Main Beam / Drive Beam Phase alignment

B. Jeanneret CERN/BE

CLIC Worshop , October 2009

Tolerance on Phase and Gradient

- Luminosity and understanding/adjustment of the Beam Delivery and of the Final Focus

D.Schulte & R.Tomas, PAC09

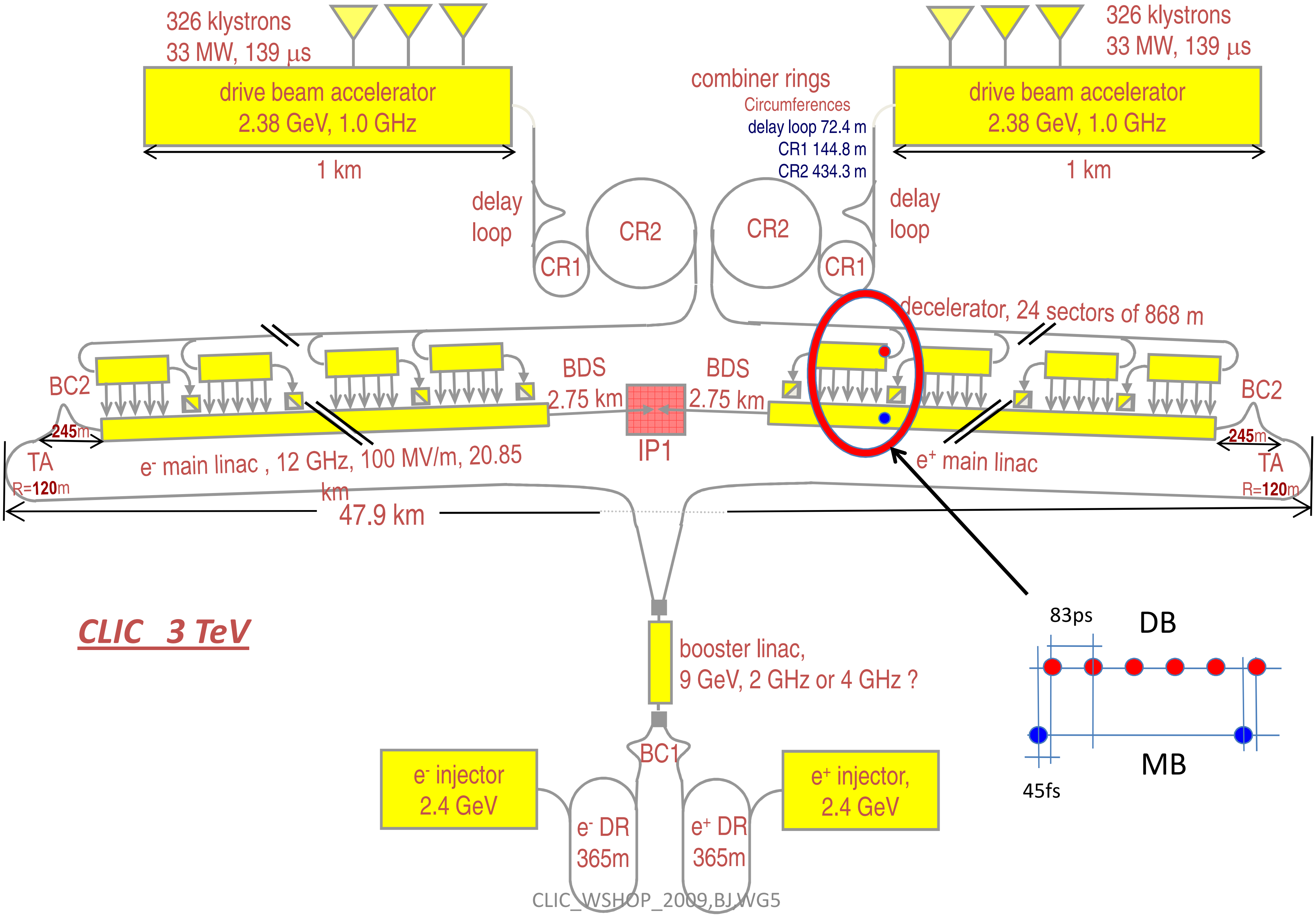
$$\left\langle \frac{\Delta \mathcal{L}}{\mathcal{L}} \right\rangle = 0.01 \left[\left(\frac{\sigma_{\phi,coh}}{0.2^o} \right)^2 + \left(\frac{\sigma_{\phi,inc}}{0.8^o} \right)^2 + \left(\frac{\sigma_{G,coh}}{0.75 \cdot 10^{-3} G} \right)^2 + \left(\frac{\sigma_{G,inc}}{2.1 \cdot 10^{-3} G} \right)^2 \right]$$

