LINEAR COLLIDER COLLABORATION

Designing the world's next great particle accelerator

The ILC positron source options

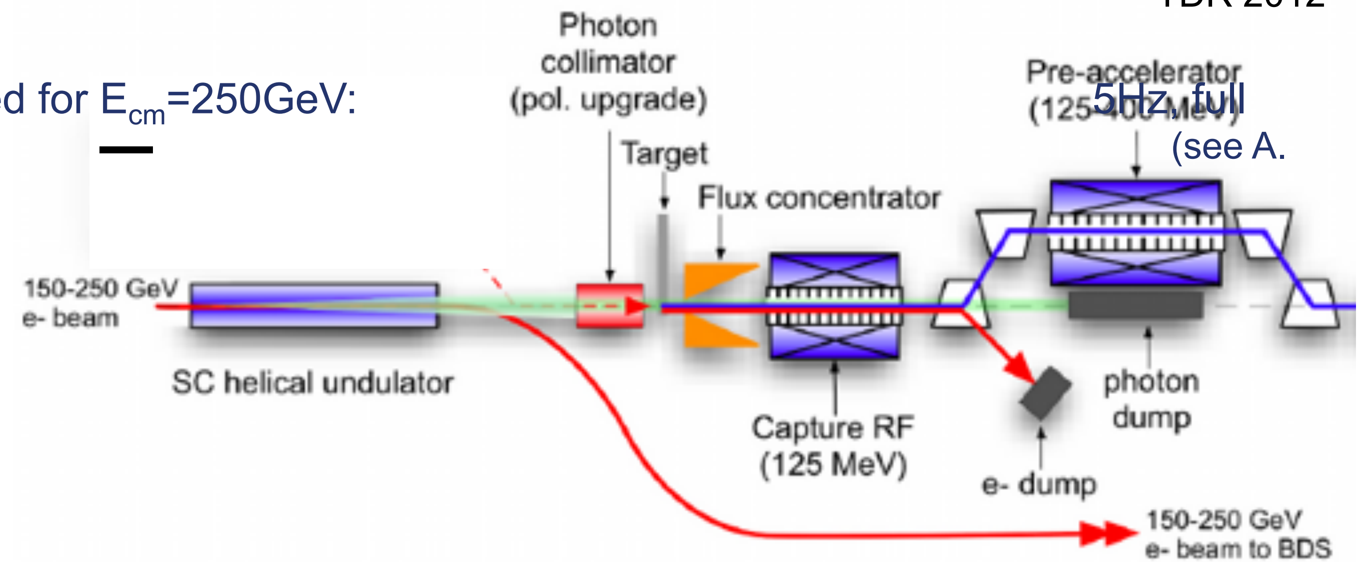
Status of e+ sources discussion (our view)

- Source options
  - undulator based source (baseline, TDR)
    - **Polarized e+ beam**
  - Electron driven
    - **Unpolarized e+ beam**
- It seems there are strong intentions to establish the e- driven source as baseline, at least for the 250GeV option. Main claims:
  - e+ target technology has not been confirmed — ***no showstopper in view!***
  - e+ polarization as update — ***why? no reason.***
  - e- driven scheme is 'safe' — ***why? never proven.***
- Recently (also at LCWS17) a cost estimate comparison was presented by K.Yokoya
- Main problem, in particular for the undulator based source: resources

Undulator based e+ source

TDR 2012

- Source scheme;
  - parameters updated for E_{cm}=250GeV: undulator length — 5Hz, full (see A. Ushakov)



- Target:
  - wheel Ø1m
  - photon beam (~60kW) ⇔ energy deposition in target ≥2kW
  - Target thickness 1.48cm Ti6Al4V for for E_{cm} ≥ 350GeV
  - **Target thickness 0.7cm Ti6Al4V for for E_{cm} = 250GeV**
  - Spinning in vacuum with 2000rpm (100m/s)
  - **Cooling by thermal radiation**
- Issues:
  - e+ source at the end of ML → all parameters have to be optimized for each E_{cm}
  - Source design and test of prototypes

