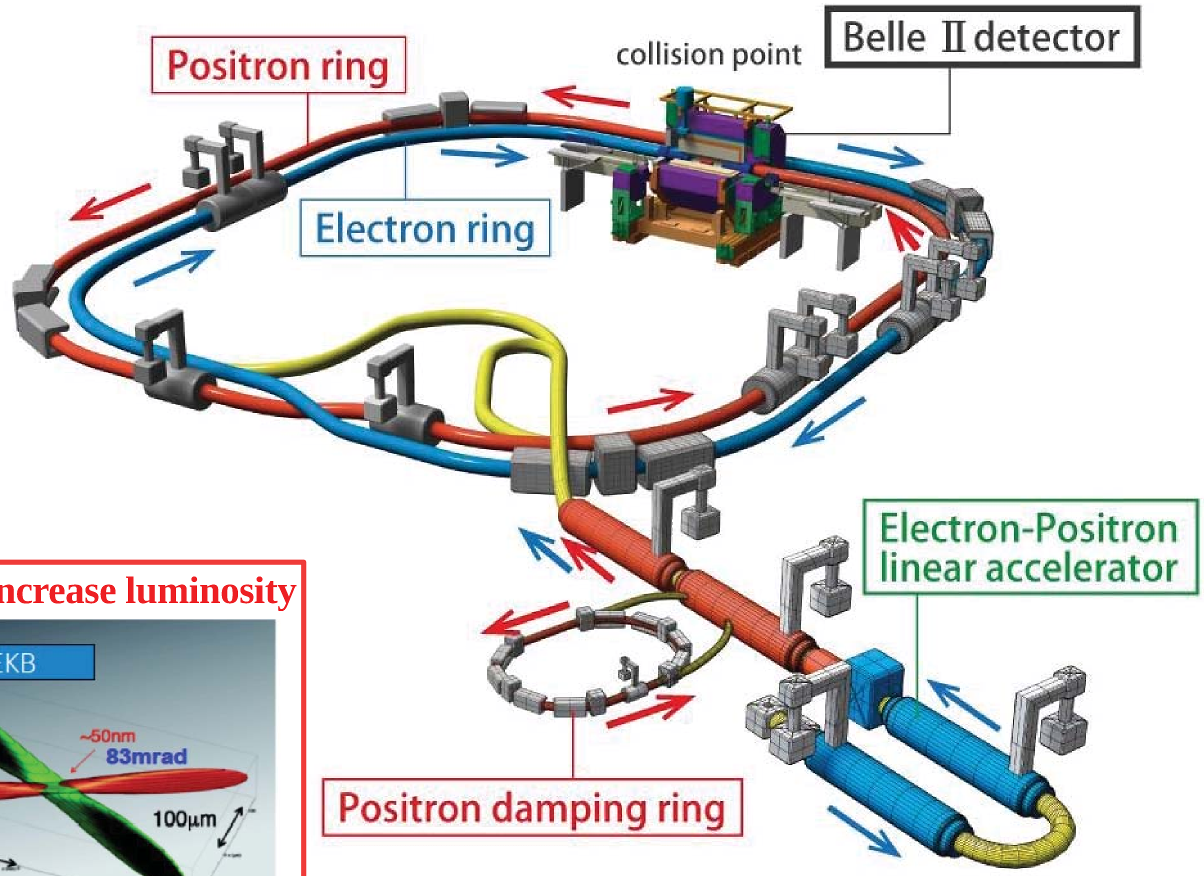
add positron damping ring

First Collisions $\left(0.5\ \text{fb}^{-1}\right)$

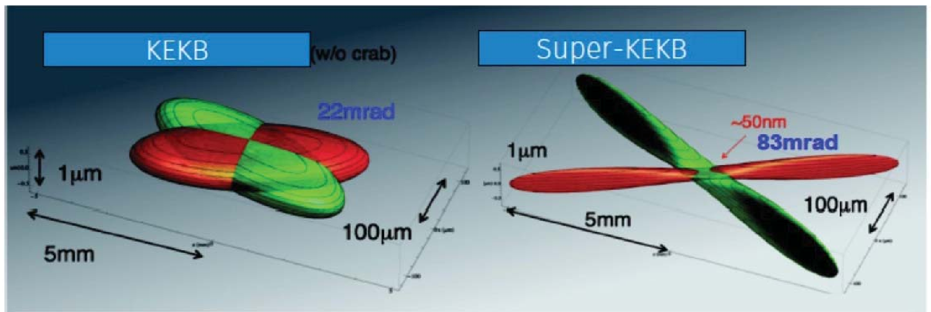
April 27 - July 17, **2018**

Phase 3: Physics run

Since April, **2019**



Nano-beams and more beam current to increase luminosity

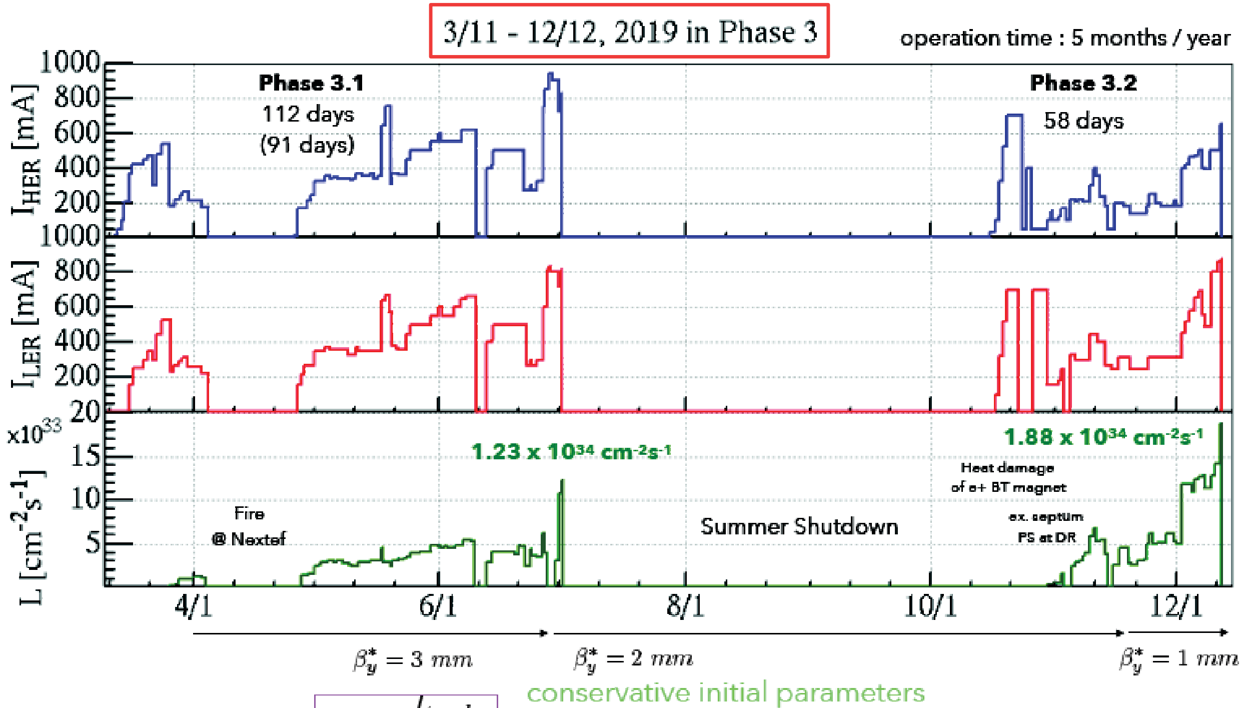


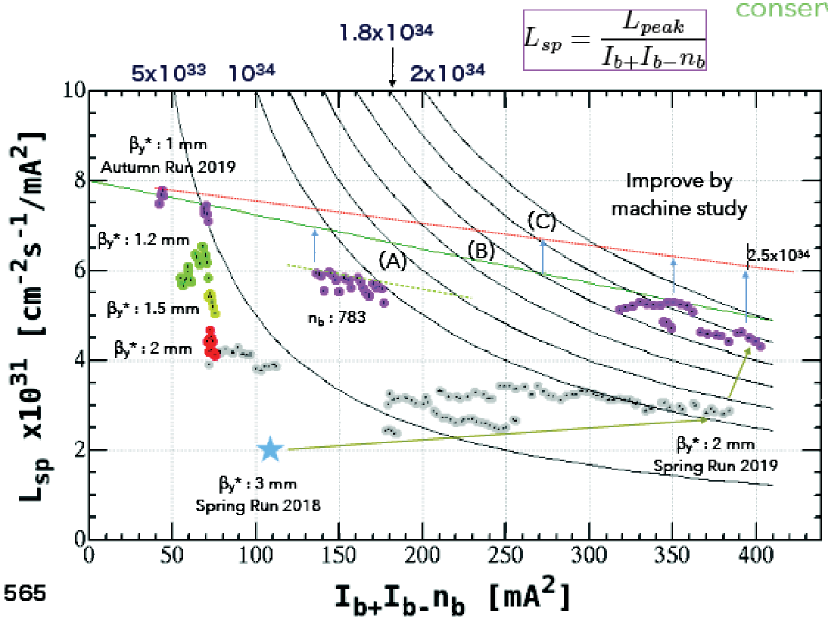
	E (GeV) LER/HER	β^*_y (mm) LER/HER	β^*_x (cm) LER/HER	φ (mrad)	I (A) LER/HER	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1×10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80×10^{34}
		factor 20			factor 2-3	

$\Rightarrow$ **to reach $8 \times 10^{35}\ cm^{-2}s^{-1}$**

$\Rightarrow$ **cumulate 50 ab^{-1} by ~2029**

SuperKEKB status





(A)
LER : 700 mA
HER : 400 mA
n_b : 1565
I_{b+} : 0.44 mA
I_{b-} : 0.25 mA
$I_{b+}I_{b-}n_b$: 180 mA²
L : 1.2 x10^{34} cm-2s-1

(B)
LER : 500 mA
HER : 370 mA
n_b : 783
I_{b+} : 0.64 mA
I_{b-} : 0.47 mA
$I_{b+}I_{b-}n_b$: 236 mA²
L : 1.46 x10^{34} cm-2s-1
(achieved: 1.19 x10^{34} cm-2s-1)

