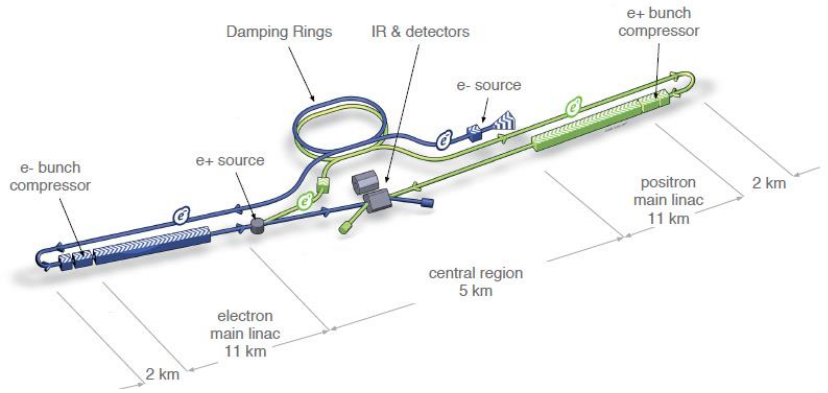
Crab Kick-off meeting

- ✓ Date/time: 24/Nov/2020 22:30~23:03 @JST

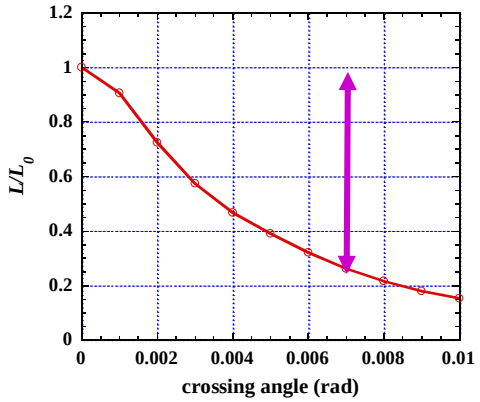
- ✓ Agenda:
  - ✓ Introduction (Kirk)
  - ✓ Specification of beam dynamics/timing to be reconfirmed (Okugi-san)
  - ✓ Items to be reconfirmed/reestablished (Kirk)
    - ✓ Available space for installation based on recent accelerator design
    - ✓ Check items before cavity/cryomodule design
    - ✓ Expected stability of RF reference signal/cavity phase
  - ✓ Discussions
  - ✓ Next meeting
- ✓ Expected attendees: P. McIntosh, G. Burt, A. Wheelhouse, S. Pattalwar, R. Calaga, S. Michizono, A. Yamamoto, H. Hayano, Okugi-san, Kirk, SRF subgroup, BDS subgroup,
  26 people counted at max.

Introduction

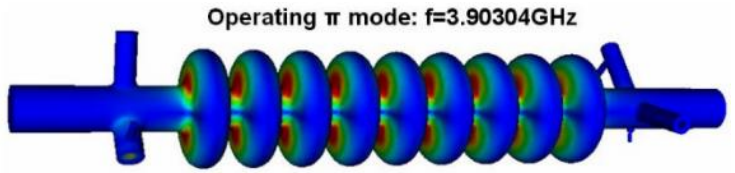
- Crab cavity system is indispensable for ILC
- No progress after TDR
- Prototype CM is necessary (Nomura Research Institute, Ltd. considered not-matured technology)
  - During the technical preparation period, prototype CM should be constructed and tested
  - Budget request is necessary (crab cavity is listed as third issue in SRF technical preparation)
    - **We have to complete the draft of budget request until 22/Dec**
- To be reconfirmed requirements from beam dynamics and timing by Okugi-san
- To be checked installation space based on the recent civil engineering design around IP and beam dynamics



ILC RDR parameter, by CAIN simulation



Cavity design presented in TDR



Not using crab cavities reduces luminosity by 80%!

