Status of the Future Linear Collider

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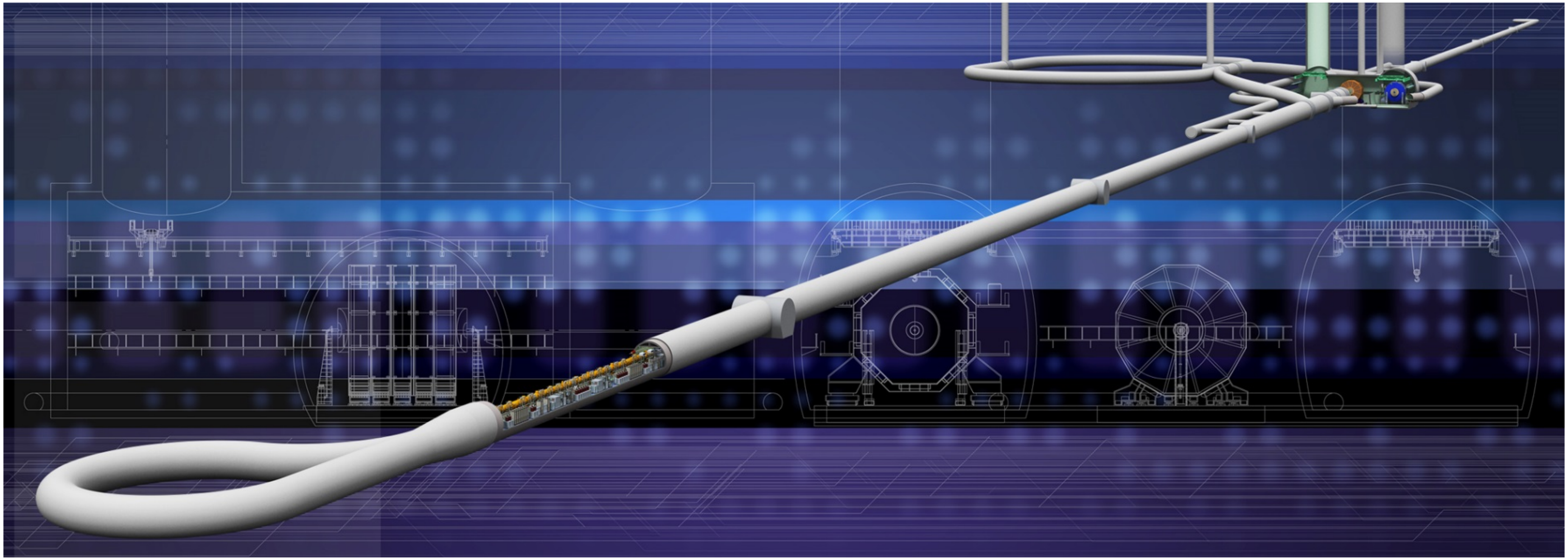
June 17, 2015

Outline

- Historical context and Canada
- Physics case in brief
- Accelerator development
- Japan and the ILC

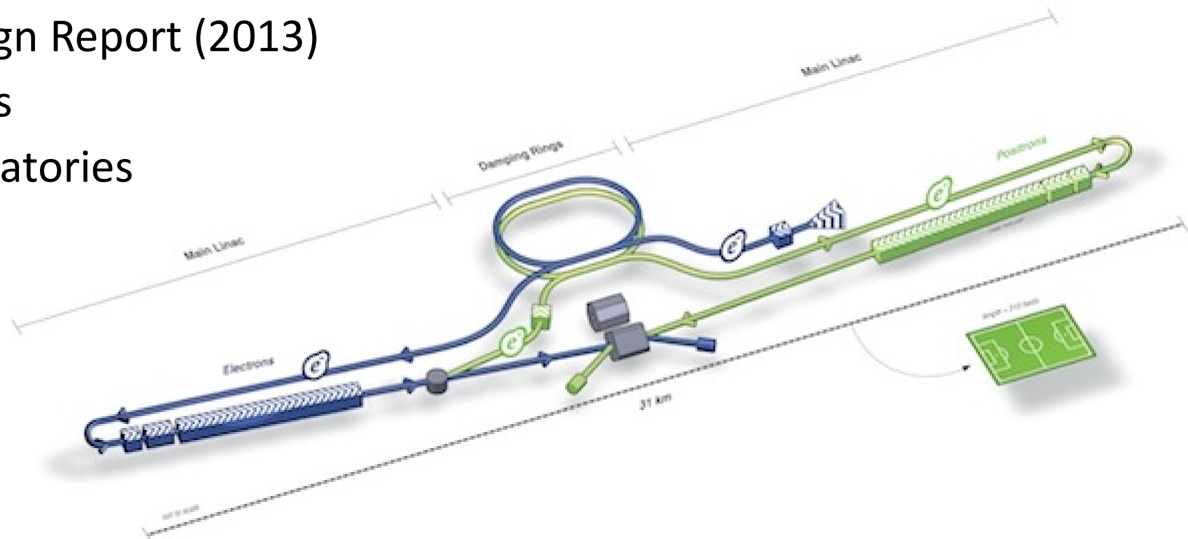


History

- In the era of the highly successful physics program at LEP (and SLC), a growing consensus developed that a higher energy electron collider was necessary to advance our field
  - due to synchrotron losses, the next step beyond LEP requires a linear rather than circular collider design
  - key elements of the physics program established
  - complementary to LHC physics
- Canada has a long standing record of participation:
  - Canadian theorists participated in studies beginning in the mid-90's.
  - In the late-90's as the LEP program was coming to an end, several physicists from OPAL began studies related to a LC TPC
  - Later, they were joined by a group working on calorimetry
- At the IPP-LRP session this week, Alain Bellerive summarized the recent activities in Canada, particularly for detectors
  - My presentation will focus on accelerators and the international scene