= 783 / 1565

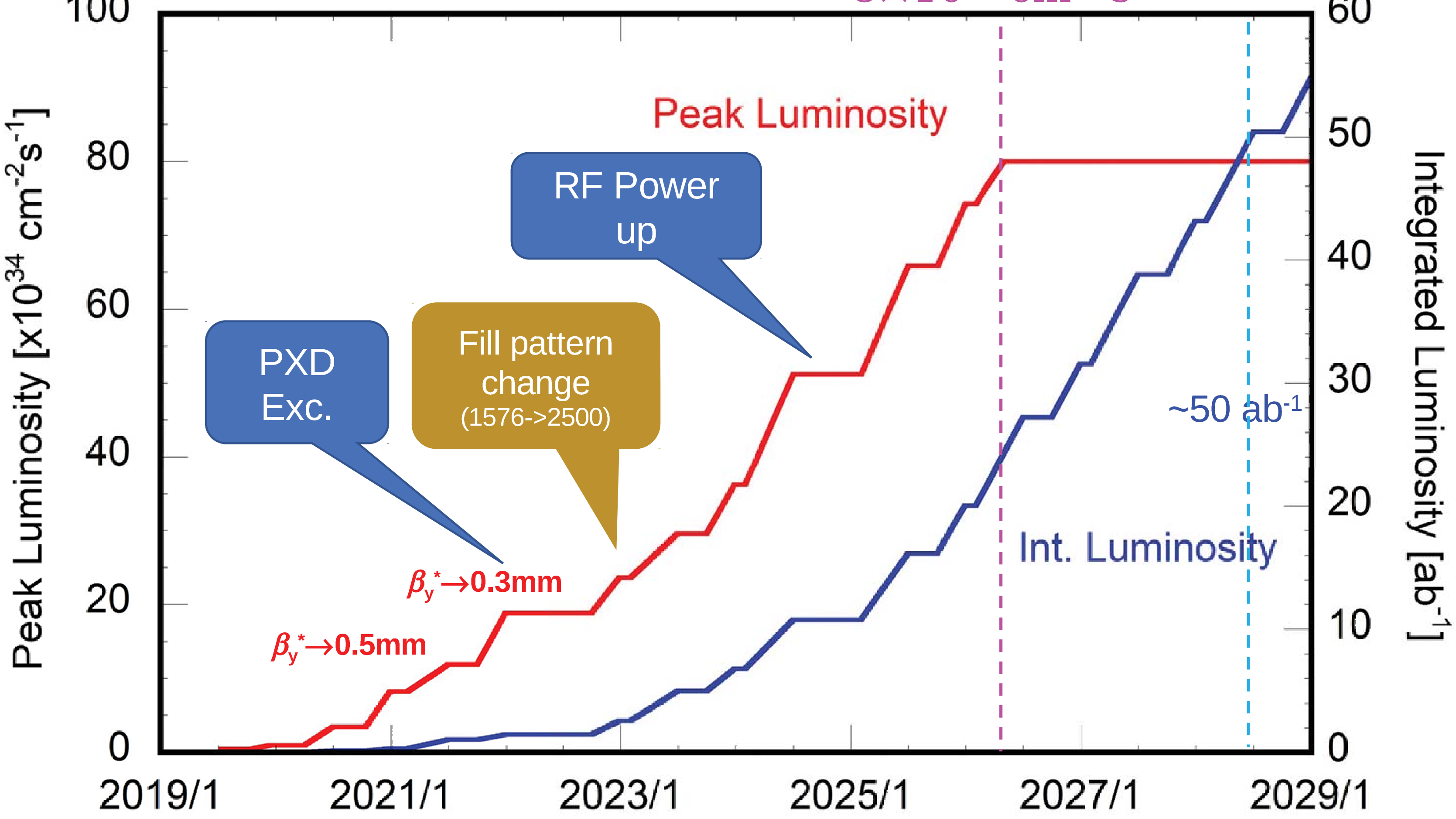
Improvements of luminosity performance

- study with crab waist LER first (spring 2020)
- Reduce beam-beam blowup
- Reduce beam-tail, ...reduce beam background
- then keep squeezing: $\beta_y^* \rightarrow$ 0.3 mm

Operation plan and luminosity projection

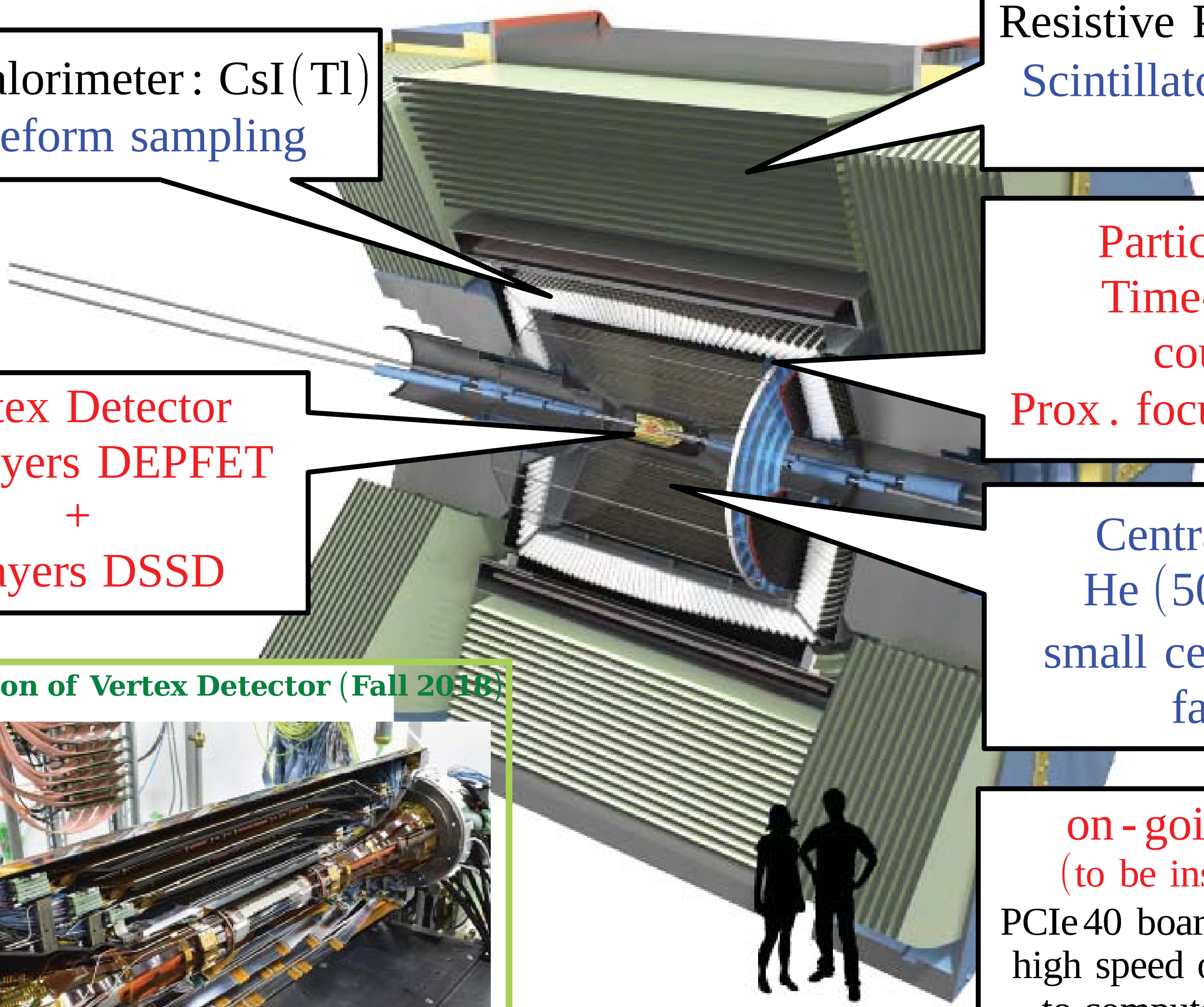
- long term (∼ 2029)
- PXD exc. 2022, RF upgrade 2024

$8 \times 10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$



just started to consider an upgrade → 250 ab^{-1}, polarized beams...