Requirement of the ILC crab cavity

Toshiyuki OKUGI, KEK

2020/11/24

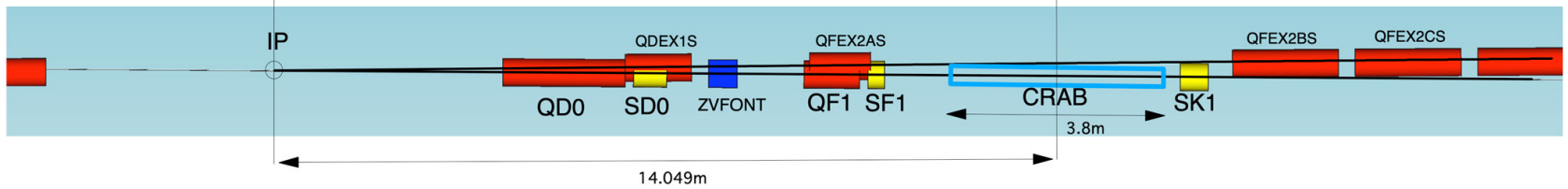
IDT WG2 SCRF, BDS joint subgroup meeting

Crab cavity location

T. Okugi

Crab cavity location (present ILC optics deck)

two beamline distance
14.05m x 0.014rad = 197mm



Crab cavity location (alternative)

two beamline distance
77m x 0.014rad = 1078mm

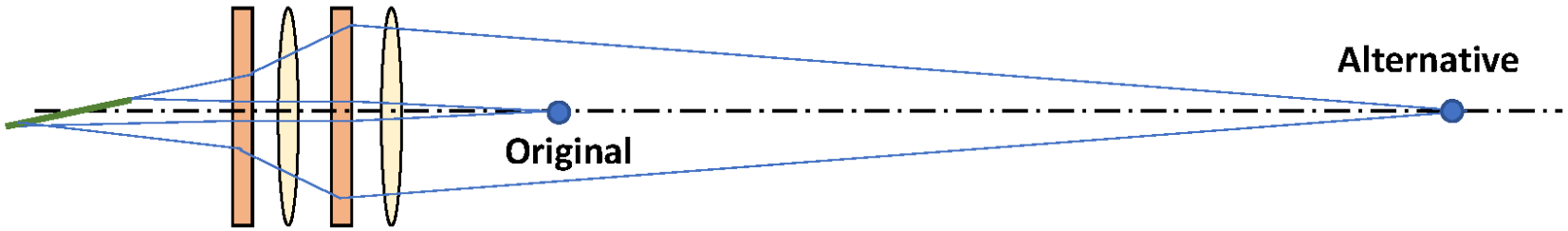
drawn by H. Hayano

- *Since lots of magnets will be put in the dump line, the next neighbor candidate to put the crab cavity **is 77 m from the IP** in order to avoid the positional influence of the magnets in the dump line.*
- *The requirement of the relative RF jitter is independent to the crab cavity location. But the jitter requirement for the next neighbor location is tighter for the distance between the crab cavities (28m and 154m).*

	Present	***Alternative***
Longitudinal distance from IP	14.05 m	77 m
Horizontal distance from dump line	0.197 m	1.078 m
R12 (crab cavity to IP)	17.4 m	12.2 m
relative timing jitter requirement	49 fs rms. (2 % luminosity drop)	

Effect to the luminosity

T. Okugi

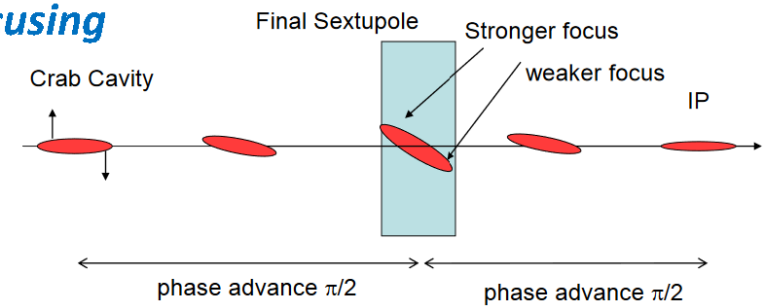


Horizontal beam orbit at FD was changed from the bunch head to the bunch tail

- *The vertical focal position was shifted from the bunch head to the bunch tail*