ILC: a well established proposal

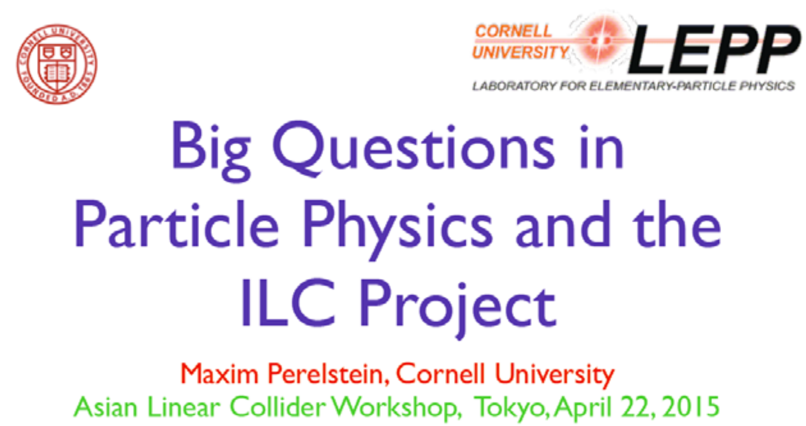
- The physics case and the technical design of the accelerator and detectors have been documented in several cycles over the years (multi-volume reports):
  - TESLA – proposal to German Government (2001)
  - ITRP – merge global effort into one design with SRF (2004)
  - Global Design Effort:
    - Reference Design Report (2007)
    - Interim Report (2011)
    - Technical Design Report (2013)
      - 5 volumes
      - 2400 signatories



Physics case

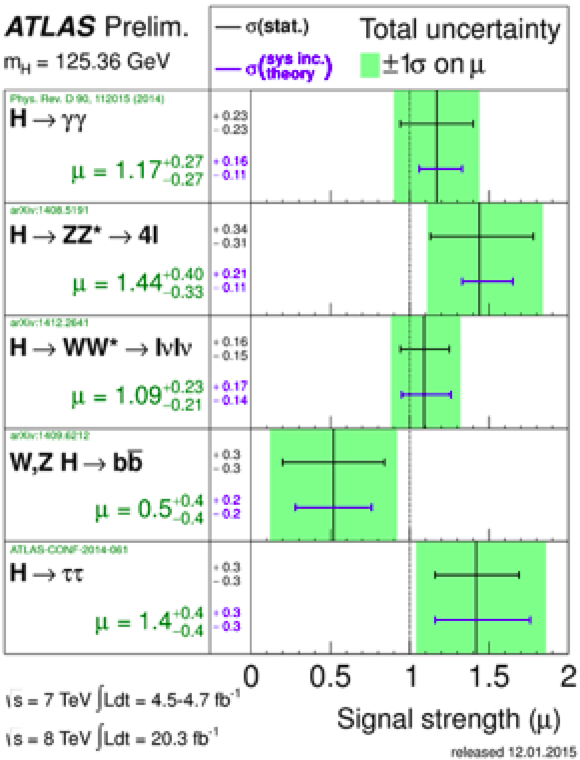
- The physics case for a future linear collider remains strong
  - Indirectly search for physics beyond the SM, using the high precision achievable at electron colliders:
    - Precision Higgs Studies
    - Precision Top Measurements
  - Direct searches for New Physics

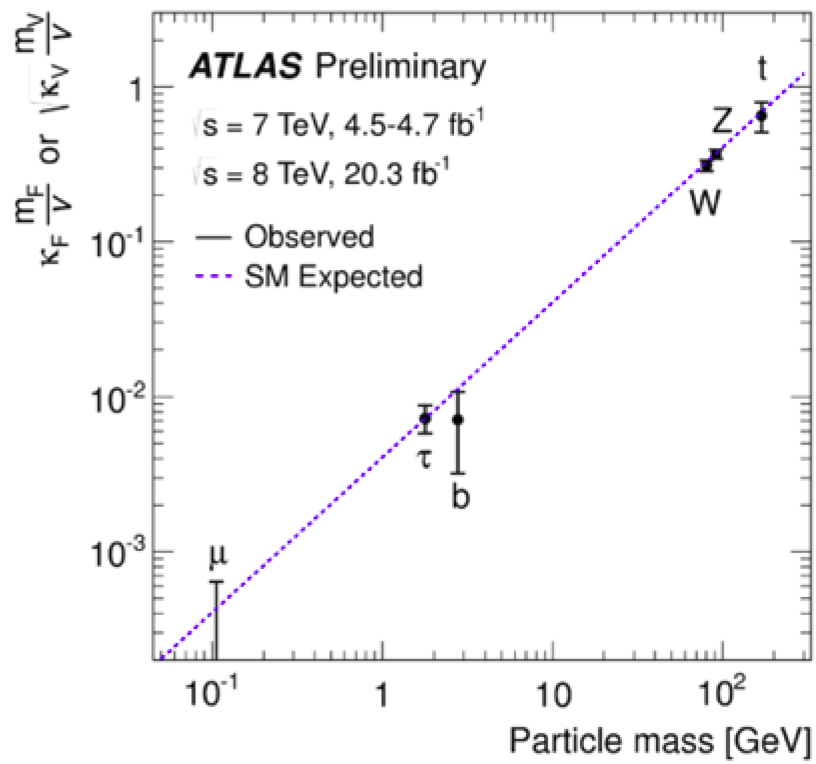
- A few examples follow, borrowing from:



Higgs: What we know from LHC

- Evidence that coupling is proportional to mass:



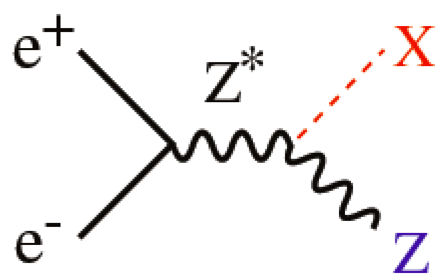


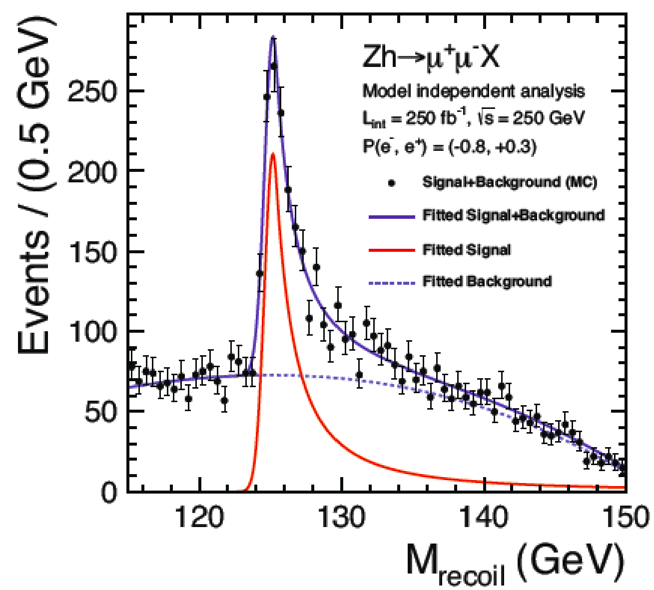
- But…. large uncertainties

Higgs: What more will a LC tell us?