Urgent tasks for the undulator source

- Calculation and design of target cooling system
  - Simulation of temperature and stress distribution in target wheel is most urgent and necessary before engineering design
  - *We do not see any showstopper for cooling by thermal radiation*
  - With 125GeV e- beam higher peak load on matching device. This is problem for the flux concentrator. Masks? QWT instead of FC should work (simulations only so far)
- Target wheel engineering design
  - After simulations, prototyping is required **money and manpower required!**
    - Check and optimize cooling efficiency using stationary target piece
    - Full wheel test including bearings
- Other issues
  - Design of OMD
    - Flux concentrator design work and prototyping (LLNL) stopped in 2012)
  - Photon dump (high power photon beam with small beam size; cannot be swept)
  - Shielding of target region
  - Target replacement scenario

Cost of Undulator System (K. Yokoya, LCWS17)

- TDR quotes 228 MILCU (accelerator components) and 72 MILCU for the CFS for the undulator e+ source.
- However, several design changes since TDR
  - **Undulator scheme:**
    - The undulator section must be lengthened 147m→231m for positron production at Ee=125GeV
      - TDR adopted 10Hz operation with 147m undulator
    - The beam dump of spent electron after photon production is needed for 10Hz operation. This will not be built in the first stage.
    - Auxiliary positron source will not be constructed, perhaps (majority of CRWG. It is not useful enough)
  - 72 MILCU for CFS could not be → number will not be used.
    - The extension for the undulator length 147m → 231m is already included in the tunnel (length for the TDR undulator scheme is 1678m)
    - ML tunnel cost for the 3GeV compensation
    - CFS cost for the dogleg is already included in positron source in TDR

Basic Cost of Undulator Scheme

(for comparison with e-driven)

K. *Yokoya*, LCWS17

- values were converted from MILCU to OkuYen

We use the same policy which we used when we converted TDR cost in MILCU to JYen for MEXT
1 MILCU = 1.09 OkuYen for tunnel civil engineering
1 MILCU = 1 OkuYen for CFS others and components

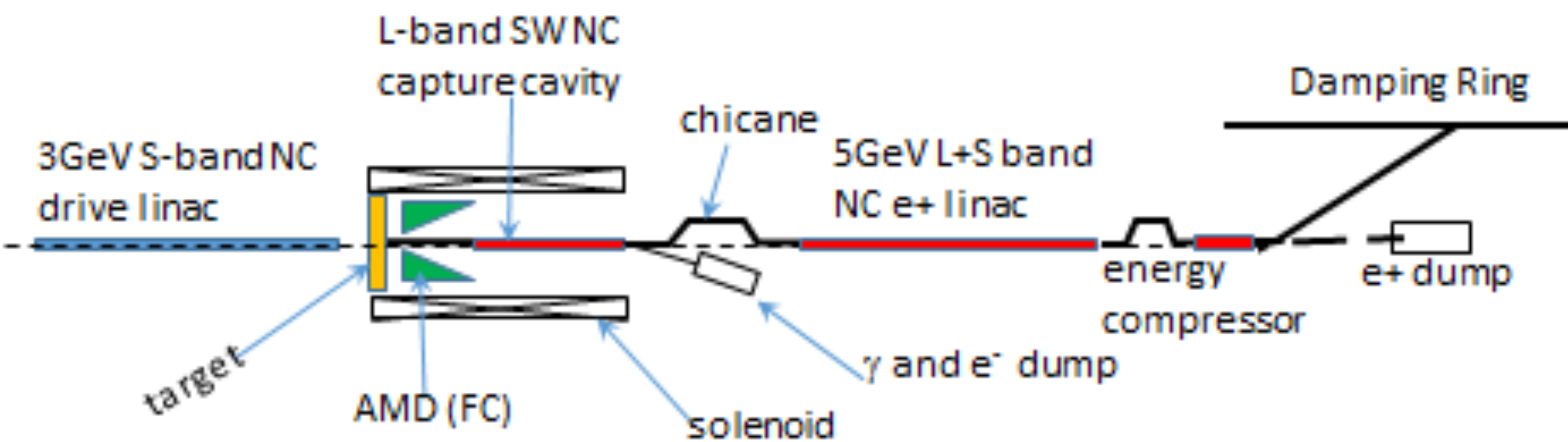
	Accelerator	**CFS**
TDR	227.5	67
Longer undulator	13.0	0
3GeV compensation	27	7.3
Dogleg	21	(1)
Beam dump for 10Hz	- 7.7	0
Auxiliary positron source	-5.9	0
SUM	273.9	74.3