	z	Present			Alternative			
		σ_x/σ_{x0}	σ_y/σ_{y0}	Δ_y/σ_z	σ_x/σ_{x0}	σ_y/σ_{y0}	Δ_y/σ_z	
Bunch head	+600 um	1.0010	1.0138	+0.14	1.16	1.45	+1.03	Weak focusing
	+300 um	1.0005	1.0044	+0.07	1.05	1.13	+0.51	
	0	1	1	0	1	1	0	
	- 300 um	1.0005	1.0044	-0.07	1.05	1.13	- 0.51	
Bunch tail	- 600 um	1.0010	1.0138	-0.14	1.16	1.45	- 1.03	Strong focusing
	Luminosity reduction	0.5 % (geometrical)			16 % (geometrical)		↑	

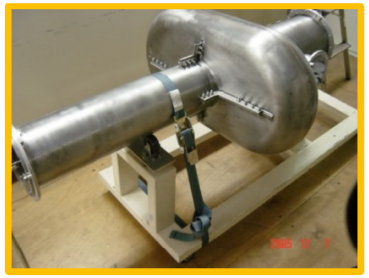
Traveling focusing



The luminosity for the alternative location will be increased that that evaluated as the geometrical luminosity by the traveling focusing of the beam-beam effect.

Requirement of the ILC crab cavity

KEKB crab cavity



Total kick voltage

- ✓ *The kick voltage was evaluated* ***for E_{CM}=250GeV ILC (beam energy is 125 GeV).***
- ✓ *Total voltage for the crab kick is smaller for the higher RF frequency.*

Cavity gradient

- ✓ *Cavity gradient was evaluated* ***by scaling to the KEKB dipole crab cavity as a reference****.*
- ✓ *The actual cavity gradient should be evaluated to be design-by-design.*