- There are some caveats to the LHC rate measurements:
  - top quark coupling is inferred from loops: could by affected by other new physics
  - to convert rate measurements into coupling measurements requires a value for the total Higgs width (so SM is assumed?)
  - Higgs decays involving invisible particles will not be seen

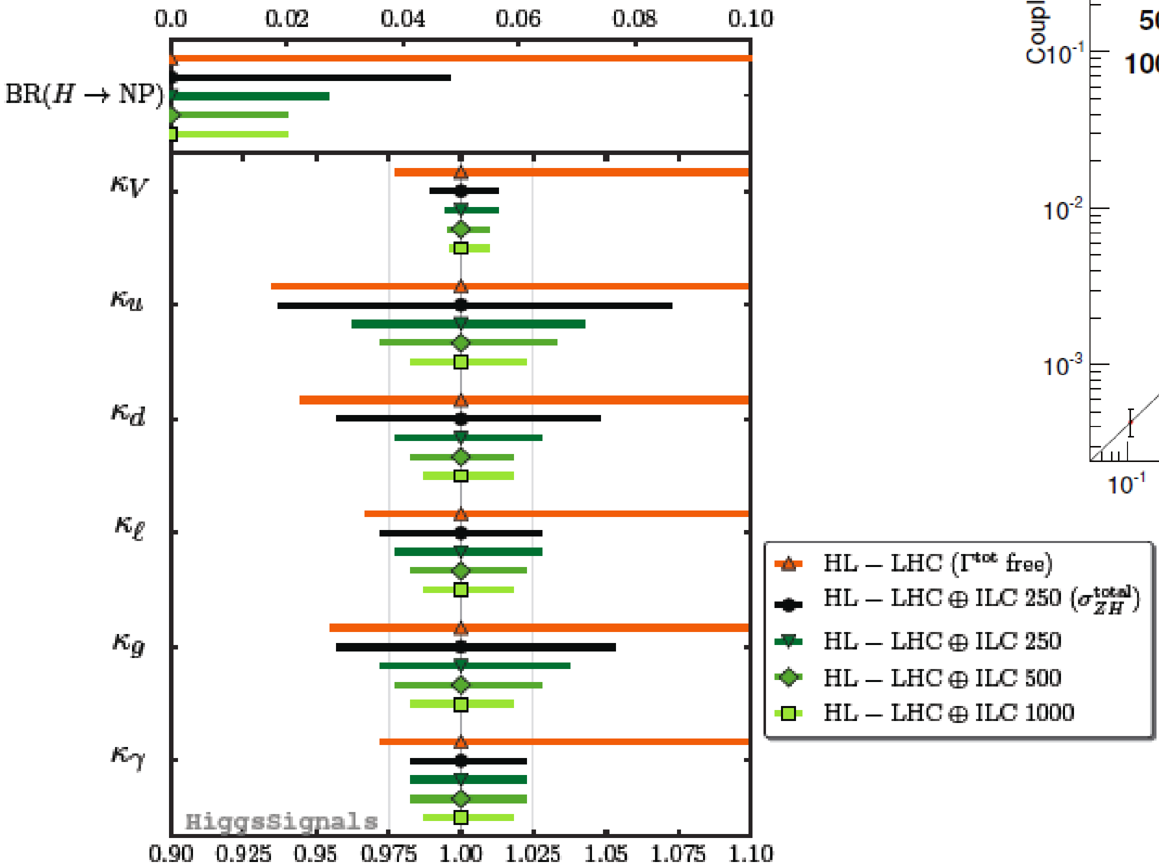
- At a LC, the "Higgsstrahlung" process allows Higgs to be tagged by the recoil Z. All decays included, so couplings can be measured.

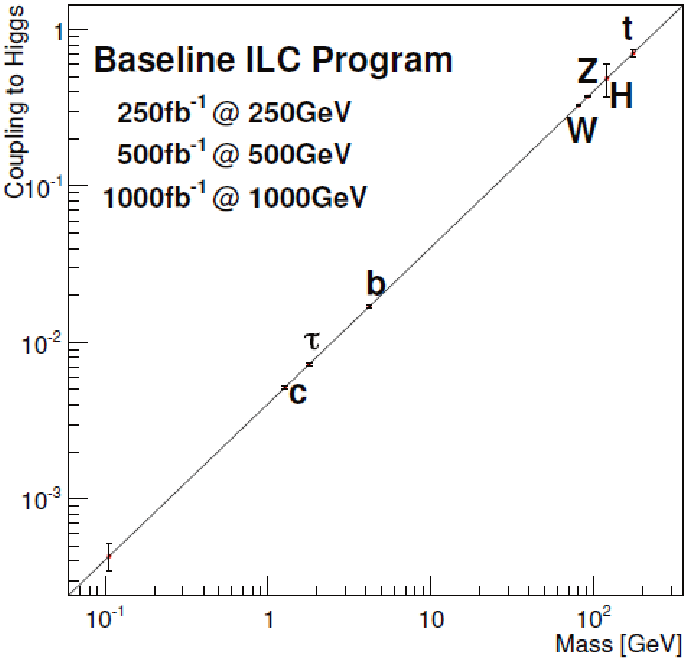




Higgs: What more will a LC tell us?