Belle II detector



EM Calorimeter: CsI(Tl)
waveform sampling

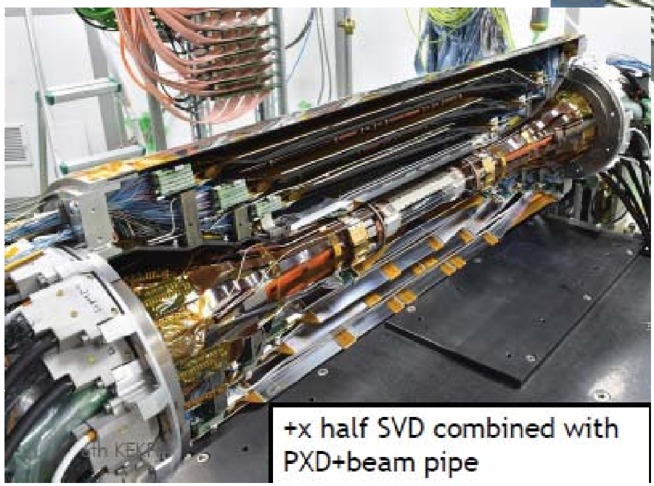
K_L and muon detector
Resistive Plate Counter (barrel)
Scintillator + WLSF + MPPC
(endcaps)

Particle Identification
Time-Of-Propagation
counter (barrel)
Prox. focusing Aerogel RICH

Vertex Detector
1/2 layers DEPFET
+
4 layers DSSD

Central Drift Chamber
He(50%):C_2H_6(50%)
small cells, long level arm,
fast electronics

Installation of Vertex Detector (Fall 2018)



on-going DAQ upgrade
(to be installed in 2020-2021)
PCIe40 board, capable of reading via high speed optical links and to write to computer at rate of 100 Gb/s:
limited number of boards (20) enough
to read entire Belle II detector

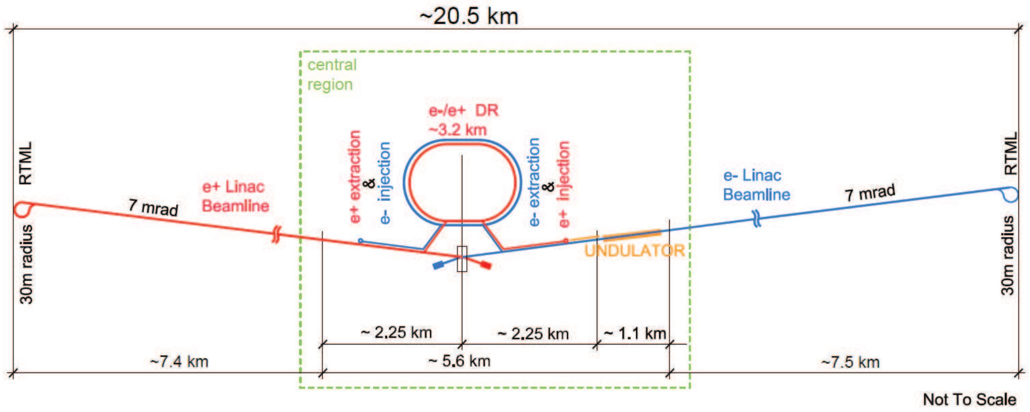
considering now VTX upgrade (2025 or later)

International Linear Collider: ILC

- Labo. impliqués: CPPM, IJCLab, IPHC, IP2I, LLR, LPCC, LPNHE, LPSC, Omega

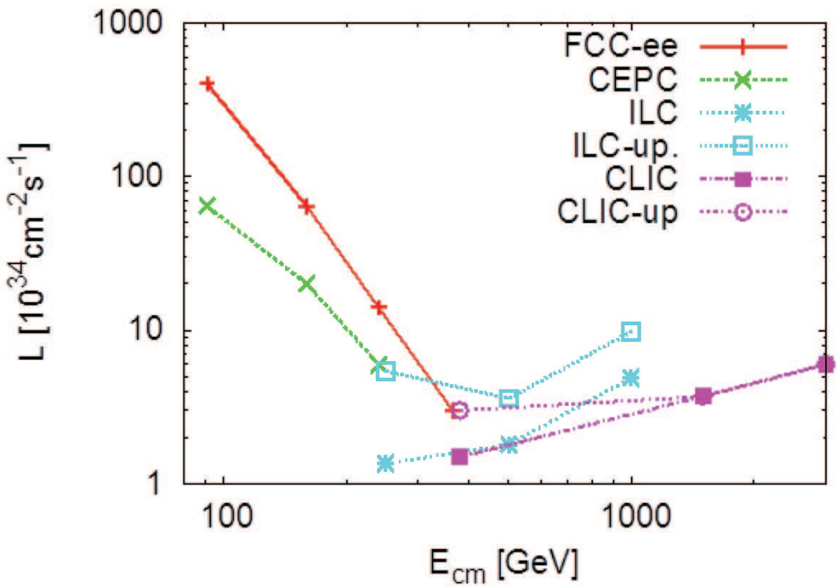
ILC Main Parametres

- **ILC $\equiv e^+e^-$ linear collider aiming for:**
  - high precision studies of Higgs boson and top-quark properties
  - high precision study of S.M. processes (e.g. fermion-pair prod.)
  - high sensitivity to BSM physics escaping from LHC's searches



- **Available C.M. energies (E_{CM}):**
  - Baseline machine design concentrating on tunable E_{CM} ranging from 250 GeV to $>$ 500 GeV, extendable $>$ 1 TeV
  - Adaptable to $E_{CM} <$ 250 GeV (e.g. Z-pole)
  - E_{CM} tunable $\Rrightarrow$ allows for threshold scan (e.g. m_{top})
  - Techno. breakthrough: Supra-conduct. accel. cavities

