Energy Extendibility of ILC

Group D

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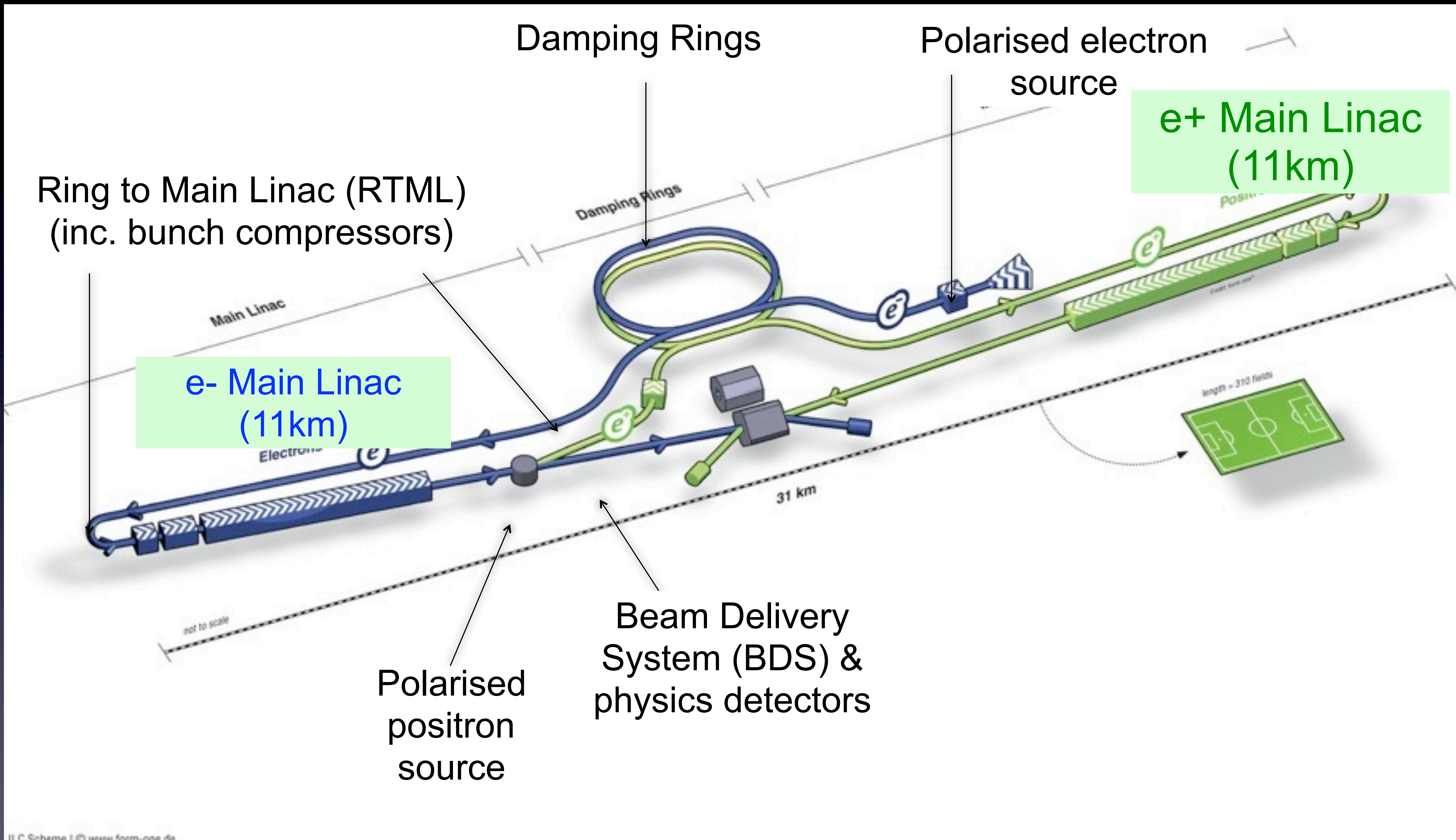
ILC Accelerator Outline



- $\sqrt{s}/2$ = accelerating gradient x ML (site) length
- 31.5MV/m x 11km x 0.72 = 250GeV

TeV Upgrade : From 500 to 1000 GeV

Assume Higher Gradient

Main Linac

$\langle G_{cavity} \rangle = 31.5$ MV/m

$G_{eff} \approx 22.7$ MV/m

(fill fact. = 0.72)

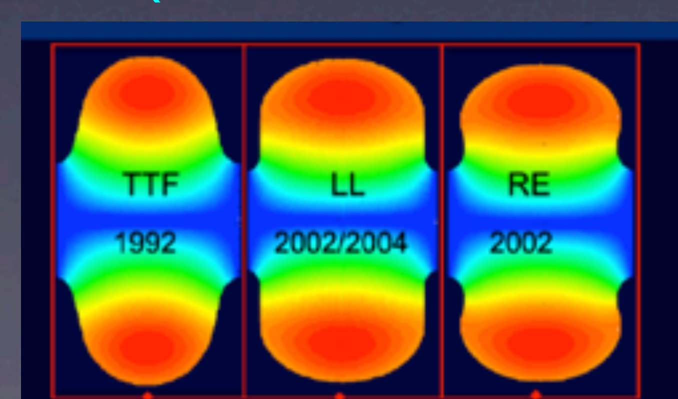
IP

central region

Snowmass 2005 baseline recommendation for TeV upgrade:

$G_{cavity} = 36$ MV/m $\Rightarrow$ 9.6 km

(VT $\geq$ 40 MV/m)



Based on use of low-loss or re-entrant cavity shapes

N.Walker, granada

The Issue

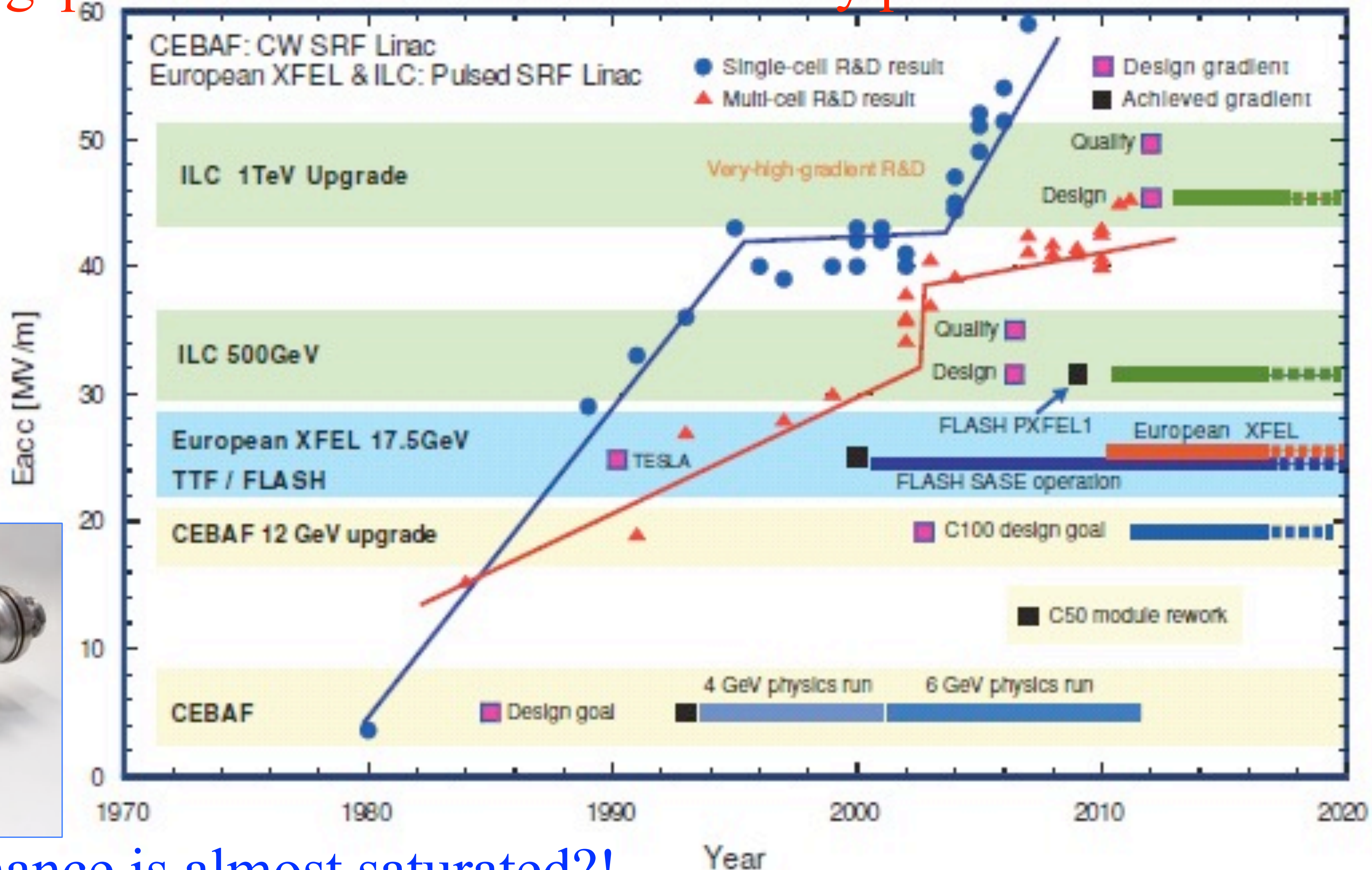
- $\sqrt{s}/2$ = accelerating gradient x ML (site) length
- Question: how high an energy can we reach eventually at Kitakami site?
  - How high is the ultimate accelerating gradient?
    - 500GeV machine design is based on the average accelerating gradient 31.5MV/m in cavities
  - How long is Kitakami site?
  - Don’t care about the cost