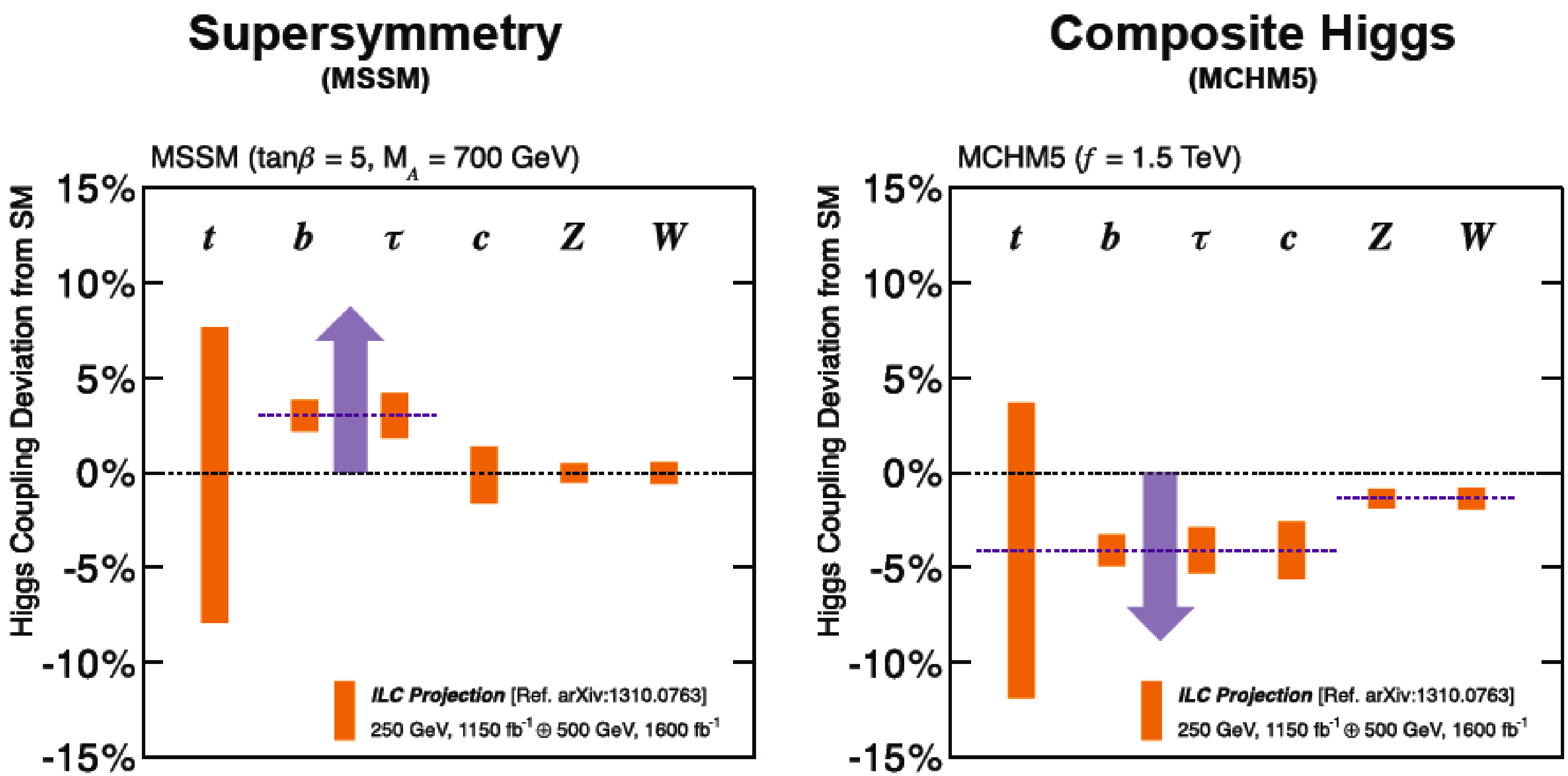
- The ILC precision will exceed even HL-LHC:





Higgs: What more will a LC tell us?

- Precision coupling measurements (1%) are important to discriminate between models:



[Asner, Barklow, et.al. '13]

Other physics examples

- LC top mass uncertainty 50-100 MeV, a factor 5-10 times better than HL-LHC projections
  - Important, as SM Vacuum is “poised precariously between stability and instability” – depending on the top mass

- LC direct searches for physics (eg. SUSY or other DM) are complementary with LHC
  - testing electron vs. quark couplings
  - lower and better understood backgrounds at a LC
  - LC brings additional sensitivity to weakly interacting states, purely hadronic or soft-jet signatures

Physics → Detector challenges

Time Projection Chamber (TPC) for ILD

TPC is the central tracker ILD

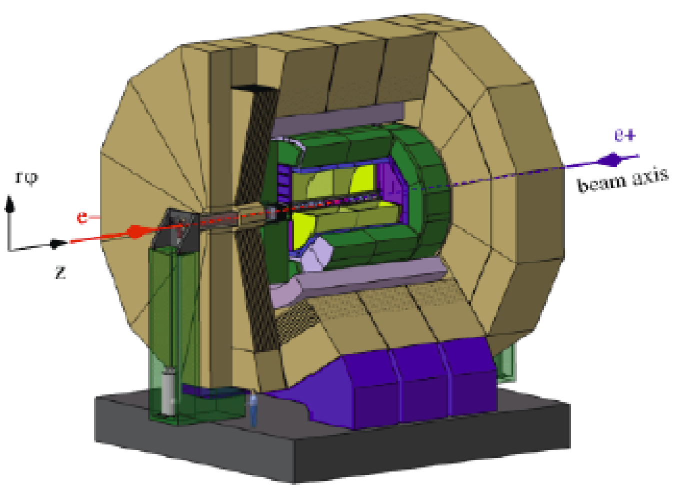
- Large number of 3D hits → continuous tracking
- More 200 positions measurements along each track
- Good track separation and pattern recognition
- Single hit $\sigma(r\phi)$ at z=0 < 60 μm

Low material budget inside the calorimeters (PFA)

- Barrel: ~5% X_0
- Endplates: ~25% X_0

TPC Requirements:

- **Momentum resolution:** $\delta(1/p_T) < 9\times10^{-5}$ GeV^{-1}
- **Single hit resolution 3.5T:** $\sigma(r\phi) < 100$ μm, $\sigma(z) < 500$ μm
- **Tracking eff.** for p_T>1 GeV: > 97%
- **dE/dx resolution** ~5%