- **Machine luminosity:**
  - Baseline L_{250} = $1.35 \cdot 10^{34}$ $cm^{-2} \cdot s^{-1}$ for $P_{tot} \simeq$ 130 MW
  - Upgradable to L_{250} = 5.4 / $8.1 \cdot 10^{34}$ $cm^{-2} \cdot s^{-1}$ for $P_{tot} \simeq$ 280 MW (6 times more BX)
  - Impact of luminosity enhanced by long. polar. : $P_- / P_+ \gtrsim \pm 80 / \pm 30$ %
  - Techno. breakthrough: nano-beams and crab-waisting



ILC Technology: General

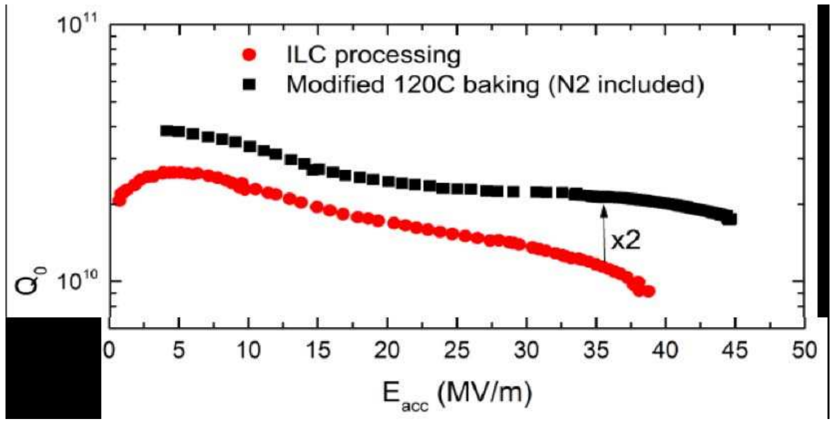
- **Beam acceleration** based on (2 x 10,000) SCRF cavities (1.3 GHz)

  ↪ European industry / expertise / involving H.E.P. labs (e.g. IJCLab, Irfu !)

- **TDR published in 2012/13** (incl. detailed costing book)

  based on world wide effort

- **Industrialisation** (prod. rate, reproducibility, cost, ...) validated with:
  - E-XFEL ($\sim$ 800 SCRF, 100 cryomodules), running since 2017
  - its extensions: LCLS-II at SLAC, etc.



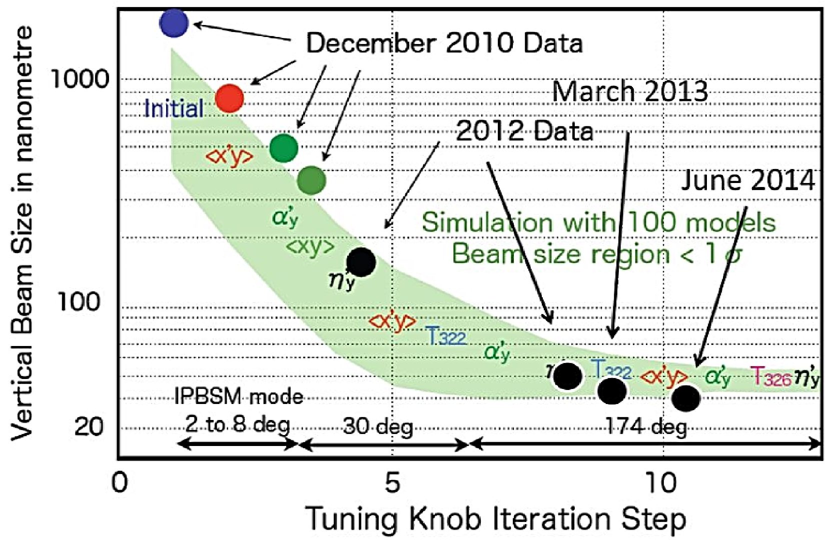
- **ILC final focus optical design & beam monitoring feedback syst.** validated with:
  - DAFNE and SuperKEKb operation
  - ATF2 (KEK): IP Beam Size Monitoring

    1.3 GeV, rep. rate = 3.12 Hz, 1-2·10^{10} e^-/bunch

    ↪ 41 (37) nm vertical extension measured $\Rightarrow$ $\sim$ 6 nm at ILC IP
  - IN2P3 strongly involved in nanobeam parametre (R&D) assessment

    and beam control fast feedback system

History of minimum beam size in ATF2



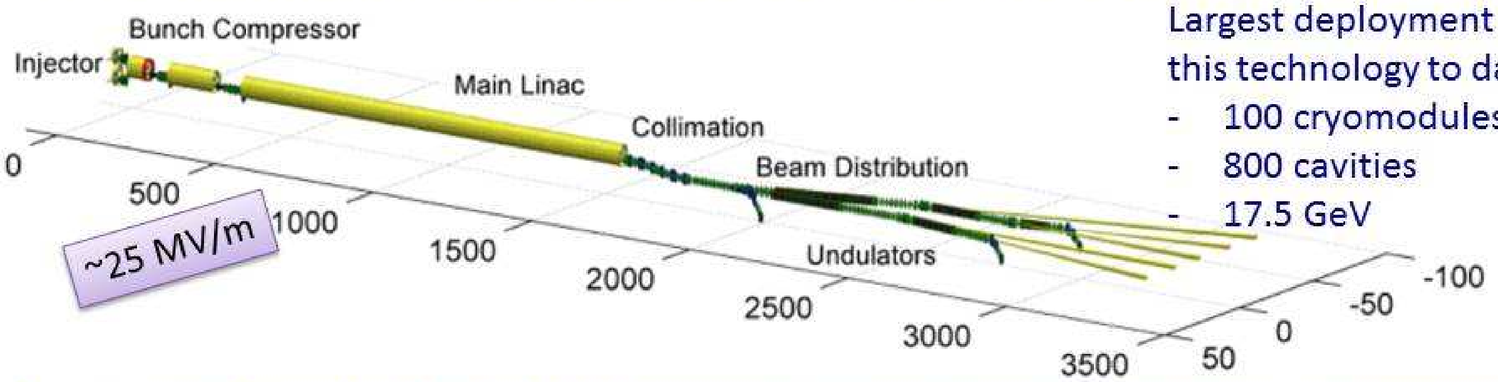
- **Most critical design aspects have all been validated**