Accelerating Gradient

Development of Niobium Cavities
Comparison of 1- and 9-cell performance

There is large gap between 1-cell and 9-cell cavity performance!

Figure 2.20 L-band SCRF niobium-cavity-gradient envelope and gradient R&D impact on SCRF linacs.



9-cell cavity

9-cell performance is almost saturated?!

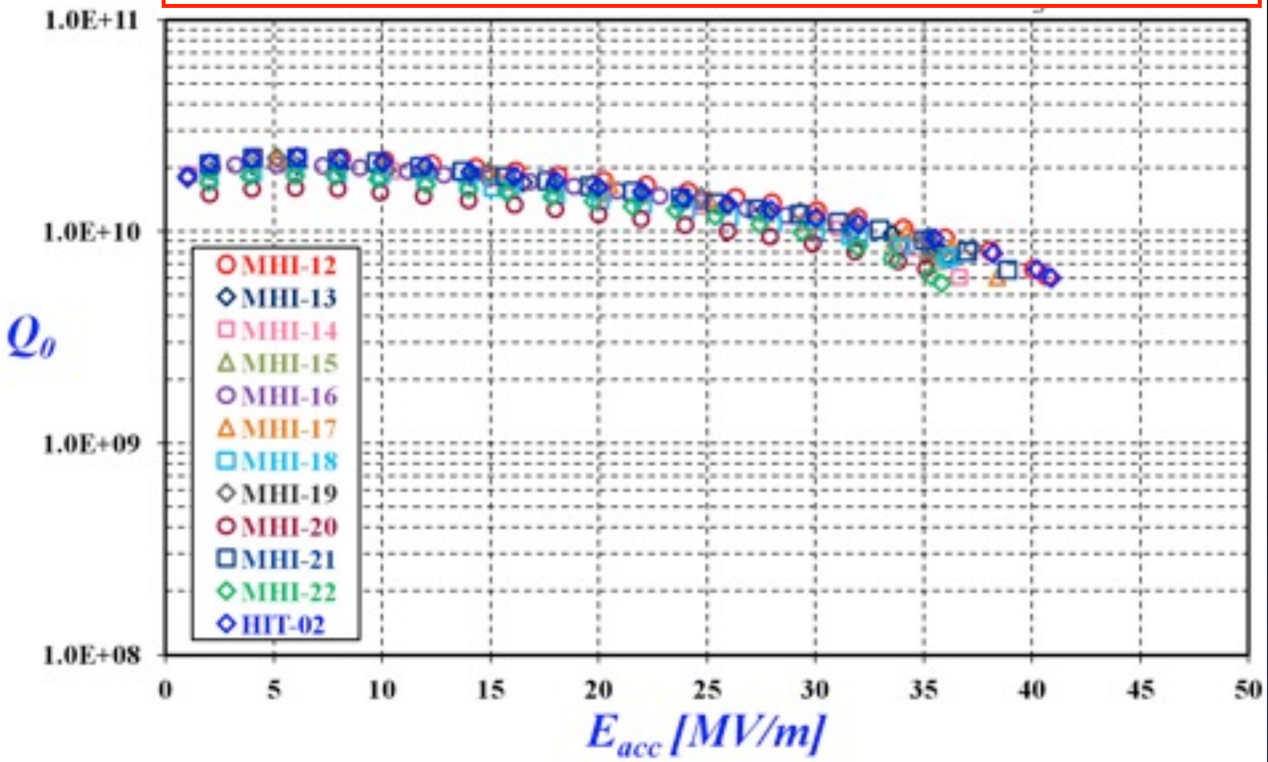
K. Yamamoto

CM Energy vs. Site Length

- The final center-of-mass energy is
  Ecm = 500 + (L-31)*(G/45)*27.8 (GeV)
  - e.g., L=50km, G=31.5MV/m → 870GeV
    L=50km, G=45MV/m → 1030GeV

Recent Cavity Performance in KEK

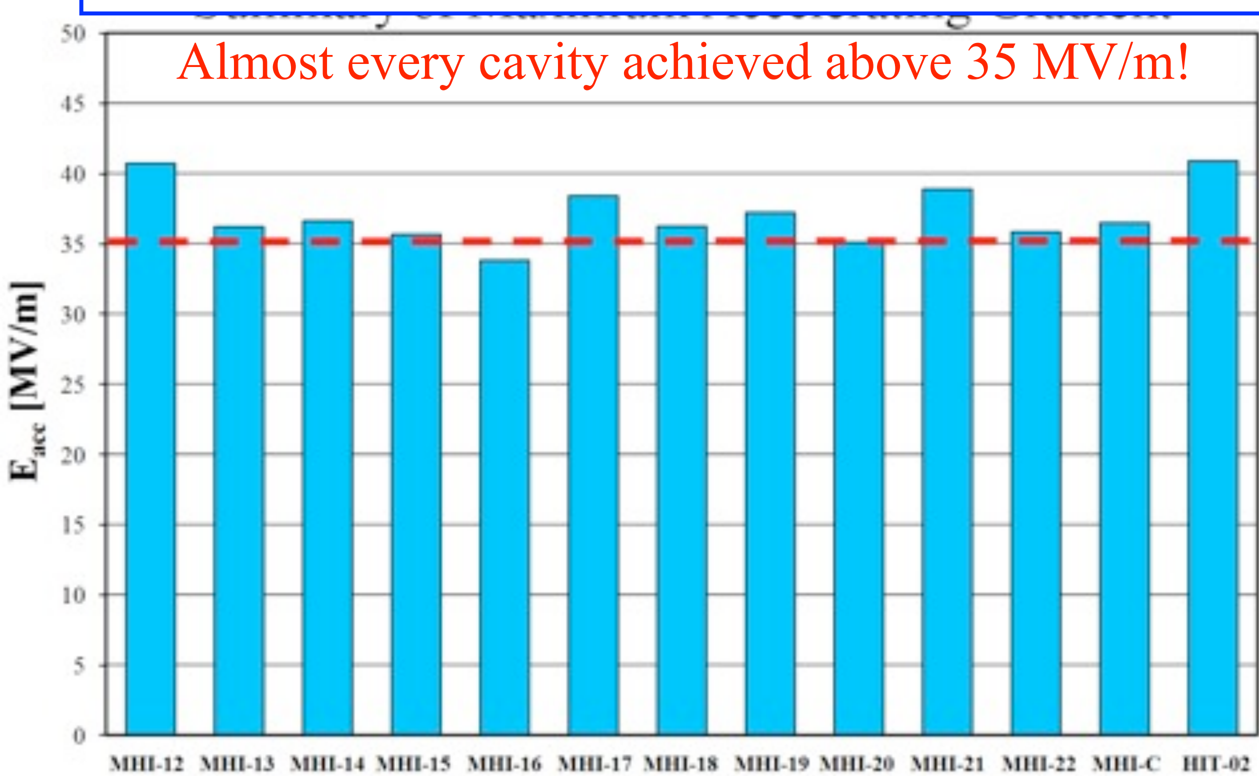
Q_0 – Eacc Curve for Recent Cavities



- All cavities achieved above 35 MV/m
- Averaging gradient 37.1±2.0 MV/m
- HIT-02 achieved 41 MV/m (Japan record).