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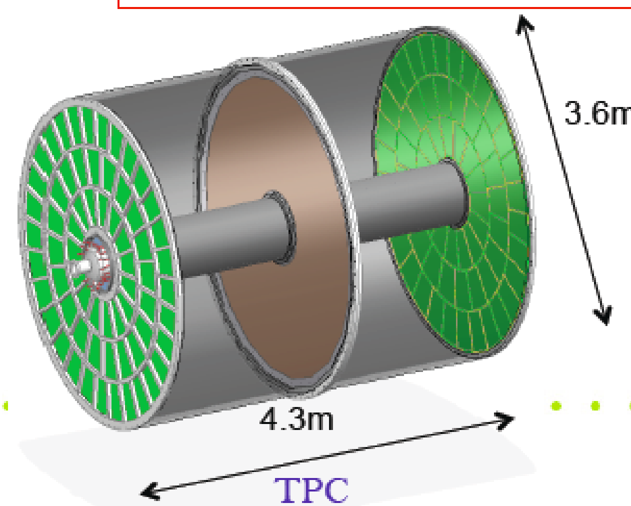
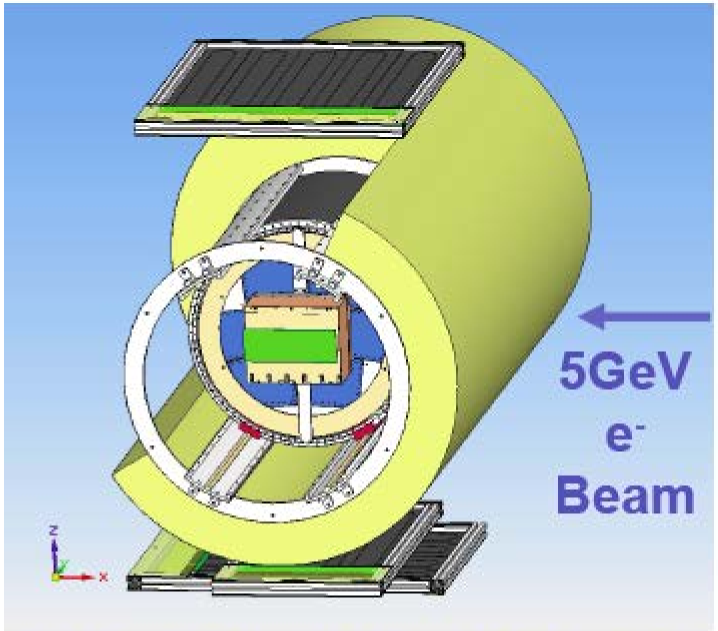


TPC

Physics → Detector challenges

Large Prototype at DESY

- Two options for endplate readout with **pads**:
  - **GEM:** 1.2×5.8 mm² pads (smaller pad – more electronics)
  - **Resistive Micromegas:** 3×7 mm² pads (larger pads – less electronics)
- Alternative: **pixel** readout with pixel size ~55×55 µm²



Physics → Detector challenges

ILC Detectors - CALICE Collaboration

CALICE is one of the largest R&D collaborations in High Energy Physics with ~360 physicists and engineers from 59 institutes out of 19 countries

Purpose:

Development, study and validation of finely segmented **imaging calorimeters**
Jet particles are measured individually
Particle Flow Algorithms are used to considerably improve jet energy resolution

Technologies:

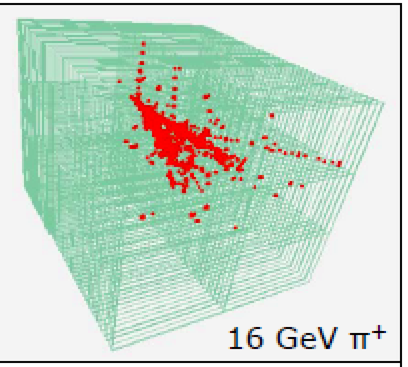
Analog vs Digital, as novel type of calorimeter
Silicon / Scintillator / MAPS / RPC / GEM / Micromegas

Synergy:

Common meetings with members of the Geant4 team
CALICE provides them a wealth of detailed data
(shower development, physics lists, ..)
Not only for ILC/CLIC detectors
Under consideration: CMS endcaps, ALICE forward calorimeter, ..

Physics → Detector challenges

CALICE - McGill Group



Composition (since 2006):
- 1 Faculty: François Corriveau
- 3 M.Sc. students:
  - Daniel Trojand (2009), Benjamin Freund (2013), Isabelle Viarouge (2015)
- 14 Undergraduate students (6 from Germany)

Past projects:
- SiPM-tile coupling, test beam data analyses (e.g. angular resolution, calibration)

Current project:
- DHCAL with Argonne National Laboratory, the 1st digital hadronic calorimeter!
- McGill contributed to the construction of the 1 m^3 prototype (480,000 channels)
- 2 DHCAL-specific publications, 1 in preparation + 8 CALICE papers
- Results on linearity, calibration, energy resolution. Extremely low noise.

DHCAL with minimal absorber:
- All steel absorber plates are removed
- 50 layers with each only 0.4 X_0 or 0.04 λ_I
- Unprecedented level of details
- Of special interest for shower simulation
- Test beams with e^+, π^+, μ^+ (1-10 GeV)
- Preliminary result on resolution:

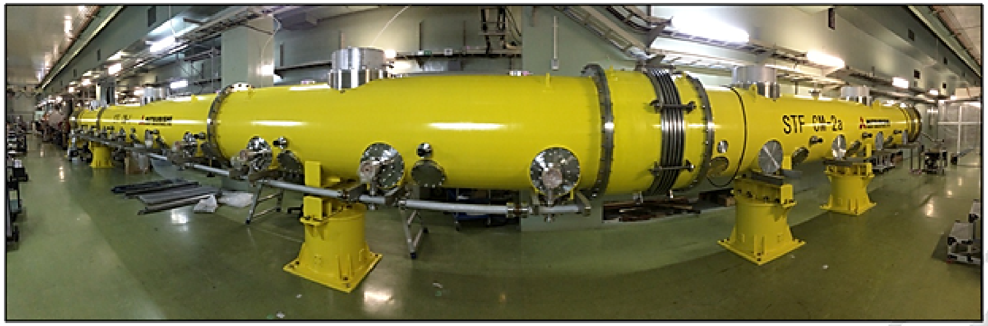
$$\frac{\sigma}{E} = 6.5\% \oplus \frac{12.4\%}{\sqrt{E}}$$

ILC accelerator status

- The Technical Design Report (not site specific) was completed and published by the GDE in 2013
- Current focus: site specific design issues and continuation on SRF technology development
- ILC cyromodule test at Fermilab reached design goal of 31.5 MV/m (across entire module of 8 cavities) in 2014
- Ongoing SRF industrialization in construction of XFEL at DESY
- Currently operating test systems:
  - KEK – ATF2: goal to reach 37 nm beam size (44 nm achieved)
  - KEK – STF: string tests