- **Still some open issues (e.g. e^+ source) to solve during preparatory phase**

ILC technology: SCRF and Cryomodules

- **E-XFEL:** ○ **Couplers validated at LAL/Orsay** ○ **Cryomodules assembled at Irfu/Saclay**

European XFEL @ DESY



Largest deployment of this technology to date

- 100 cryomodules
- 800 cavities
- 17.5 GeV

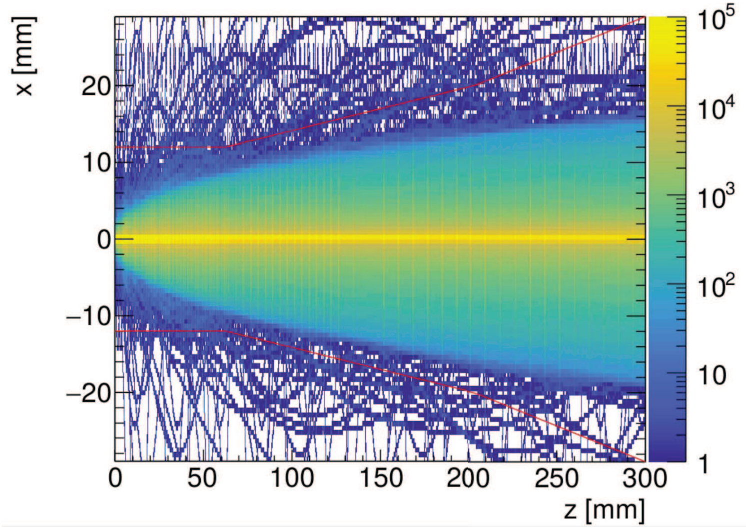
Institute	Component Task
CEA Saclay / IRFU, France	Cavity string and module assembly; cold beam position monitors
CNRS / LAL Orsay, France	RF main input coupler incl. RF conditioning
DESY, Germany	Cavities & cryostats; contributions to string & module assembly; coupler interlock; frequency tuner; cold-vacuum system; integration of superconducting magnets; cold beam-position monitors
INFN Milano, Italy	Cavities & cryostats
Soltan Inst., Poland	Higher-order-mode coupler & absorber
CIEMAT, Spain	Superconducting magnets
IFJ PAN Cracow, Poland	RF cavity and cryomodule testing
BINP, Russia	Cold vacuum components

The ultimate 'integrated systems test' for ILC. Commissioning with beam 2nd half 2015

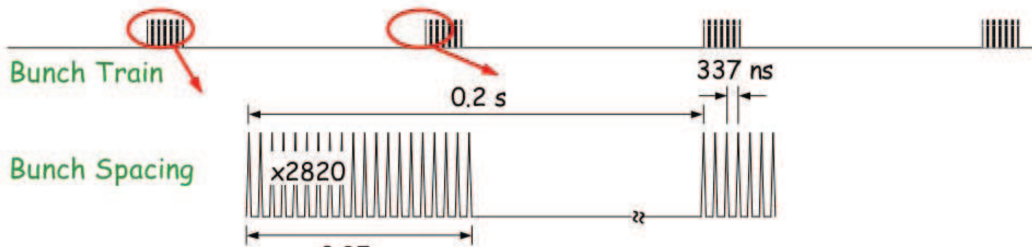
N. Walker (DESY) – ILC Worldwide Event – CERN – 12 June 2013 18

ILC Running Conditions

- **General remarks:**
  - e^+e^- collisions: Very precise knowledge of parametres ruling elementary interaction: E, p, polar., ...
  - EW interactions: $\sim$ no QCD background ("clean final states")
  - Modest radioactivity and particle rate $\Rrightarrow$ detector design gives priority to physics oriented requirements (granularity, material budget, ...)
  - Interactions of interest: O(10) Hz + Bhabha scatt.
  - 1 Higgs boson for 10^2 EW interactions (LHC: 1 / 10^{10})
  - 2 detectors operated in push-pull mode at IP



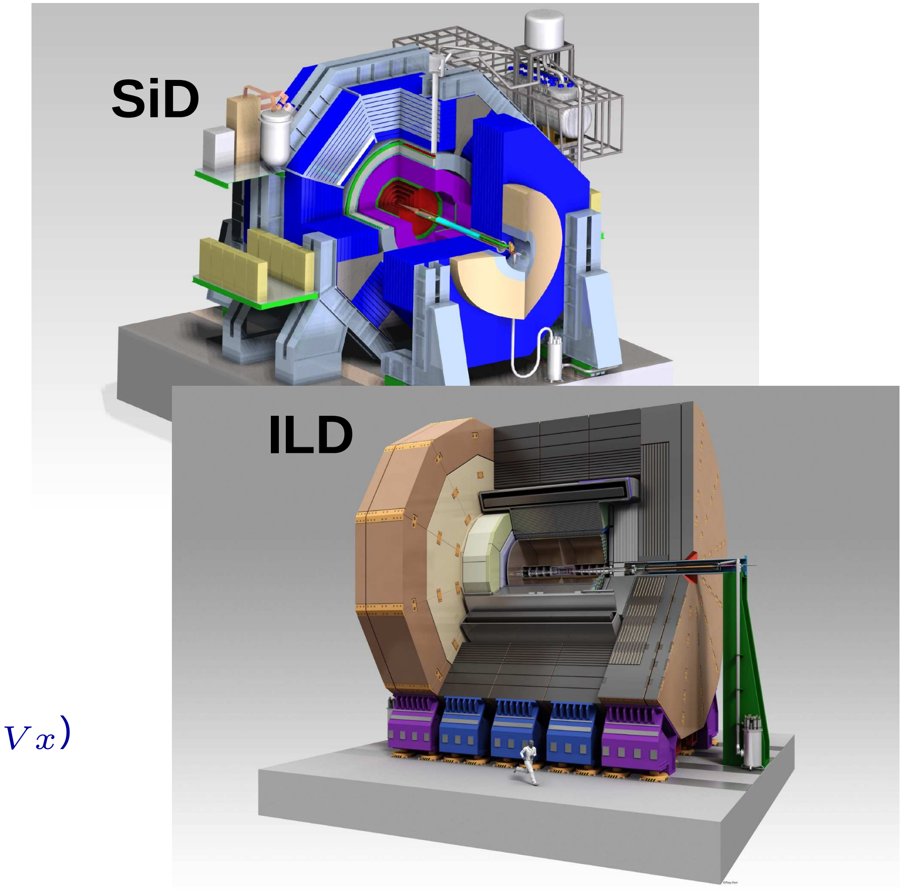
- **Beam time structure:**
  - Beams arranged in trains made of O(10^3) particle bunches & separated by O(100) ms
  - Machine duty cycle $\lesssim$ 1 % $\Rrightarrow$ favours power saving
  - Interbunch separation O(300-500) ns
    $\Rrightarrow$ single bunch tagging quite easy & modest power demanding