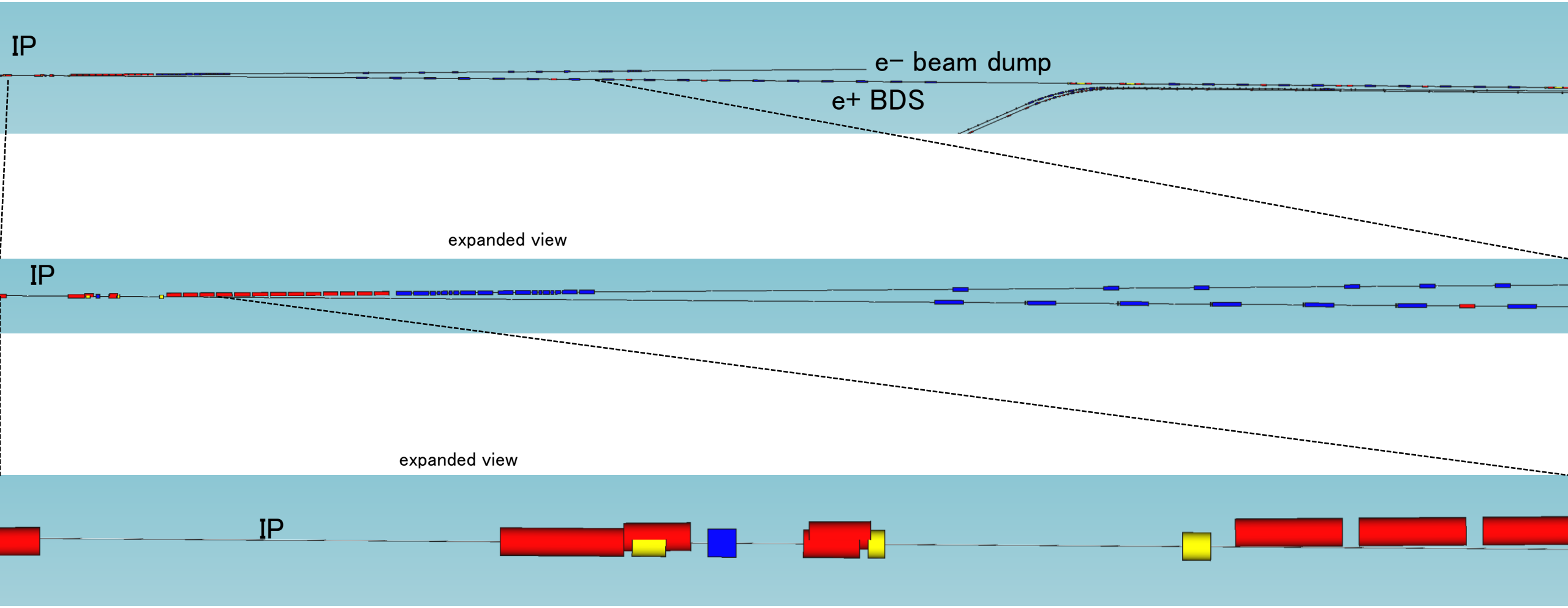
Relative RF phase jitter

- ✓ *Since the requirement of the timing jitter is independent to the RF frequency,* ***the requirement of the phase jitter is severe for the lower frequency.***

Frequency		3.9 GHz	1.3 GHz	
# of cell		9 cell	3 cell	9 cell
Total length (pi/2 mode)		0.346 m	0.346 m	1.038 m
Total kick voltage	***Present location***	0.615 MV	1.845 MV	
	Alternative (s=77m)	0.878 MV	2.633 MV	
Cavity gradient	***Present location***	8.14 MV/m	24.4 MV/m	8.14 MV/m
	Alternative (s=77m)	11.6 MV/m	34.9 MV/m	11.6 MV/m
Relative RF phase jitter		0.069 deg rms. (49 fs rms.)	0.023 deg rms. (49 fs rms.)	

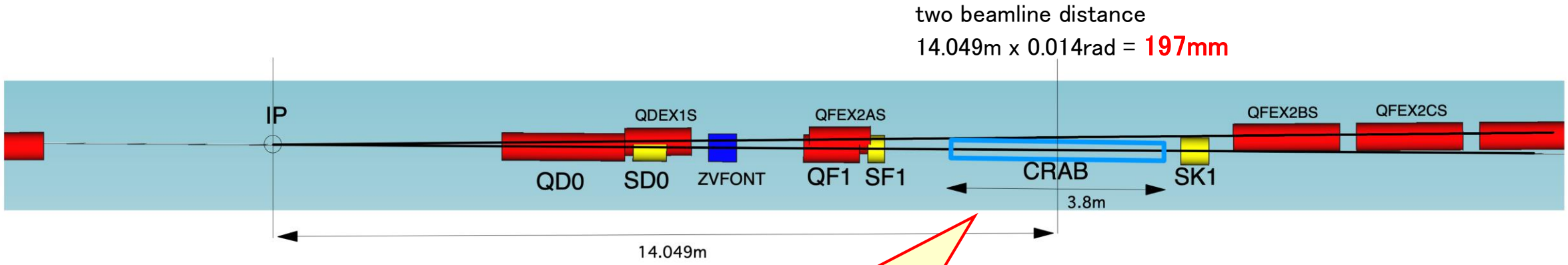
e+ BDS

H. Hayano



H. Hayano

Crab cavity position



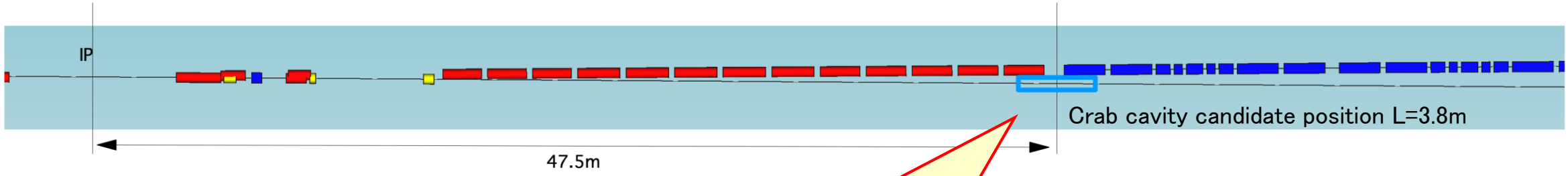
Here is the original location presented in TDR.
But, there is too narrow space between two beam lines!
Then, we can think about the other better location.

magnet symbol is not real scale.
it is just a symbol.
(logituinal length is scaled, width is not.)