(1) CFS cost for dogleg is already included in TDR

K. Yokoya, LCWS17

Basic Assumptions for e-Driven Scheme

- Number of bunches per pulse 1312
- Number of positrons per bunch 3×10^{10} (incl. margin)
- Beam pulse structure
  - Repetition 5Hz : 200ms interval
  - 20 times 0.48μs pulse in 63ms (300Hz)
  - Bunch distance 6.15ns
  - No pulse in the rest 137ms



Sum of Accelerator System e- driven

K. *Yokoya*, LCWS17

Electron drive linac (incl. electron gun)	58.38
Target system (excl. linac)	16.50
L-band capture linac	32.80
L+S band booster linac (incl. chicane)	158.84
Energy compressor	5.68
others	
Sum	272.2

- 'Others' should include (but level of a few OkuYen)
  - photon&electron dump after capture linac
  - positron tuning dump
  - Electron dump right after drive linac (perhaps needed)
  - Beamline from end of energy compressor to DR

Comparison of the Basic Cost

K. *Yokoya*, LCWS17

	Undulator	e-Driven
Accelerator	274 OkuYen	272 OkuYen
CFS	74 OkuYen	44 OkuYen
Sum	348 OkuYen	316 OkuYen

Not included here:
cost saving due to higher effective luminosity for Undulator source !

Final Cost Comparison

K. *Yokoya*, LCWS17

	Undulator	e-Driven
Basic cost (1)	348	316 (2)
Empty space for timing (3) for 31.5 MV/m	26	
for 35 MV/m	46	
Sum for 31.5 MV/m	374	316
35 MV/m	394	316

(1) components+CFS, including 3GeV compensation, dogleg

(2) Assume the space for undulater+photon drift is eliminated.
If reserved, the cost increases by ~23 OkuYen

(3) CFS + RTML beam line + main beam line. Only the positron wing

- Luminosity upgrade is source technology dependent, it is not covered here…….*lots of open questions concerning shielding to e-driven source from our side!!!*

- Lumi upgrade propably easier with undulator source
- More details see in Yokoya's talk at LCWS'17, https://agenda.linearcollider.org/event/7645/contributions/40017/attachments/32323/49050/PositronSourceComparison-LCWS2017.pdf

e+ polarization:

expect ~30% for E_{cm} = 250GeV → effective luminosity for s-channel processes is enhanced by 24% (P_e=80%)

à **Shorter running time**

à **Cost reduction**

So far, this fact has never been included into cost estimates!

e+ source ‘undulator group’

- Currently only DESY/Uni HH
  - SR, Andriy Ushakov (contract until …18), Felix Dietrich (engineer, contract until 7/18); Khaled Alharbi (PhD student from Saudi Arabia) and myself
- Topics:
  - Undulator based source:
    - Parameter optimization
    - Target temperature and cooling
    - Target wheel design
    - Design preparation for prototyping
    - Studies take into account a realistic undulator B field based on measurements of prototype modules manufactured in UK
    - Photon dump design (together with P. Sievers, CERN, some recent activity also started in Japan)
    - Shielding & radiation aspects at the e+ source
  - Experimental tests to study and confirm material resistance against high cyclic and long-term load
  - To minor extent also contribution to studies for the e- driven scheme

Further activities and plans at DESY&UHH

- E-beam at Mainz: we had already successful runs at 3.5 MeV and 14 MeV
  - 3/16, 11/16, 1/17, 3/17,…. next run probably begin 2018
  - generating similar load as for ILC target within short time
  - several targets, different thickness,
  - targets survived, but changes in structure: IPAC proceeding, http://inspirehep.net/record/1626363/files/tupab002.pdf
  - we also have a set-up to measure the emissivity
  - still targets under analyses: detailed laser scanning etc.

➔ stay tuned, interesting results need to be confirmed

New Plans for MAMI

- Current grant proposal foresees runs with electrons up to 180 MeV
  - get required PeakEnergyDepositionDensity within short time
  - expect higher rise in ΔT (~100^0-200^0)
  - short-term overloading
- Precise analysis afterwards:
  - T-rise, thermic stress
  - structure, hardness, deformation
  - modelling of deformation, cracks etc.
- Methods:
  - Laser scanning etc. (started already)
  - synchrotron scattering (new!)