ILC spec.: 35 MV/m ± 20%

Maximum Gradient for Recent Cavities



Almost all cavities were **limited by administration limit**.
Typically, that is the RF power limitation.

This means the cavity performance becomes higher possibly.

We can achieve around 40 MV/m possibly!

K. Yamamoto

What approach can we take?

According to TDR (Volume 3, Part 1, Page 28)...

1. Cavity Shape
   - Low Loss, Re-Entrant, Low Surface Field
2. Material (niobium)
   - Large Grain, Seam-less
3. Surface Treatment
   - Recently, new idea trying
4. Packing Factor of Cryomodule
   - Exchanging Q-mag to Cavity

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① Cavity Shape

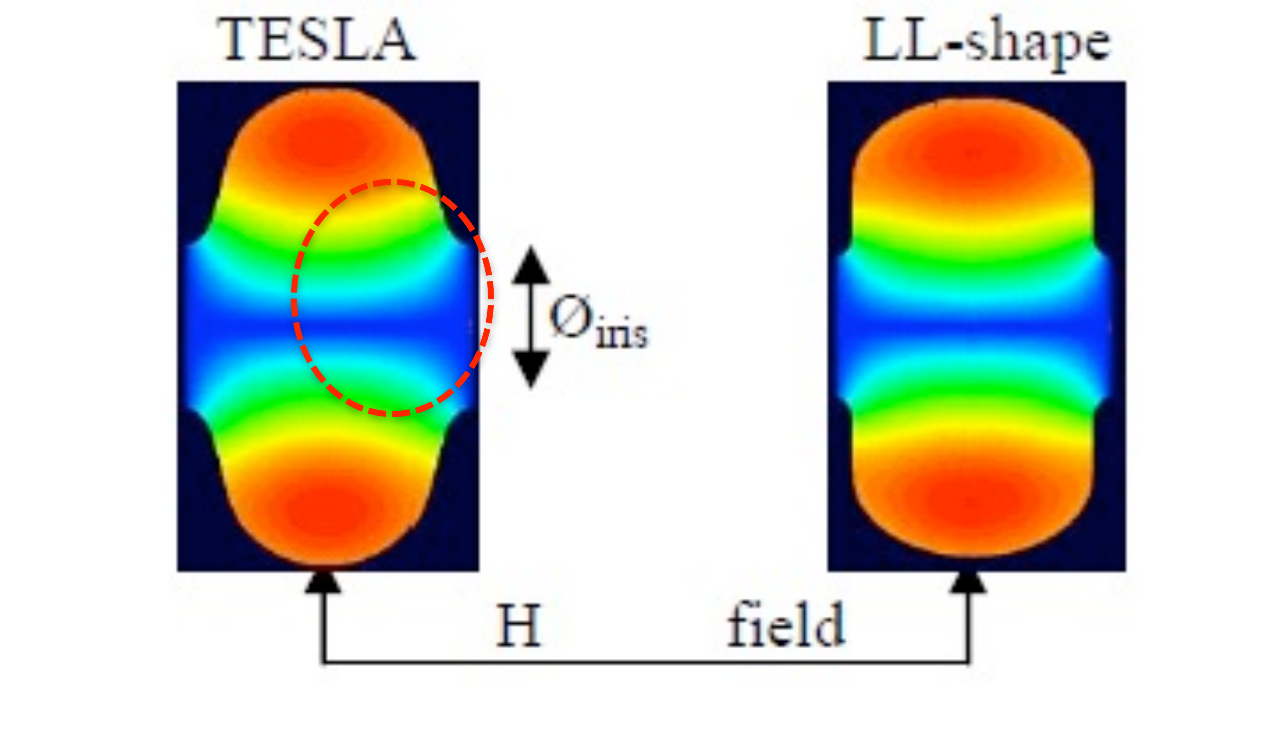
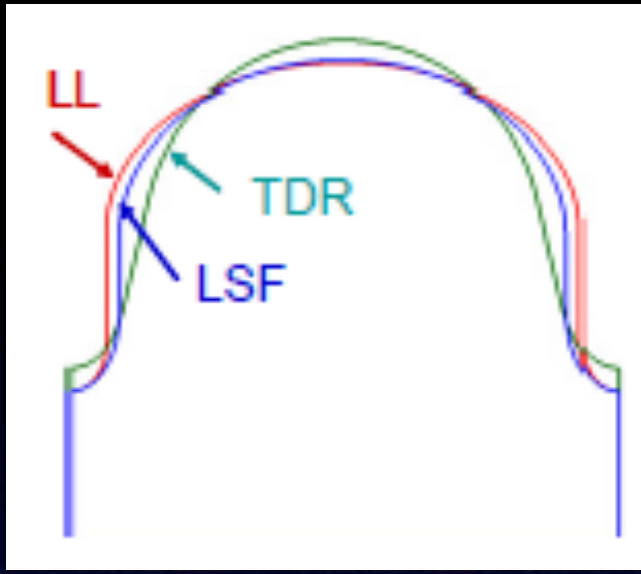
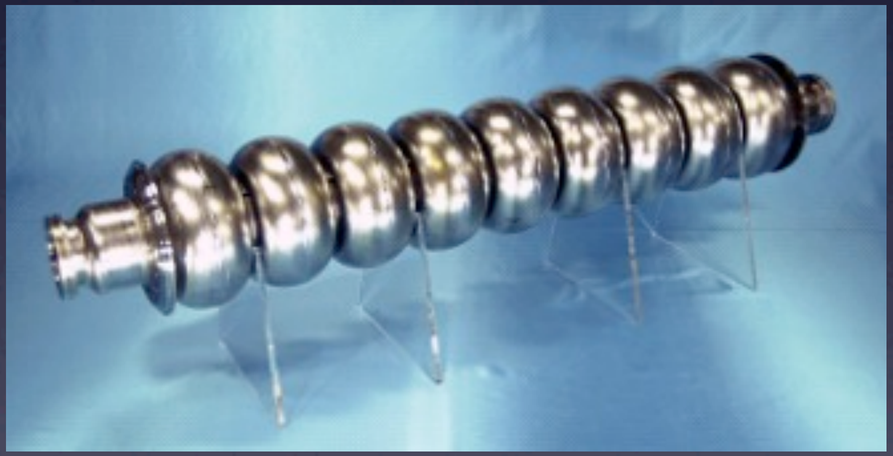


Figure 1: H contour in two shapes of inner cell.





Reduce the maximum magnetic field on the niobium surface

K.Yamamoto

Remarks of Rongli Geng at IWLC2010

Final Remarks

- Baseline cavity technology R&D a success
  - TDP-1 gradient R&D milestone of 50% yield at 35 MV/m on "global" bases delivered.
  - Gradient advanced – practical gradient limit in 9-cell cavity raised to 38 – 42 MV/m.
  - An example of 90% yield at 35 MV/m w/ Q0 8E9 set based on 10 cavities built by one vendor and processed at one lab without bias.
  - TDP-2 gradient goal of 90% yield at 35 MV/m on global bases can be expected.
- Alternative shape cavity work should increase
  - Important for ILC TeV upgrade.
  - 9-cell demonstration of 45-50 MV/m can be expected by end of this year.
- Very-High-Gradient issues & countermeasures need studies
  - What is the nature of quench at 35 – 55 MV/m?
  - What is the nature of sudden turn on "event" at > 40 MV/m?
  - What HOM coupler design changes are needed for VHG cavities?
- Focused material R&D important for SRF based LC
  - 60 MV/m seems within reach of niobium material.
  - New material is the future for > 60 MV/m.
  - Likely path is thin film coated cavities.