H. Hayano

Crab cavity position : other candidate

two beamline distance
47.5m x 0.014rad = 665mm



Unfortunately, vertical chicane is installed at this location, then it may be difficult to install crab cavity

magnet symbol is not real scale.
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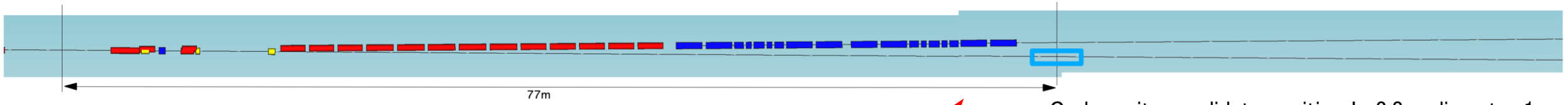
(logituinal length is scaled, width is not.)

H. Hayano

Crab cavity position : other candidate 2

two beamline distance
77m x 0.014rad = **1078mm**



Crab cavity candidate position L=3.8m, diameter 1m

We found the better location than original.
We think here is the best candidate site.
But, recently, we found luminosity is lowered.

magnet symbol is not real scale.
it is just a symbol.
(logituinal length is scaled, width is not.)

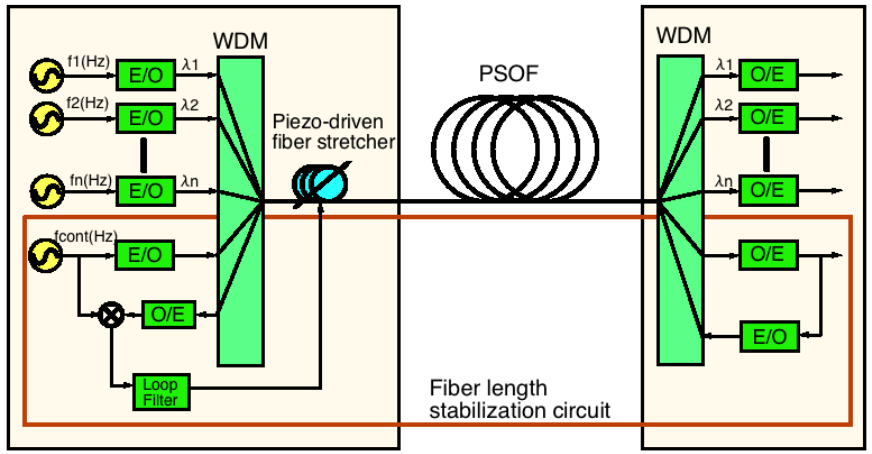
Check items before cavity/cryomodule design

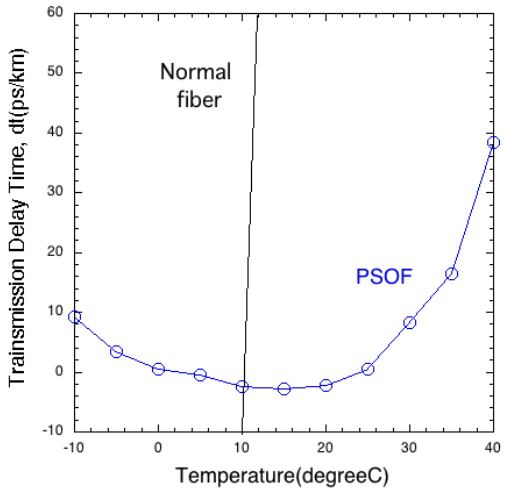
- ✓ Design optimized to “real” installation site
  - ✓ How much space can crab cavity use?
    - ✓ Magnets/beam monitors are symmetrically installed between electron and positron?
  - ✓ How to install CM into real site?
  - ✓ Cryogenics/RF distribution system are available?
    - ✓ Where are the cryogenic and RF stations around IP?
  - ✓ Need to investigate the impact on luminosity, especially 47 m/77 m site
    - ✓ Effect by SX magnet is not negligible
    - ✓ Beam simulation is still under progress