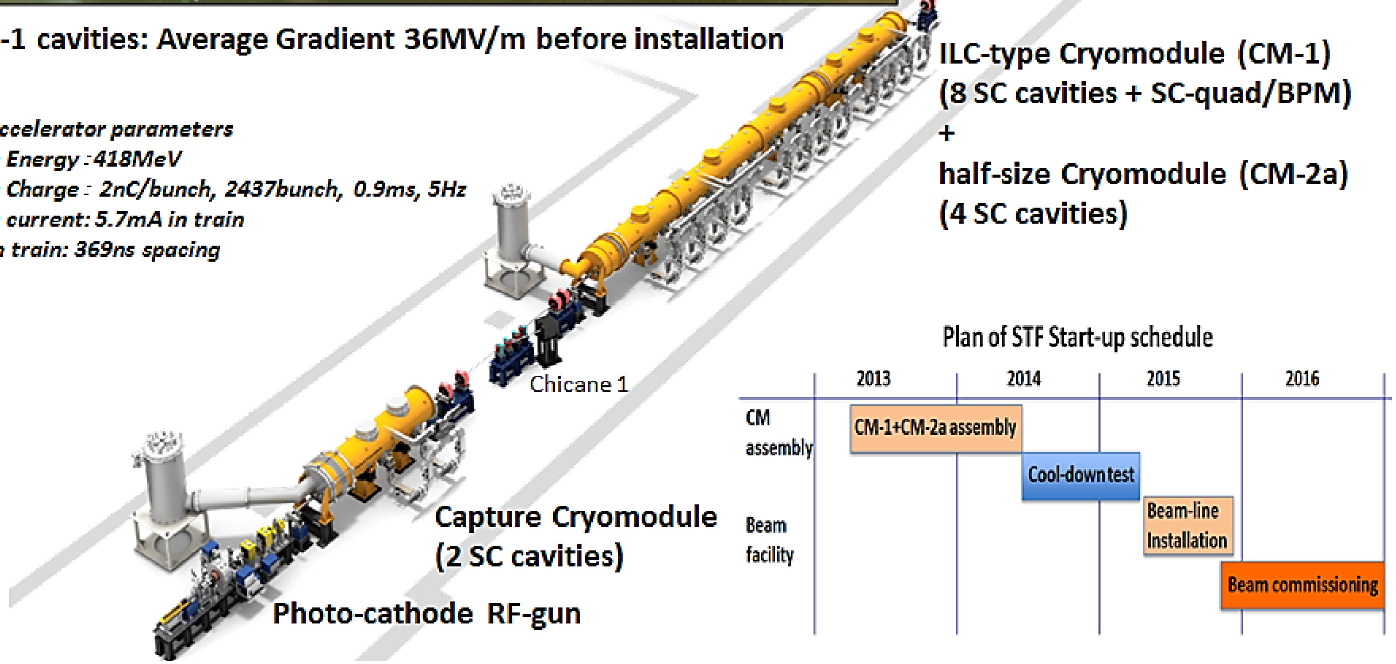
ILC facilities at KEK

ILC STF Accelerator under construction



CM-1 cavities: Average Gradient 36MV/m before installation

STF Accelerator parameters
Beam Energy :418MeV
Beam Charge : 2nC/bunch, 2437bunch, 0.9ms, 5Hz
Beam current: 5.7mA in train
Bunch train: 369ns spacing