H. Hayano

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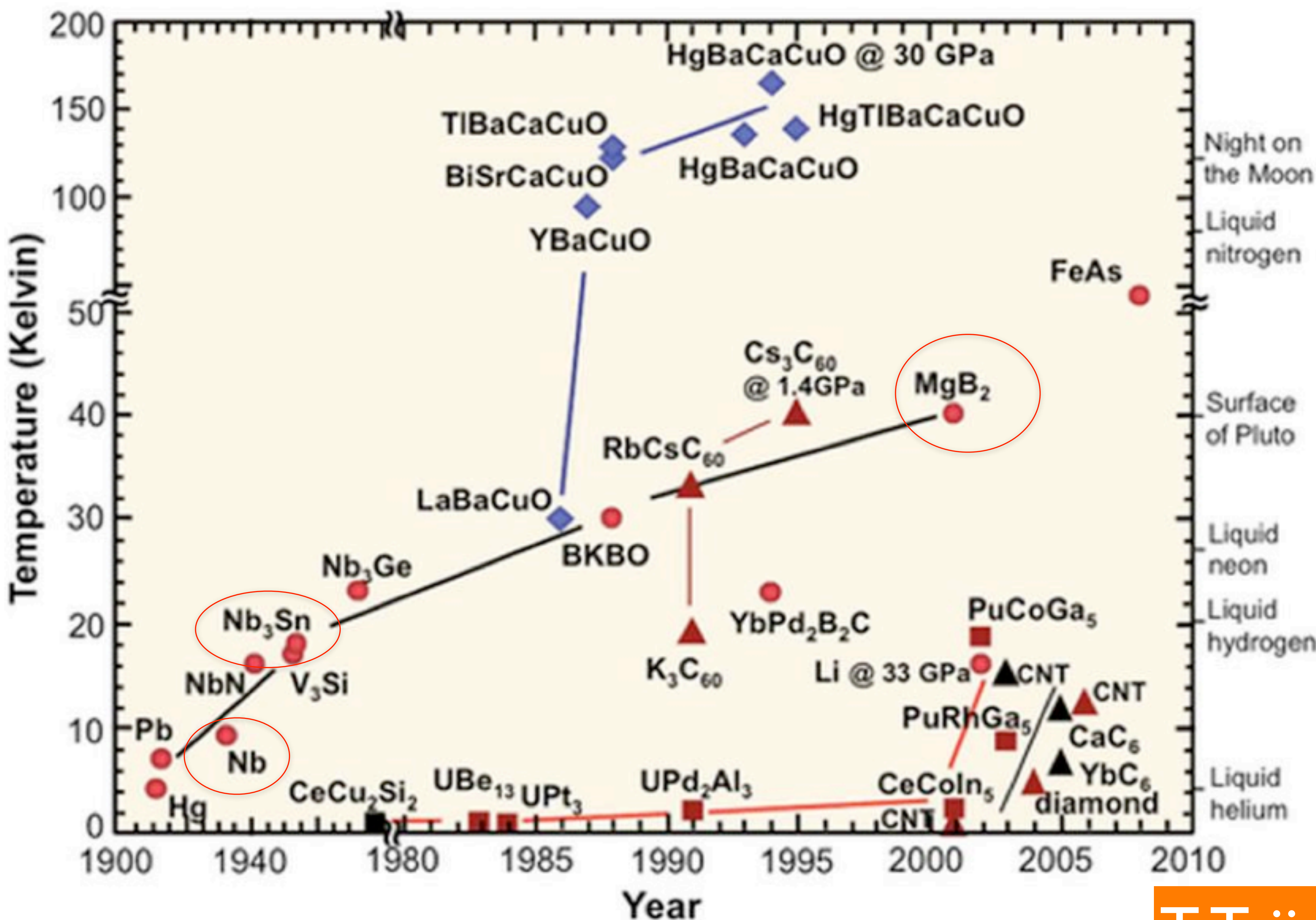
Discoveries of Superconductors

http://en.wikipedia.org/wiki/File:Sc_history.gif



T. Tajima

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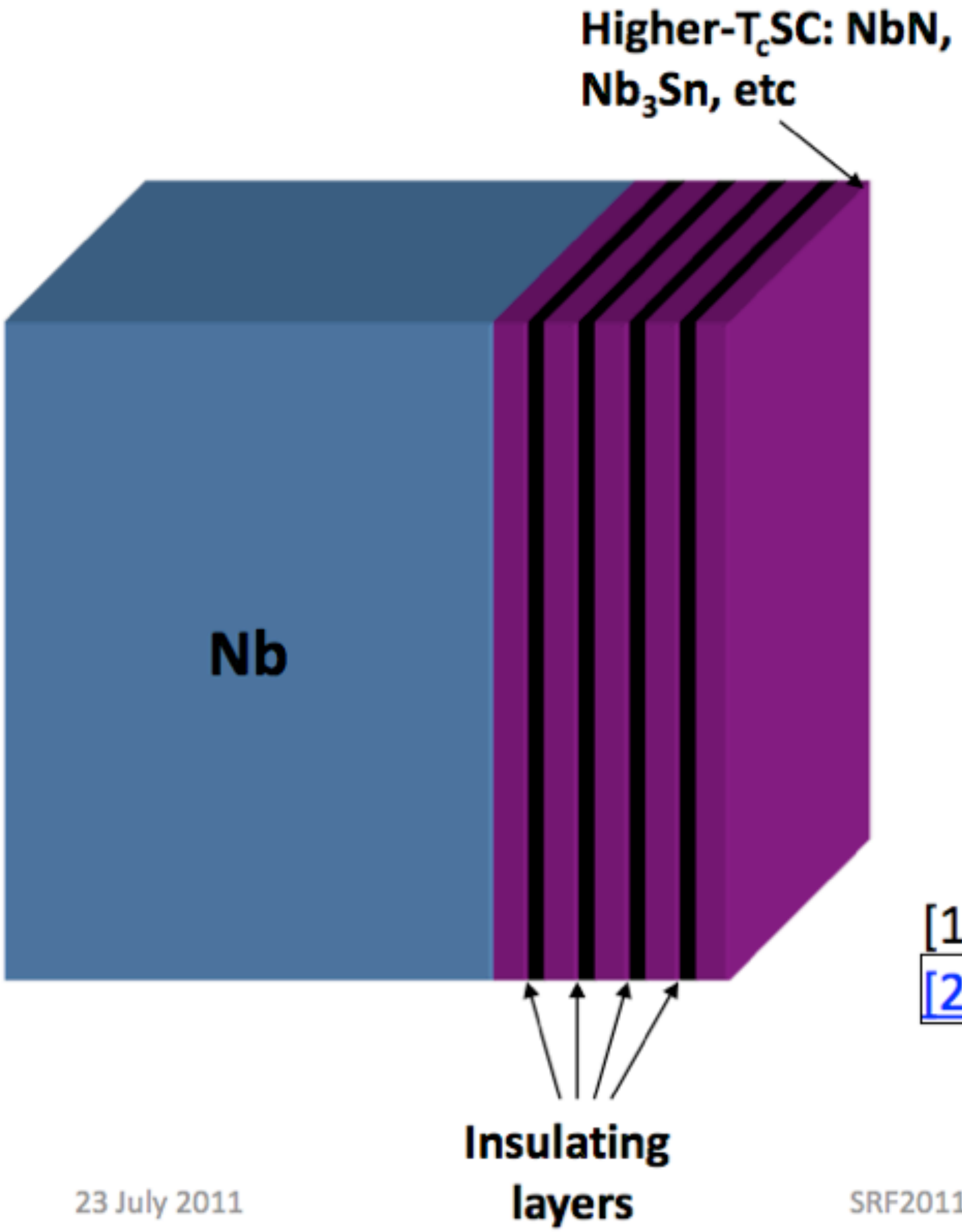
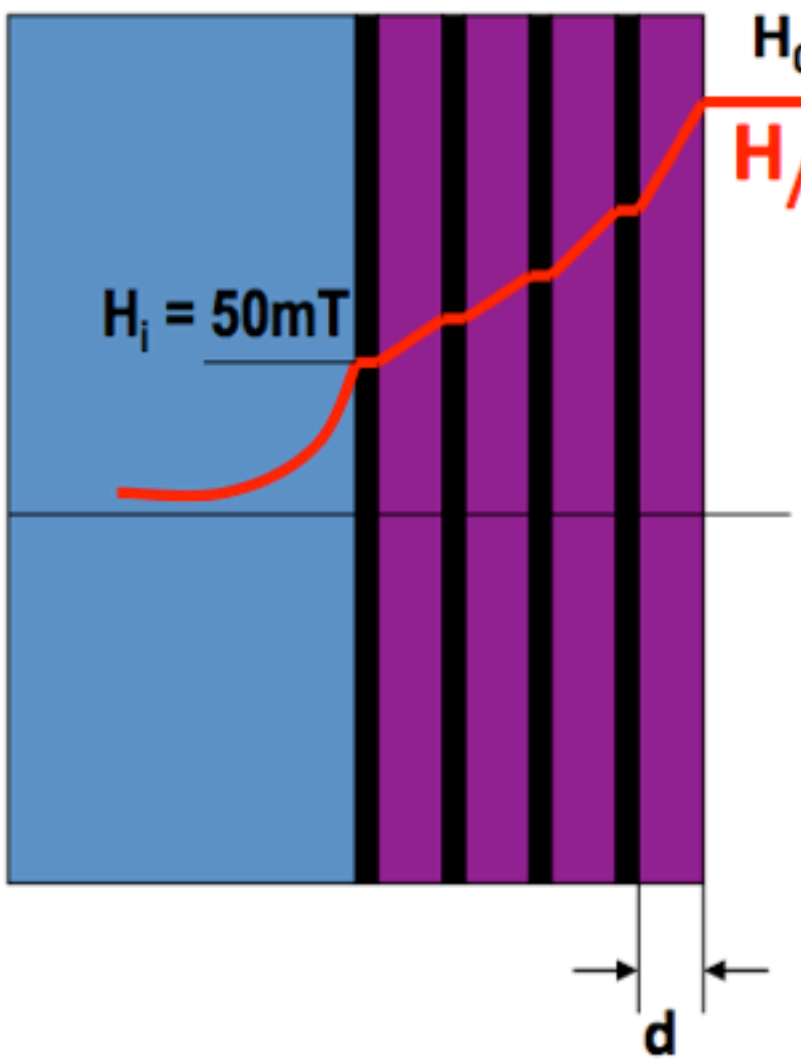
Multilayer thin film superconductors concept proposed by Alex Gurevich [1, 2]