Reference Line Stabilization

T.Naito

Reference signal distribution using PSOF and phase feedback

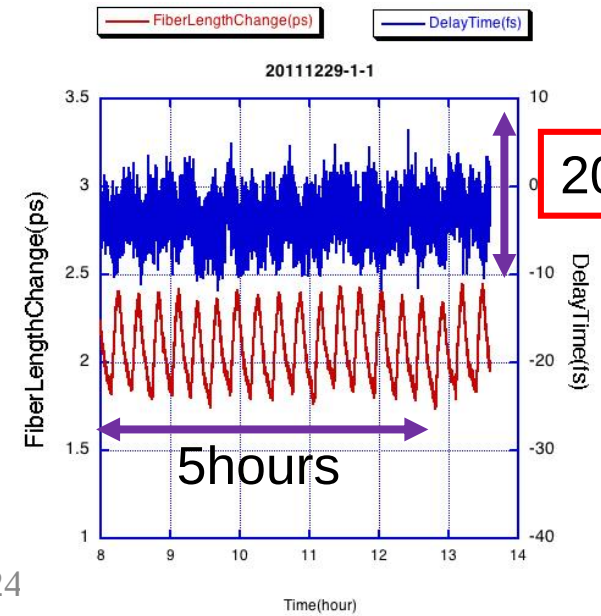




Phase stabilized optical fiber(PSOF)
5ps/km/degC

Requirements:
- Stability of reference signals between electron and positron crab cavities
- Phase stability in each cavity

Achievements:
- 20 fs (peak-to-peak) achieved
- From viewpoint of 3.9 GHz LLRF,
  0.1° (70 fs) → no problem
  0.01° (7 fs) → probably no problem



S-band(2856MHz) signal transmission test:
Red line shows the fiber length change and Blue line shows the timing change at the output. The signal could keep the stability less than 20fs.

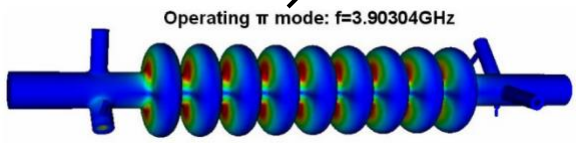
If we use 1.3 GHz crab cavity, these requirements will be more relaxed

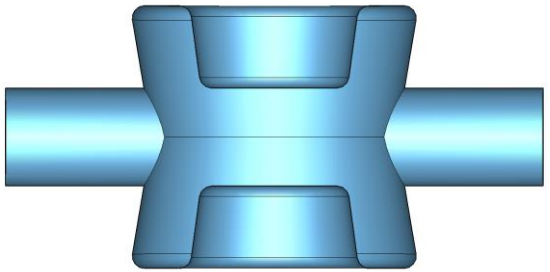
Next meeting

We will have the next meeting (2 hours!) on **30/Nov (Mon)**.
22:00@Japan, 14:00@EU Central, 13:00@UK, 8:00@US Eastern, 7:00@US Central, 5:00@US Pacific

Are you convenient?

Please consider whether each type of crab cavity can be installed in each installation location (14, 47, 77 m)





Courtesy of Rama-san

New idea?

Questions/Discussions/Comments (memorandum) @1st meeting

Translation by Kirk

- Japan was involved with crab cavity in TDR around 2012?
  - No. At that time, UK and US teams were responsible for that
- About luminosity degradation
  - How about β function, bunch length, dispersion at crab cavity?
  - Still don't understand why luminosity is so degraded
  - More simulation is necessary to check it
- Two crab cavities for electron and positron are simultaneously driven by **one** klystron. If the distance between them is too far, timing for harmonization would become difficult. At present, 14 m site is the best. 20 fs is not so easy for 3.9 GHz.
  - **It looks available even in 3.9 GHz from KEK's investigation**
- 14 m site
  - It looks available for installation of crab cavity, if the optimized re-design is done. Recently, a lot of designs are considered for application of crab cavity. It may be possible.

- Next meeting
  - Everybody is convenient on 30/Nov
  - Necessary to sort out the issues
  - Necessary to make the draft of budget request
  - FNAL and J-LAB will join, of course other laboratory is welcome
  - **If you have any idea and suggestion, please send us them by e-mail before the meeting**