New Plans forDESY

'ex-situ'

- Using PETRA-3 beam for analyzing material
  - high-energetic synchrotron radiation of high brilliance: röntgen diffraction
  - γ-beam practically no divergence
  - point-like analysis of material (beam <200μm)
  - understanding of micro structure
  - high-energetic radiation (50keV-200keV) allows to analyse material of several mm thickness!
    - exactly what we need,……
- Planned: e.g. study different Ti-alloys, which phase, etc.

Further new Plans for DESY

'in-situ'

- New installation of e-beam at 1-10 MeV
  - mean current strength of ~600μA (100 Hz)
  - material tests not only with Ti-alloy, also WF
  - design study for shielding

- Further idea: use e-beam directly at PETRA-3
  - allows 'in-situ' target tests
  - *observe changes in target structures 'online'!*

Conclusions

- No showstopper for the baseline source, but engineering work needed….more manpower, please!
- e- driven source not yet in such mature level: shielding, vacuum requirements, engineering design still under study….
- cost estimates show equal footing for both design
- should be very carefully interpreted…..made assumptions are not always on ‘equal footing’!
- Further options: lumi upgrade, polarization upgrade…..but we do need it for the physics case
- Exciting material results ongoing at Mainz, but with improved material analysis via laser scanning + diffraction technique
- Promising new test on the target materials planned here at DESY facilities even ‘in-situ’ via diffraction technique!
- ***Stay tuned! …Lots of interesting results are going to happen!***

Questions (1)

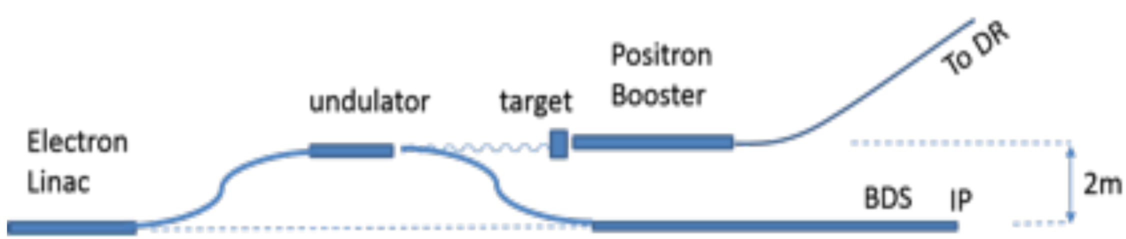
K. *Yokoya*, LCWS17

- The following items might be accounted for the cost comparison.
- The 250GeV stage that we are studying now (option C, Option D) includes some empty tunnel for global timing adjustment for undulator scheme, which is not necessary for e-driven case. Should we eliminate it from the beginning?
  - Rigorously speaking, the timing constraint is necessary in the positron wing only. The empty tunnel in the electron side is added for future extension to higher CM energy
  - The empty space is larger if we assume 35MV/m rather than 31.5MV/m. Can we cut this space? (less margin for 250GeV)
  - In the present staging study we assume we do not change the DRs because of the presently available manpower. It is certainly possible to choose a DR circumference which makes extra empty tunnel unnecessary for timing adjustment

Questions (2)