[1] A. Gurevich, APL **88** (2006) 012511

[2] A. Gurevich, SRF Materials Workshop, FNAL, 23-24 May 2007

Application of "thin-film on Nb" to ILC?

- Required Technology;
  - nm-level Smooth Nb cavity surface,
    Tumbling, electro-polish, etc.
    Hydroforming without welding.
  - Well controlled thin-film formation on Nb cavity,will be required.
    Atomic Layer Deposition (ALD)
- Then, we can reach >100MV/m with TESLA cavity

H.Hayano

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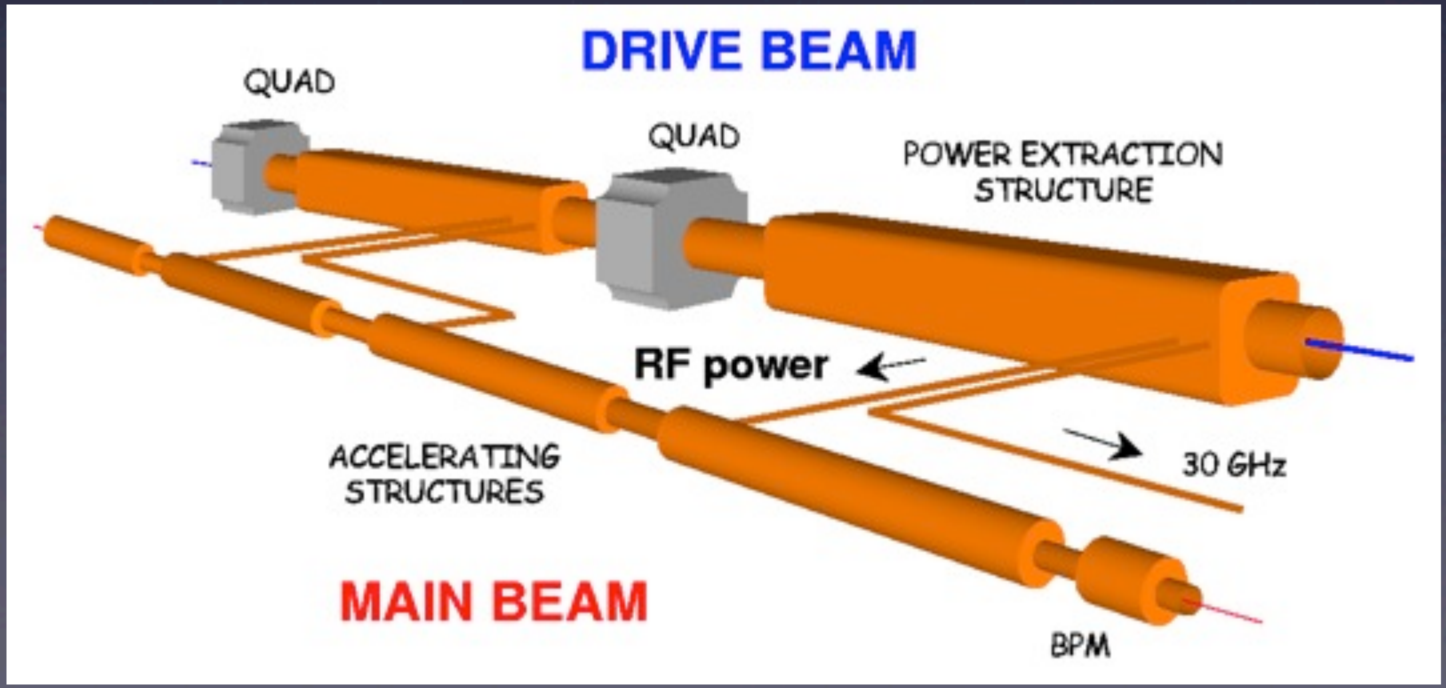
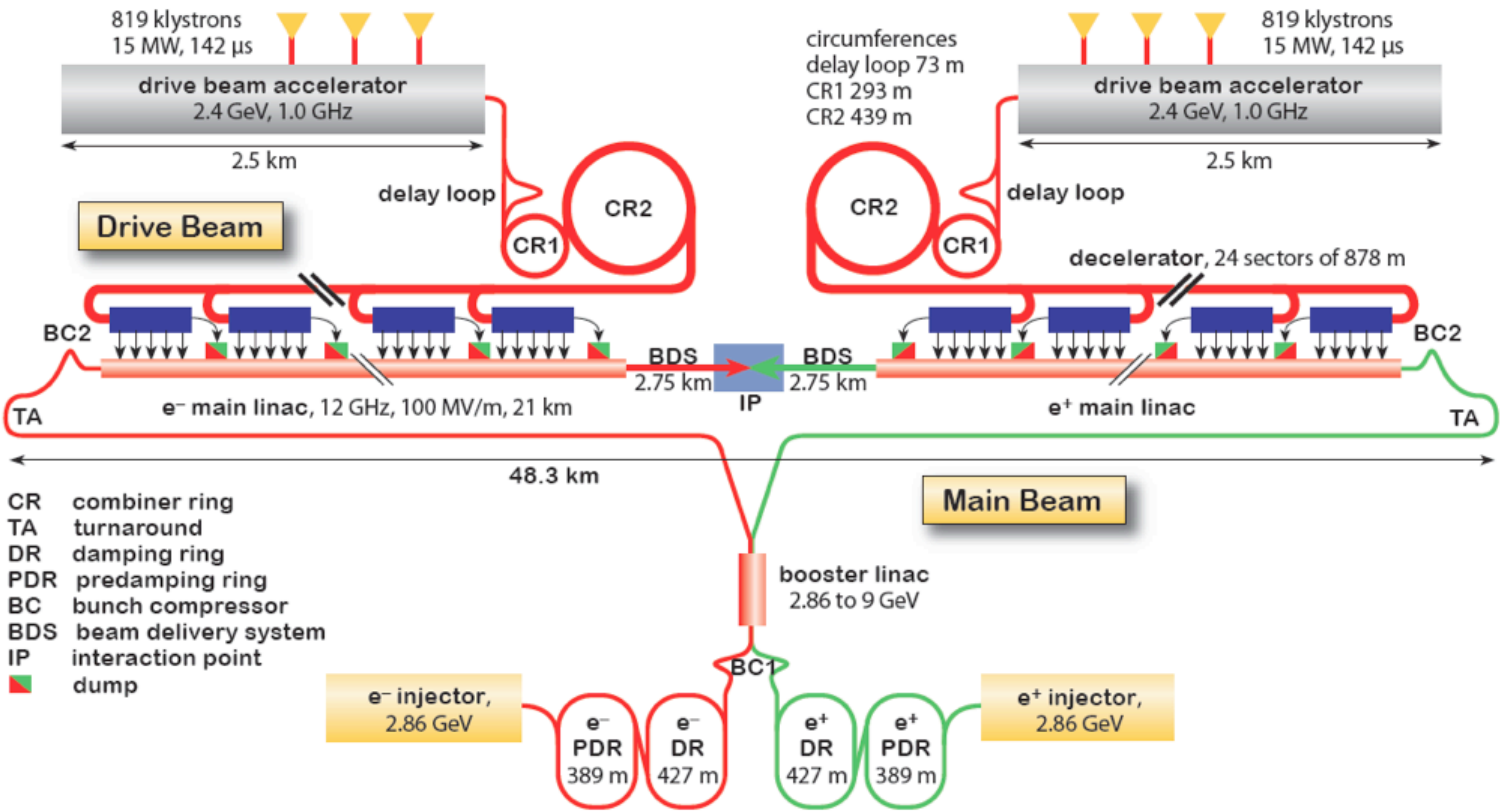
    L=50km, G=60MV/m → 1200GeV
    L=50km, G=100MV/m → 1670GeV