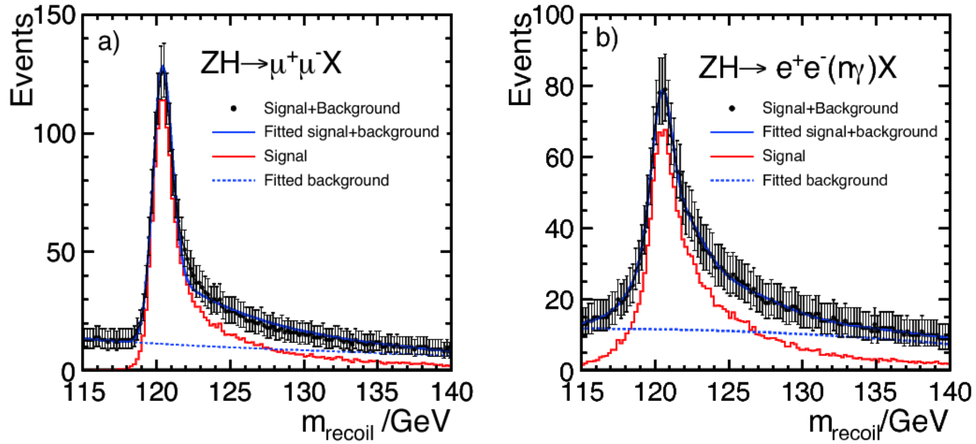
- **Consequences of nano-beams:**
  - Strong focusing at I.P. $\Rrightarrow$ EM background, E_{CM} dispersion
  - Crossing angle: EM background backscattered from shallow angle detectors & quadruples
  - IP equipped with sophisticated system of beam monitoring with fast feedback exploiting huge EM radiation along beam line

ILC Detector Issues

- **Physics oriented requirements govern detector concepts:**
  - High jet multiplicity final states $\Rrightarrow$ efficient & precise rec. of each jet
    $\hookrightarrow$ incl. jet flavour & charge
  - Particle Flow: highly efficient rec. of each charged & neutral particles over large solid angle
  - Tracking achieved with $\sim$ 10% X_0 mat. bud. in front of ECAL
  - Calorimetres reconstruct ALL neutral particles, incl. hadrons



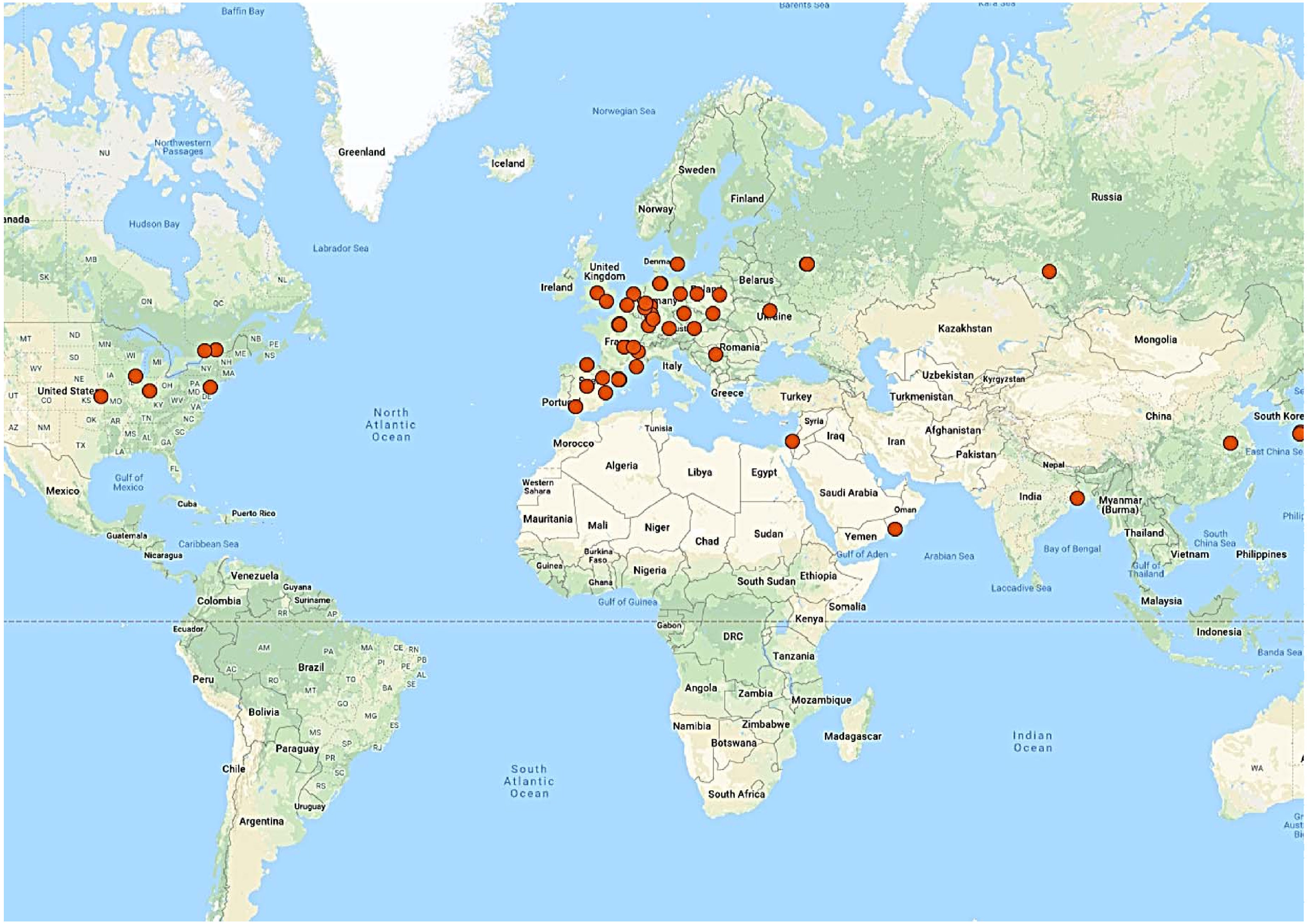
- **Extreme (3D) granularity is a must !**
  - Vertexing: $\sigma_{i.p.} \lesssim 5\ \mu m \oplus 10\ \mu m/p \cdot \sin^{3/2}\theta$ (charm, b inside jets, Q_{Vx})
  - Tracking: $\sigma(1/p_t) \lesssim 2{\cdot}10^{-5}$ (HZ final state)
  - Calorimetry: $\Delta E_{jet} \sim 3$ % (W - Z separation)
  - High field solenoid: 3.5 - 5 T (tracking, Beamstrahlung rejection)
  - Readout without hardware trigger (faint rare final states)