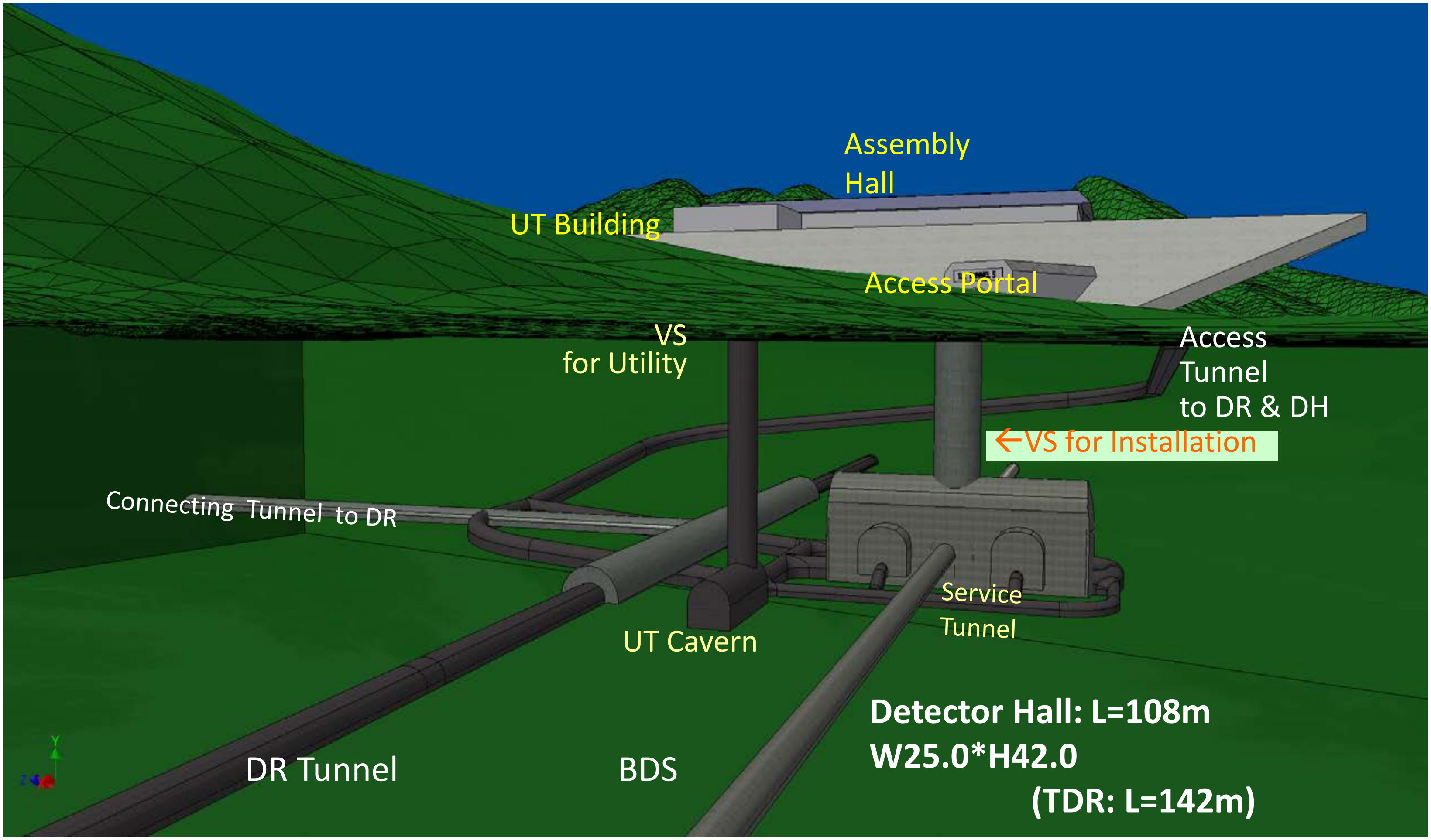
ILC facilities at KEK

Superconducting Application Promotion Center

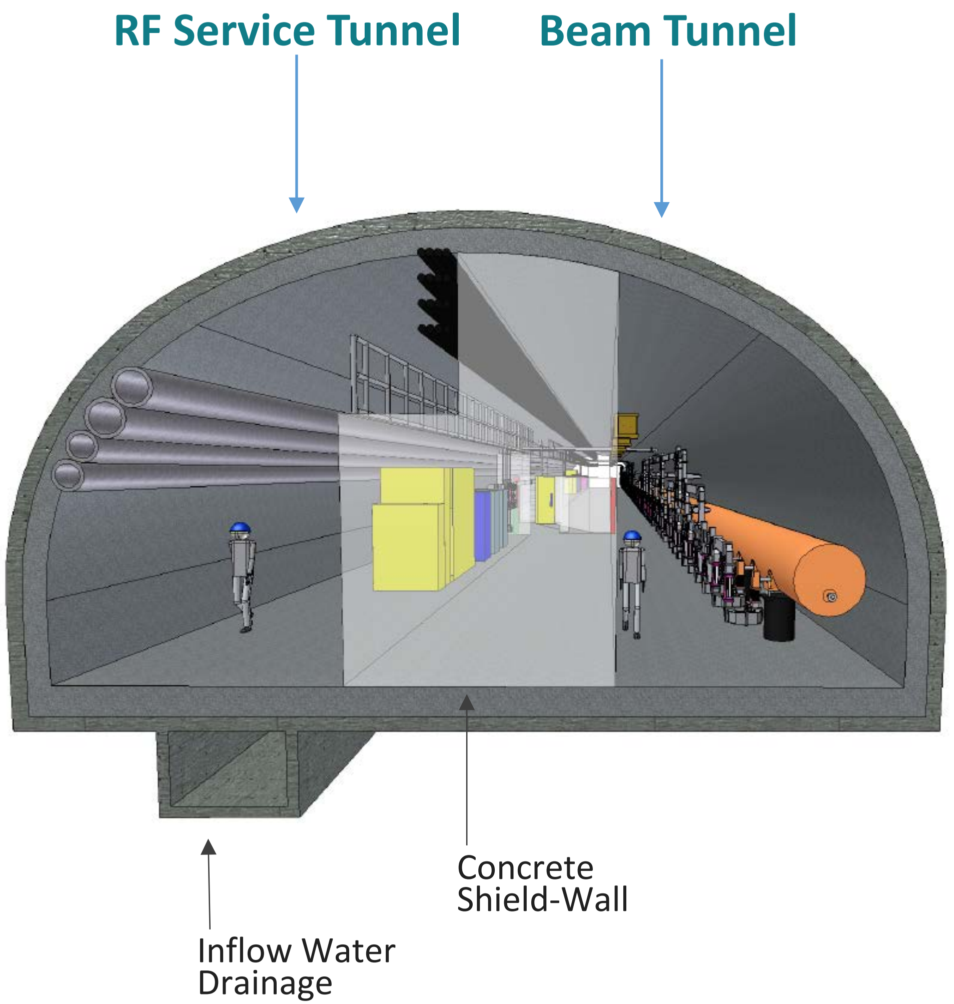
H. Hayano

As of January, 2015

Site specific designs underway

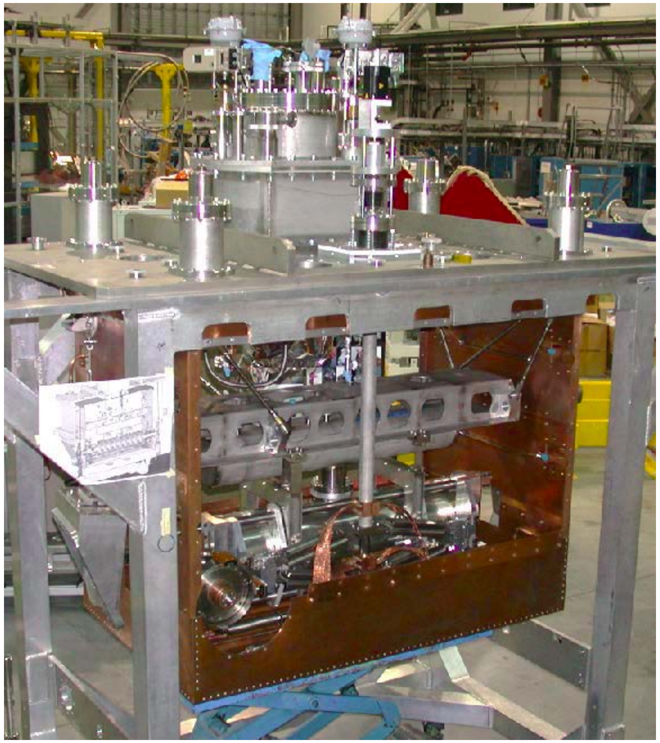


Single tunnel concept



Canada and ILC accelerator technology

- The ILC SRF cavity design at the heart of the ARIEL e-linac at TRIUMF
  - End group design modified for high power operation
  - Worked with local company (PAVAC) to develop SRF manufacturing capability in Canadian industry



Canada and ILC accelerator technology

- ARIEL-I phase completed with the first commissioning of the e-linac, September 2014.