CLIC (Compact(CERN) Linear Collider)

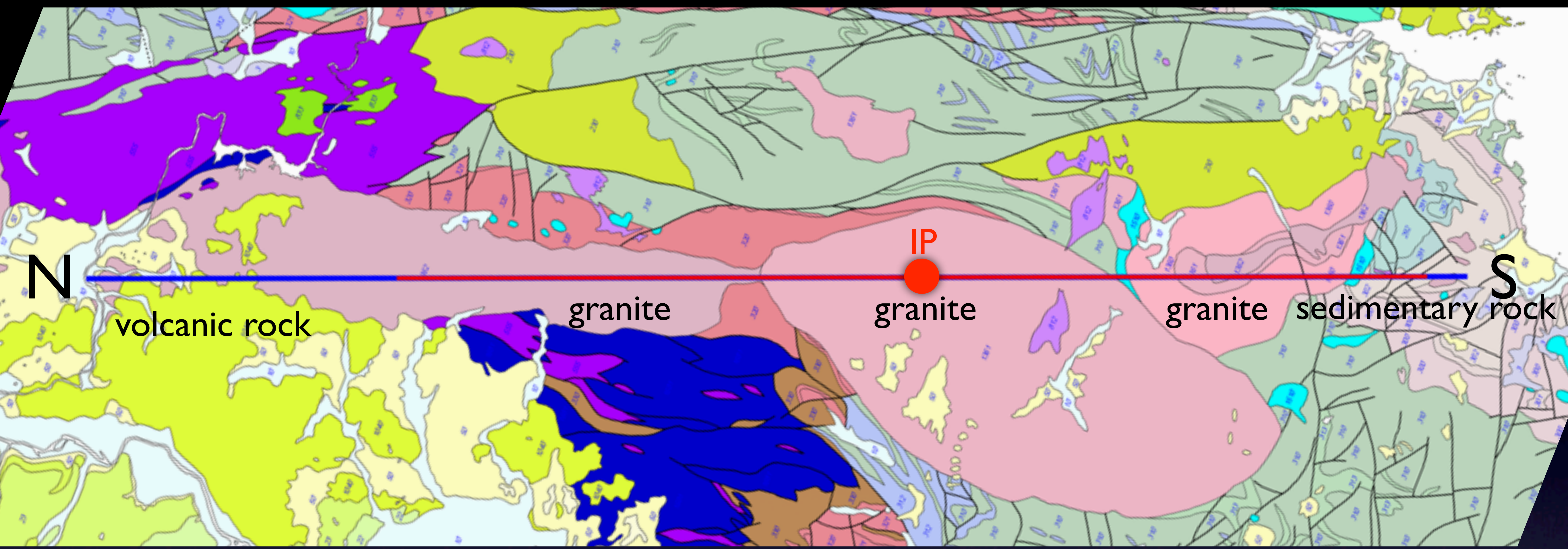
- CLIC is anther linear collider technology (normal-conducting)
- Has been developed under CERN leader ship
- Now in international framework
    - Part of LCC (Linear Collider Collaboration)
- Conceptual Design Report (CDR) completed
    - Still premature for construction start
    - But will be ready by the time 500GeV ILC completion