K. *Yokoya*, LCWS17

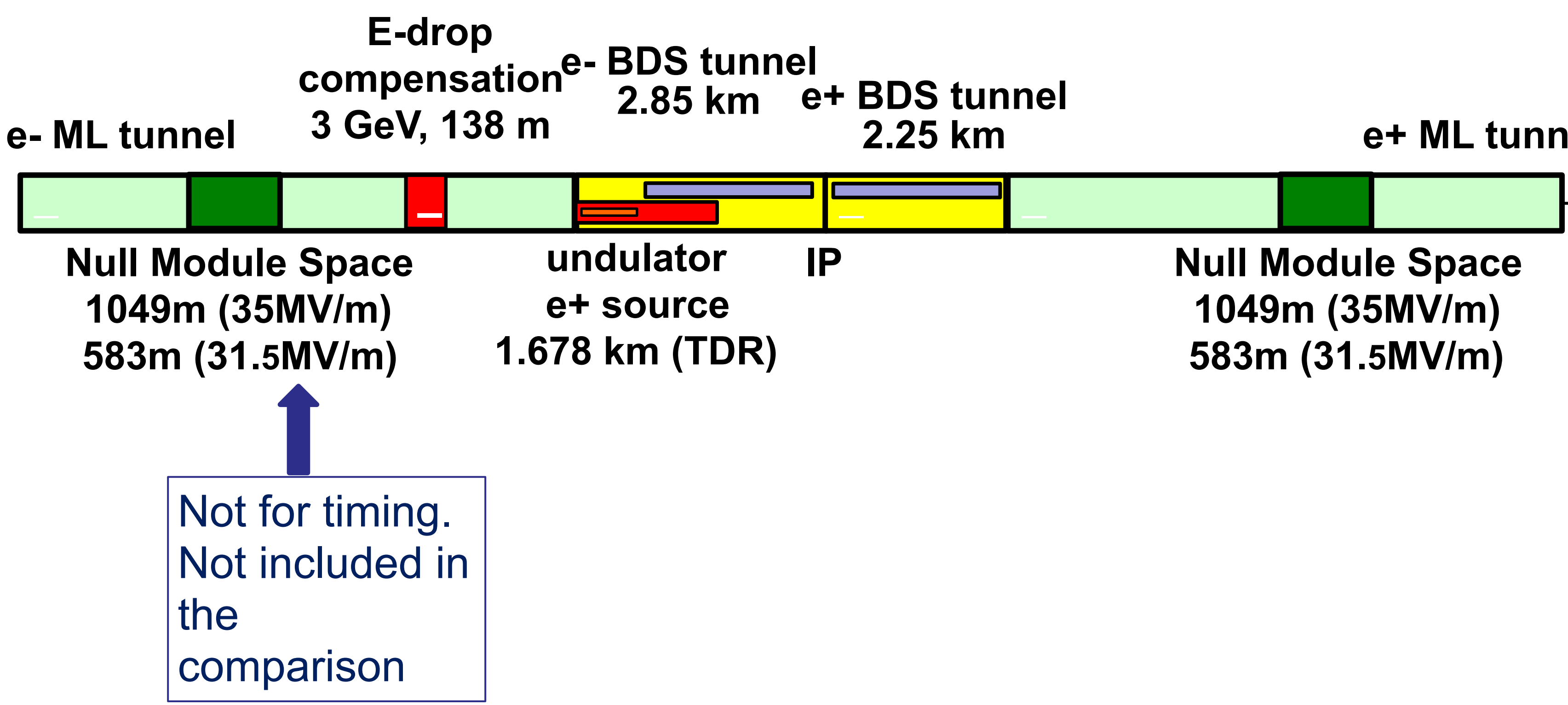
- Should the space of the undulator (and subsequent photon drift) be reserved for later upgrade?
  - The tunnel of this region is laser-straight in TDR. Presumably, we can manage from beam dynamics view point, even if it is bent. (BDS part must still be laser-straight)
  - Note: to reserve this space does not immediately mean that we can go to undulator scheme any time
- Should the dogleg of electron beam line after undulator be eliminated (different tunnel layout)? This brings about further cost reduction but a pair of doglegs (not a single dogleg) would be needed for later upgrade to undulator source if it is not implemented.