Japan and the ILC

Support from policy-makers:

Federation of Diet Members (Multiple Parties)

Chair: Mr. Takeo Kawamura
Secretary-General: Mr. Ryu Shionoya

(150+ Diet Members, March 2014)

August 6, 2013 Presented Resolution and Policy Report to PM Shinzo Abe

"The ILC should be promoted as a Prime Minister project, to be funded separately from the normal government budget, in the growth-for-Japan framework in view of the national strategic areas" (partial translation of resolution)

Support from Business Communities

- Japan Association of Corporate Executives (April 2013, August 2013)
- Japan Chamber of Commerce and Industry (August 2013)
- Japan Business Federation (January 20, 2014)

Prime Minister Shinzo Abe (interviews by Media in Dec. 2014)
"Project merit is understood. Japanese government has started reviews on the project. Issues are cost and especially international sharing."

Japan and the ILC

US - Japan

January 2014, MEXT Minister Shimomura @ Washington, DC
Meeting with **Dr. Ernest Monitz, Secretary of Energy**

December 2014

From the Facebook page of MEXT Minister Shimomura

Hakubun Shimomura
January 10 ·

モニーツ米国エネルギー省長官を訪問し、国際リニアコライダー計画などについての会談を行いました。

Discussed with Secretary Monitz on ILC et al.

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January 2014, Washington DC
Mr. Kosaka meeting with **Dr. E. William Colglazier, Science and Technology Adviser to the Secretary of State**

Recognize ILC as an important project

Mr. Kenji Kosaka
Vice-Chair, Federation of Diet Members for ILC

Japan and the ILC

Meeting with Dr. John P. Holdren, Assistant to the President for S&T, Director of OSTP

July 23, 2014, White House, Eisenhower Executive Office Building

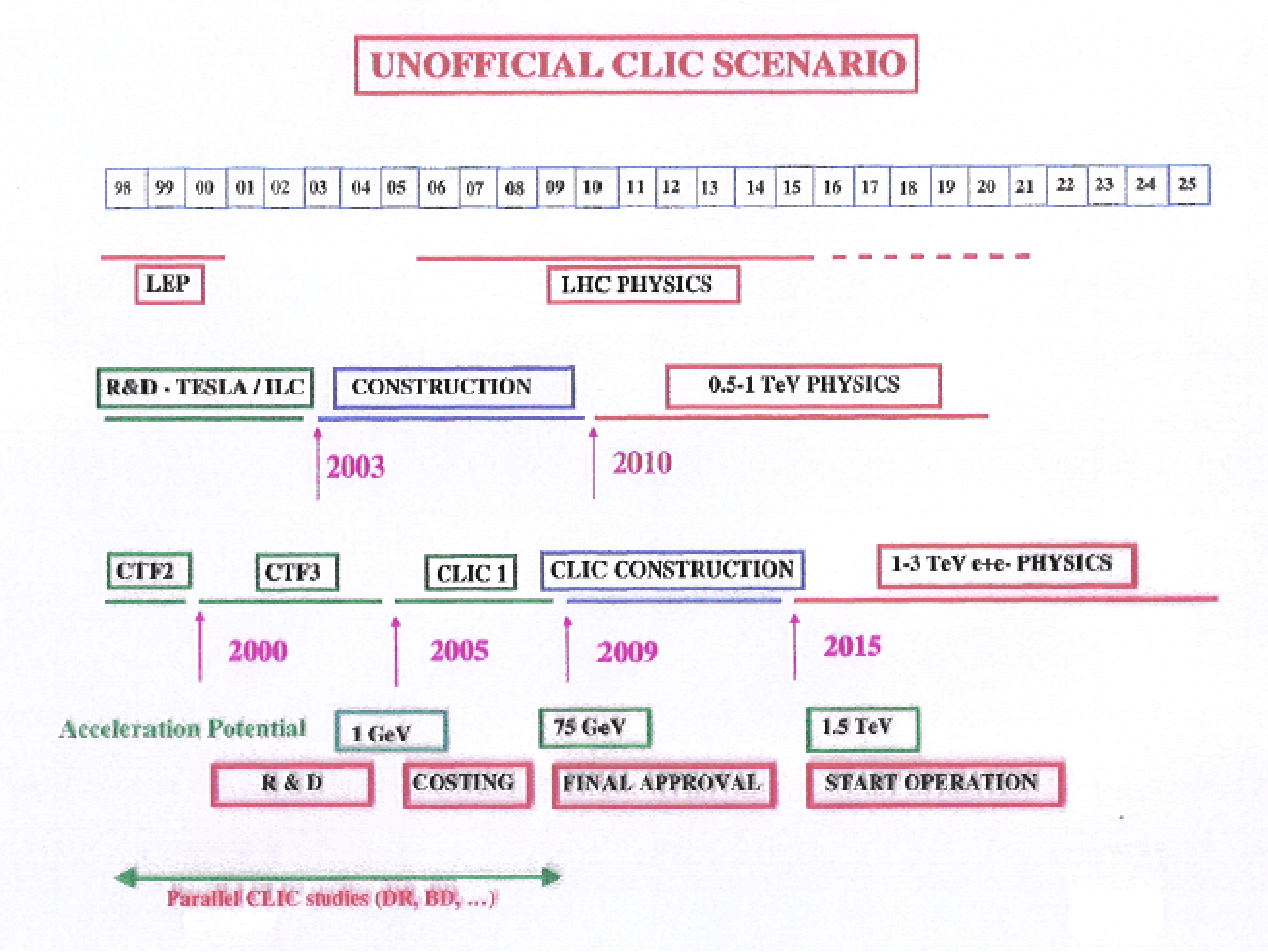
ILC Tokyo Event, April 22, 2015

- ALCW moved to Tokyo – to hear from political leaders
- Keynote address from Hiroya Masuda, Chairman of the Japanese Policy Council (and former Iwate governor)
  - Japan faces a crisis of rapidly declining population
  - Government policy to promote immigration from large cities to rural areas
  - Interest in attracting researchers from around the world


特定猟具使用禁止区域
（ 銃 ）
茨 城 県
CERTAIN HUNTING EQUIPMENT
PROHIBITED AREA
(GUN)
IBARAKI PREFECTURE

Looking back…

- Circa 2000



Upcoming workshop and school