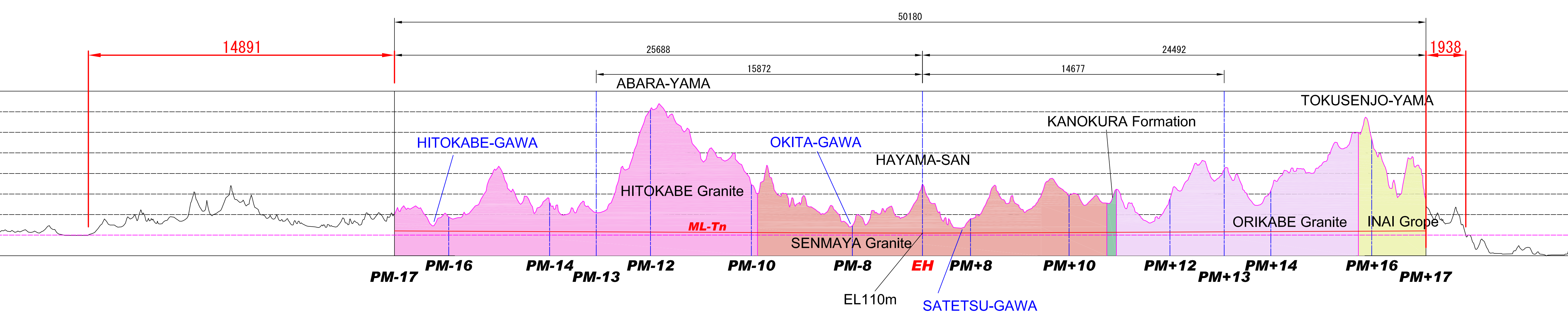




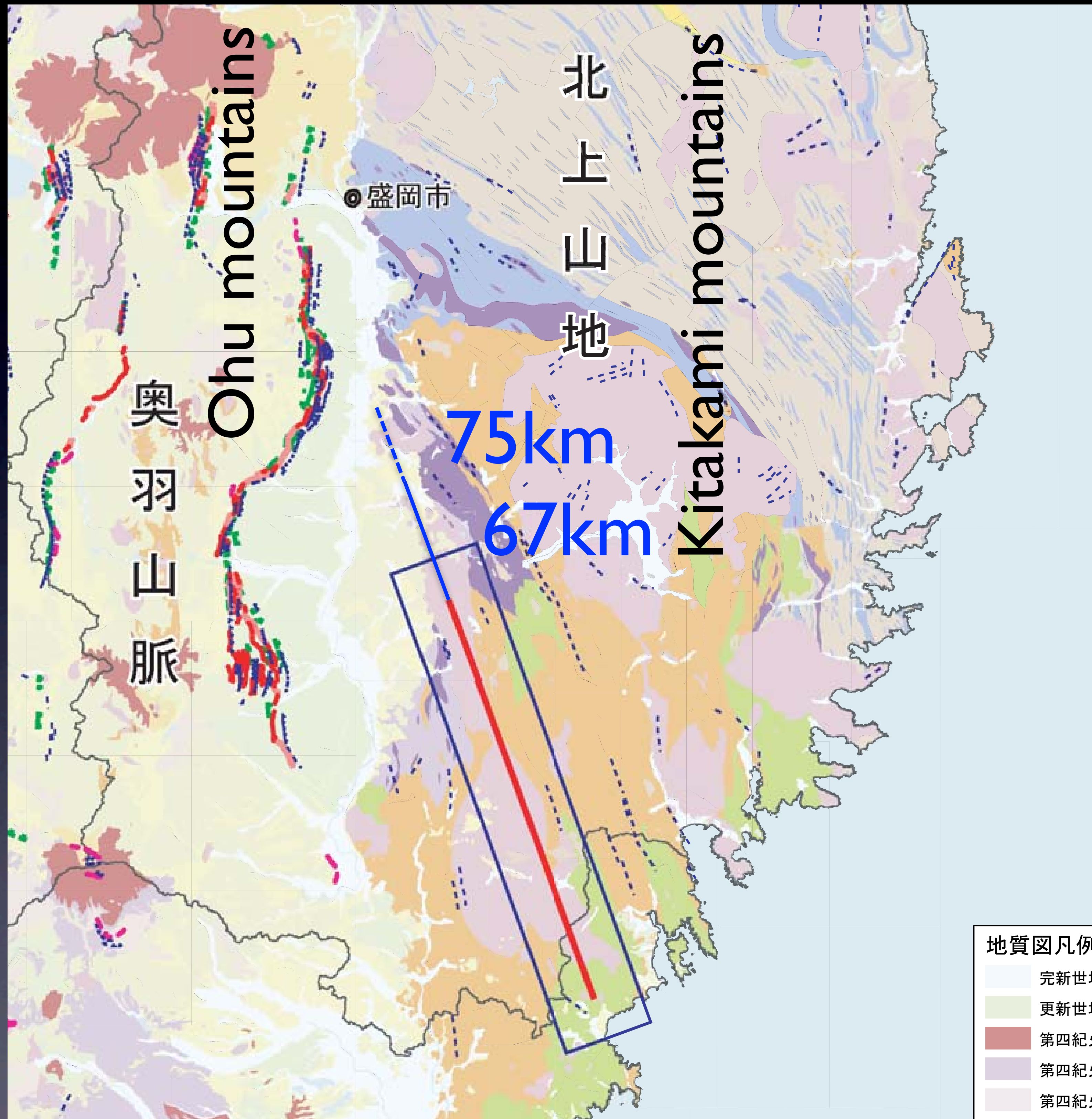
Can reach 3TeV in a 50km site

Site Length

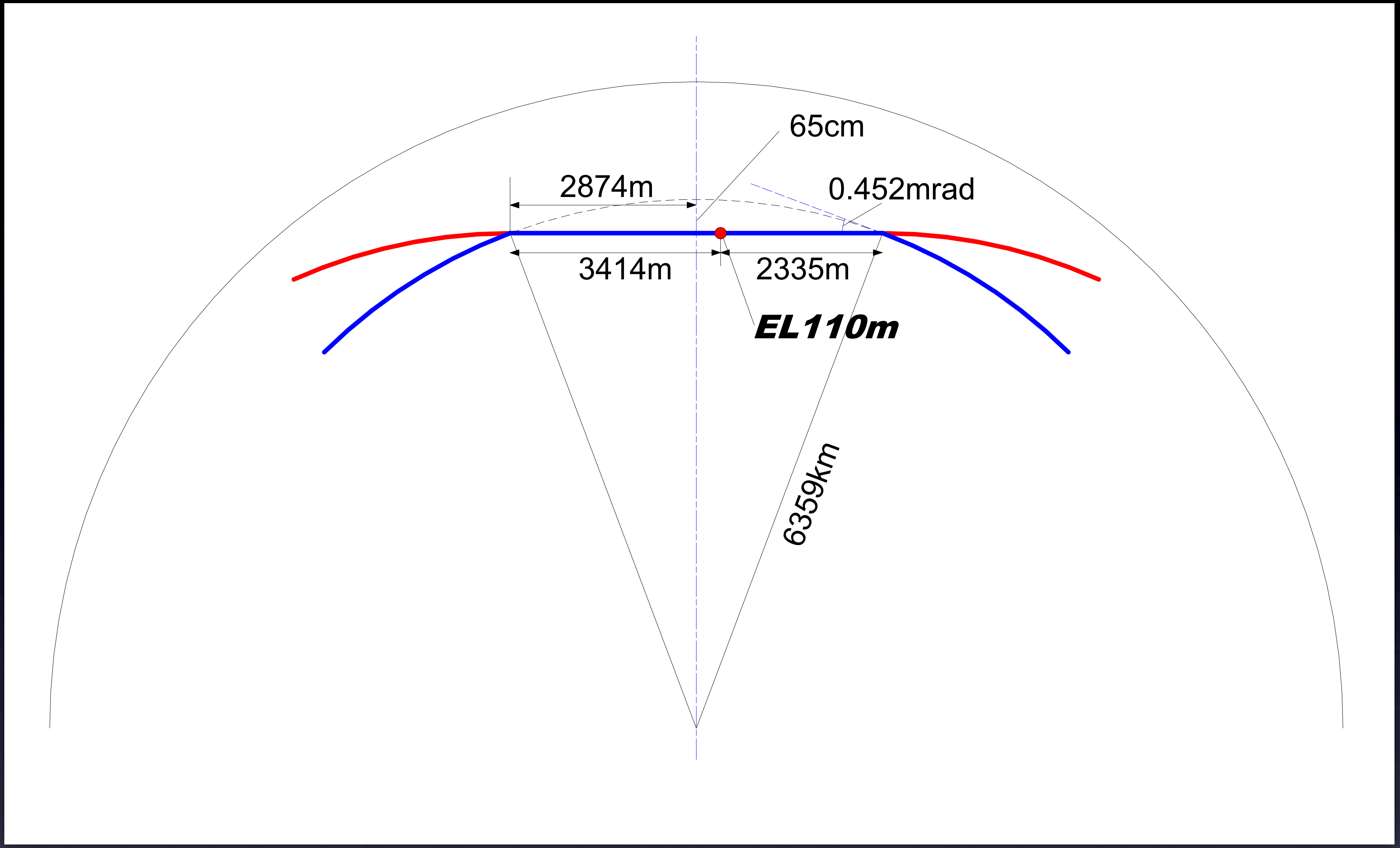




- Can be extended more to the north
- 14.9km + 50.2km + 1.9km = 67km
- 75km may be possible by further extension to the north



盛岡市
北上山地
Kitakami mountains
Ohu mountains
奥羽山脈
75km
67km
地質図凡例
完新世堆
更新世堆
第四紀火
第四紀火
第四紀火



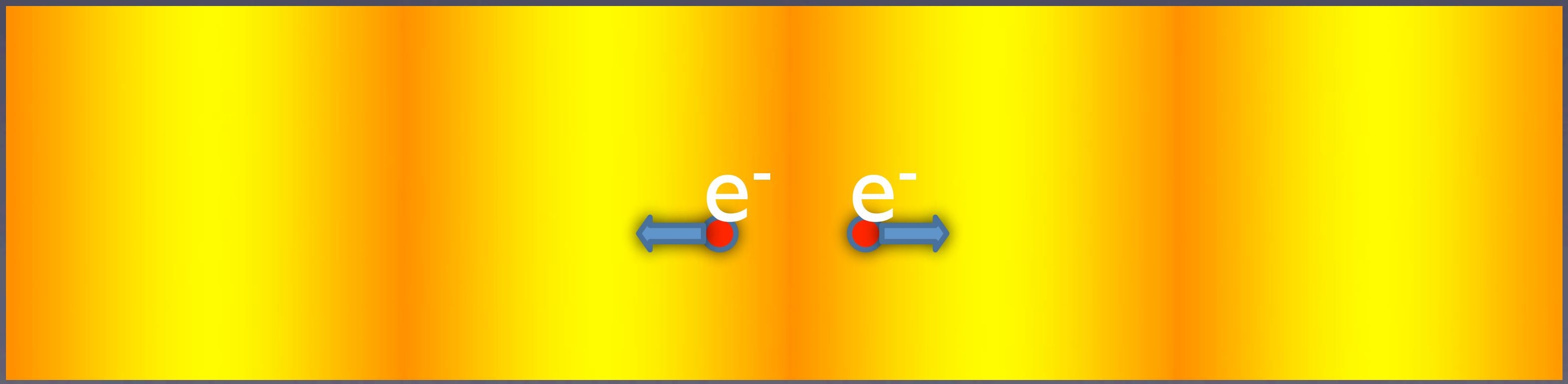
ML in the North wing ~ 11.5+9.5+15 km
=> Tunnel EL = 126m a.s.l. at the Northern end