250GeV Stage for Undulator Scheme

K. *Yokoya*, LCWS17

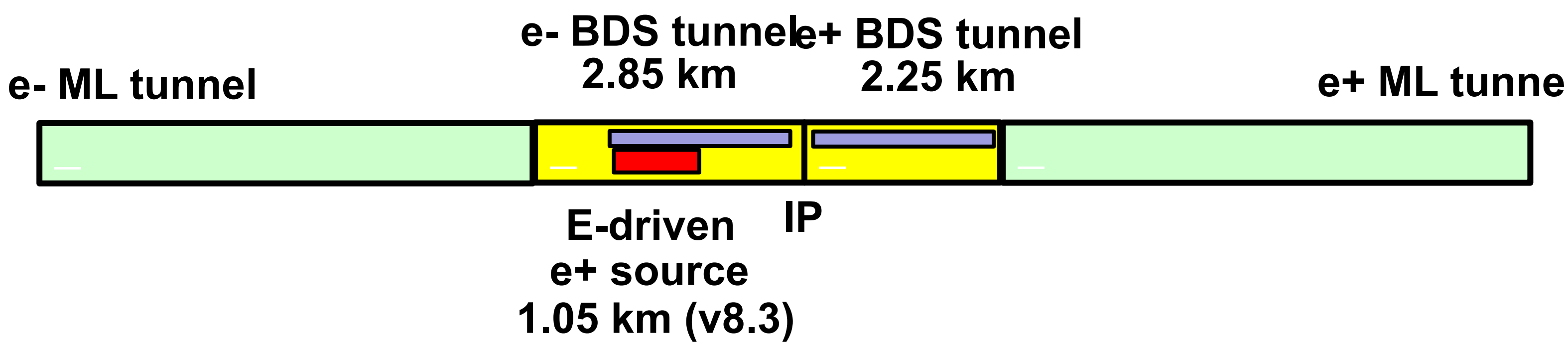
- Option C



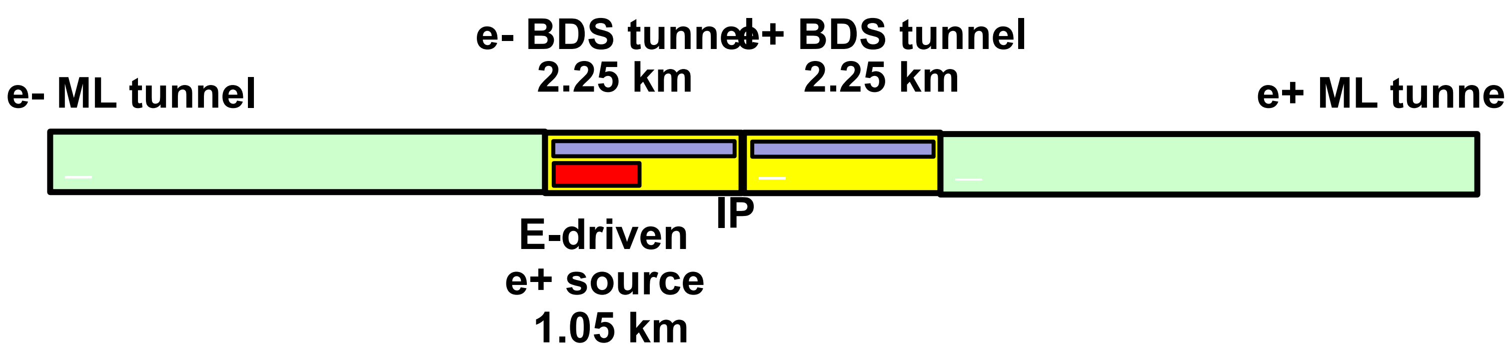
Tunnel for e-Driven Scheme

K. *Yokoya*, LCWS17

- With undulator/dogleg space



- **Without undulator/dogleg space**



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Luminosity Upgrade (1)

K. *Yokoya*, LCWS17

- Here, we cannot avoid mentioning the technology
- Basic change for upgrade 1312→2625 bunches
  - Reinforce main linac RF system (common to und.&edriven)
  - Electron damping ring (common to und.&edriven)
    - More RF system
    - Faster injection/extraction kicker
  - Positron damping ring
    - Same as electron DR if the e-cloud instability allows doubled beam current.
      - The first stage has factor ~3 margin to the instability. So, high possibility to double the bunches
      - We will get sufficient info from superKEKB and 1^{st} stage ILC
    - If not, add one more positron DR. The room reserved.

Luminosity Upgrade (2)

K. *Yokoya*, LCWS17

- Required change for e-driven source
  - Add one more positron DR (independent on electron-cloud)
    - Beam-loading compensation difficult with 3ns bunch spacing
    - ~166 MILCU
    - Might be possible with one e+ DR if not doubling the bunches
  - Increase the energy of drive electron 3 → 4.8GeV
    - ~ 31 OkuYen (simple scaling)
    - Tunnel length extension unnecessary (determined by BDS length)
  - Re-inforce modulators of drive linac and booster
    - due to longer beam pulse
    - Assume tunnel width is large enough
- Required change for undulator source
  - Target technology not confirmed yet
    - Target wheel would be heavier
  - To add positron DR or not depends only on the electron-cloud issue
  - Re-inforce RF of booster linac