- **Specific running conditions:**
  - Extreme focusing of beams at I.P. $\Rrightarrow$ beamstrahlung background
  - Beam time structure ($\lesssim$ 1 % duty cycle)
    $\Rrightarrow$ power cycling ($\equiv$ saving)
  - Low radiation level: $\lesssim$ 100 kRad & 10^{11} n_{eq}/yr

ILD Concept: Map of Institutes involved

- **Research teams involved in the ILD concept activities $\lesssim$ 70 institutes**



Hosting ILC in Japan

- **General framework:**
  - A wave of academics, industrials, regional and Diet politicians of Japan tends since long to propose hosting the ILC to the international community
  - But the governmental decision has to follow an internal procedure intended to reach a consensus/acceptation by academics at large and by public (media) due to the large resources required

  $\Rrightarrow$ **(very) slow decision process !**

- **Evaluation process has started in 2013:**
  - **MEXT called for 2 internal and one external (CSJ) evaluations**
  - 1st step (FY13 to FY16) $\Rrightarrow$ request by MEXT of drastic cost reduction $\Rrightarrow$ E_{CM} = 250 GeV
  - 2nd step (FY17 to FY19):
    Dec.'18: Intermediate report $\Rrightarrow$ MEXT Declaration at ICFA meeting of March '19
    30th Jan.'20: Final report $\Rrightarrow$ ILC project should proceed through standard procedure towards hearing
  - 31st Jan.'20: MEXT and MSST Ministers make press conference where they announce that Japanese government takes over & pursues evaluation process
  - 20th Feb.'20 (ICFA-LCB / SLAC): MEXT Deputy Dir. Masuko and Diet Pres. of Fed. for ILC Kawamura declare intention of Japanese gvt to go ahead and start international discussions
  - 22nd Feb.'20: Statement by ICFA commenting and supporting the plans of the Japanese gvt

Geological & Economical Studies of Kitakami Mountains

ICFA Statement (22.02.2020)

- ICFA was encouraged by the reports from Mr. H. Masuko, Deputy-Director General, MEXT Research Promotion Bureau and Hon. T. Kawamura, Chairperson of the Federation of Diet Members for the ILC, ...:
- ICFA reconfirms the international consensus for a Higgs factory and wishes to see the timely construction of the ILC in Japan.
- ICFA acknowledges and welcomes the inter-governmental discussion between Japan, the United States and European nations, to advance international collaborative activities for the ILC.
- ICFA notes the need for a preparatory phase ahead of the establishment of the ILC laboratory and the construction of the ILC in Japan.
- ICFA advocates establishment of an international development team to facilitate transition into the preparatory phase.
  - The development team should be hosted by KEK, with leadership chosen with the help of ICFA
  - The team would develop a plan for the preparatory phase for the construction of the ILC, including technical, organizational and governance issues. It also would be tasked with understanding the activities and resources required in the preparatory phase. The process of developing the plan should involve the interested laboratories and community.
  - ICFA anticipates that these development activities could be completed in approximately one year, at which point it would be possible to launch the preparatory phase for the ILC, provided Japan expresses intent to do so together with international partners.

- **In view of progress towards realisation of the ILC in Japan, ICFA encourages the interested members of the high energy physics community, laboratories, and nations, to support and participate in these preparations aimed at the successful establishment of the ILC.**

ILC Project Timeline

- **Japanese objectives:**
  - Until $<$ Mid-2021 (tbc): framing the preparatory phase (incl. official choice of site ?)
  - ”Preparatory phase” starting around Mid-2021

    (discussions on template for governance & contribution sharing, etc.)
  - Anticipated construction start (if consensus reached) around 2025
  - Physics start would follow around 2035

- **International positioning:**
  - U.S. (DoE HQ) has declared strong interest for ILC
  - European Strategy Update on the way (ESG proposal may be discussed by end of March)

SUMMARY

- **SuperKEKb:**
  - New accelerator still commissionning, aiming at increasing the instantaneous luminosity while keeping the beam related background under control
  - Strong impact of physics programme anticipated on flavour physics
  - Crucial forerunner for future machines relying on nano-beam concept (e.g. ILC)
- **ILC:**
  - Most advanced design of a Higgs factory ($\equiv$ European Strategy priority)
  - Japanese gvt seems ready to examine its feasibility within international partnership (construction start around 2025, physics start around 2035)
  - US appears much supportive
  - European industry & large P.P. labs (incl. Irfu & IJCLab) have well established expertise in (SC) accelerator key elements $\Rrightarrow$ Europe would be a leading partner
  - IN2P3 groups are prominent detector R&D actors (calorimetry, Si trackers, MDI, nano-beam monitoring)
  - ICFA Statement: In view of progress towards realisation of the ILC in Japan, ICFA encourages the interested members of the high energy physics community, laboratories, and nations, to support and participate in these preparations aimed at the successful establishment of the ILC.