Maximum Energy Reach

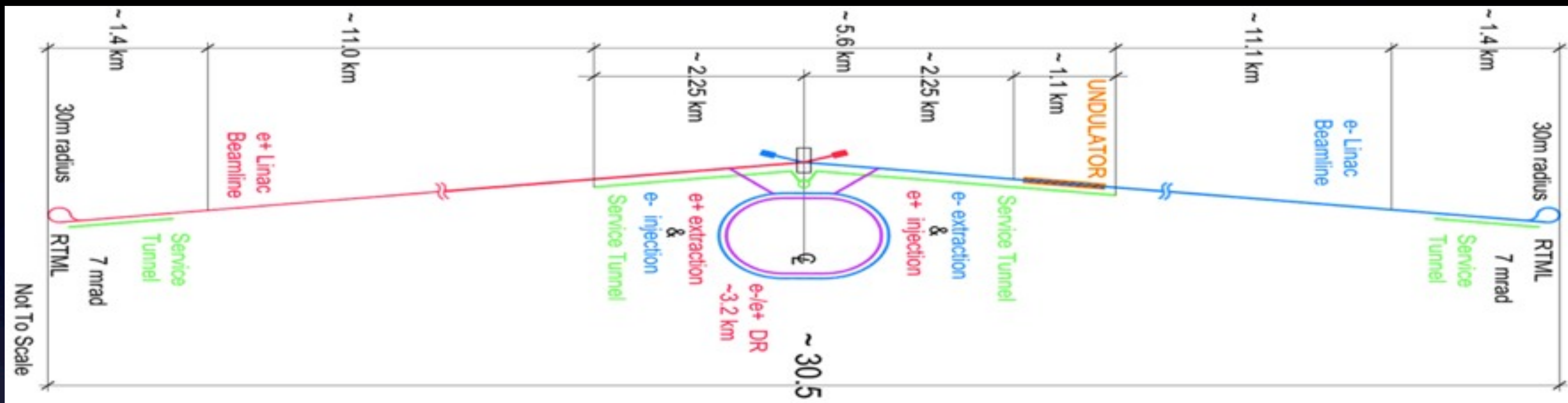
- Re-install 100MV/m cavities
- $\sqrt{s}/2$ = accelerating gradient x ML (site) length
  - 100 MV/m x (75-5)/2 km x 0.72 ~ 2500GeV
- Energy reach ~ 5TeV

Another Solution: Plasma Accelerator

- Linac in the past has been driven by microwave technology
- Plane wave in vacuum cannot accelerate beams: needs material to make boundary condition
- →Breakdown at high gradient
  - binding energy of matter: eV/angstrom = 10GeV/m
- **Plasma wave** can accelerate electrons (and positrons)
- Need not worry about breakdown with plasma
  - can reach > 10GeV/m



An alternative ILC upgrade by PWFA from 250GeV to 1 TeV and beyond?



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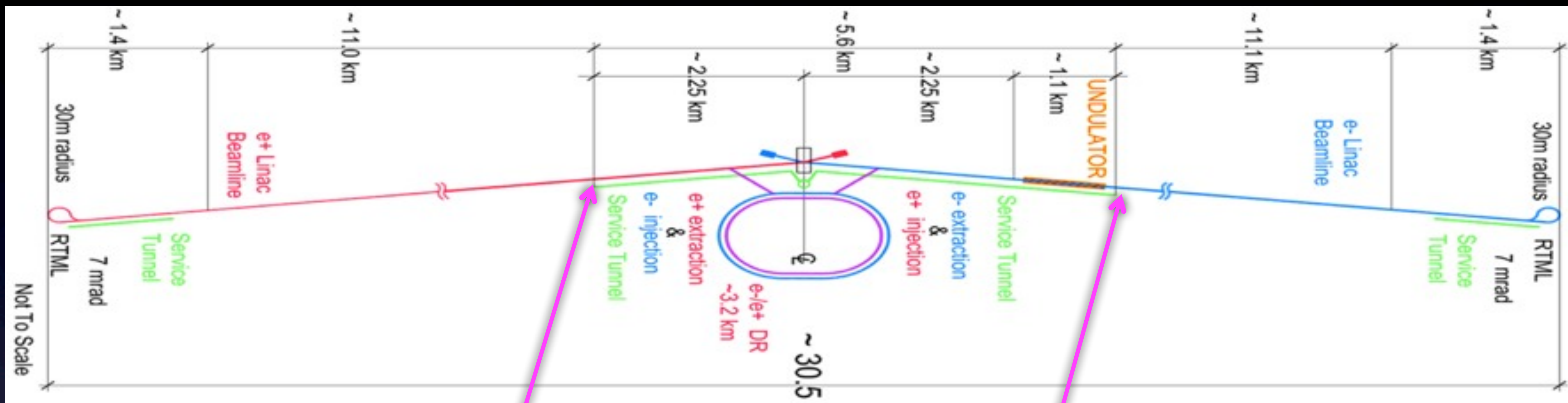

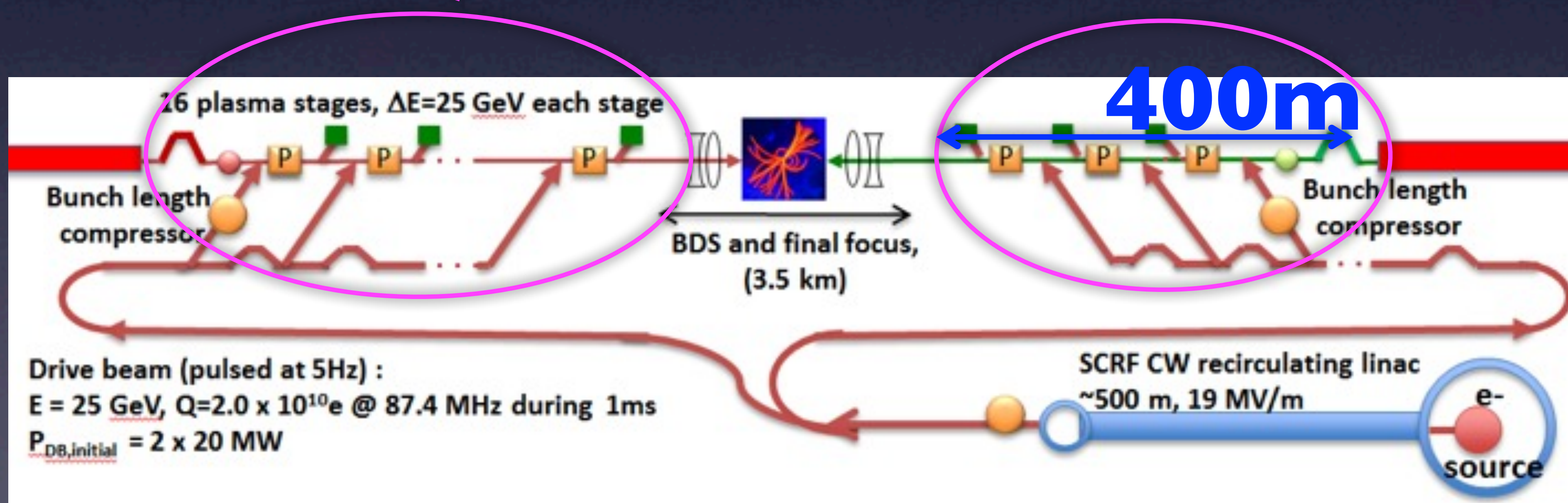

Conclusion

- ILC can be certainly extended to ~1TeV by a natural extension of the present technology of niobium cavity
  - Can be 1.5TeV with full use of 67km site
- Even higher energy might be reached (3TeV?) using a new SC technology such as thin film
- Obviously, quantitative studies are needed including the luminosity estimation, etc.
- CLIC technology allows to reach ~3TeV in the prepared Kitakami site (~50km)
- Plasma accelerator technology may bring about even higher energy (after several tens of years)

Homework

- Detailed studies on geology and topography
  - (Active) faults, geological survey
- Systematic studies of cavity technology
  - material
  - surface treatment
- Optimize the plan of ILC facilities (500GeV) in consideration of >1TeV ILC