Overall cycle

DB intertrain (or sector to sector)

$$\delta \mathcal{L} \sim \delta_\phi^2 \text{ and } \delta_G^2$$

→ Not much margin on these


326 klystrons
33 MW, 139 μs
drive beam accelerator
2.38 GeV, 1.0 GHz
1 km
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combiner rings
Circumferences
delay loop 72.4 m
CR1 144.8 m
CR2 434.3 m
delay loop
CR2
CR1
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decelerator, 24 sectors of 868 m
BC2
BDS
2.75 km
BDS
2.75 km
BC2
245m
245m
TA
R=120m
e^- main linac , 12 GHz, 100 MV/m, 20.85 km
IP1
e^+ main linac
TA
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booster linac,
9 GeV, 2 GHz or 4 GHz ?
BC1
e^- injector
2.4 GeV
e^- DR
365m
e^+ DR
365m
e^+ injector,
2.4 GeV
83ps
DB
MB
45fs

CLIC 3 TeV

Implications for different systems

$$\delta\phi = 0.2^o \ @\mathrm{f}_0 = 12\mathrm{GHz} \ \equiv \ \delta z_{\mathrm{tol}} = 14 \ \mu \ \equiv \ \delta t_0 = 46 \ \mathrm{fs}$$

Tolerance to rms : divide by 3 → $\sigma_z = 5$ µm , $\sigma_t = 15$ fs

- RF :
  - DB Linac : 1 GHz
  - → Unless feed-back in between : $\delta\phi = 0.015^o$
- Timing system :
  - transmission stable over ~km down to 5µm
- Instrumentation :
  - Detection accuracy down to 15fs
- (Quasi-) Static path-length error in rings
- Ground stability/vibrations in rings

Not discussed today

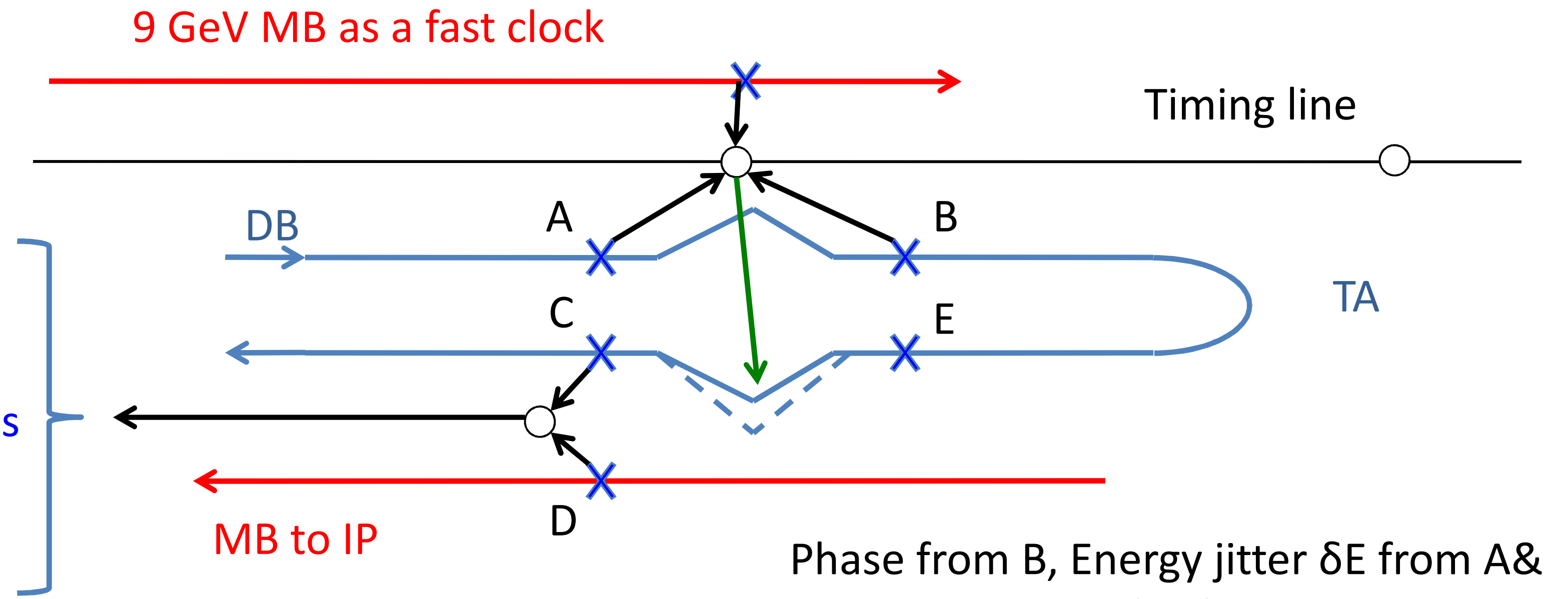
Phase control / RF

Timing and feed-back strategy in the tunnel

- To relax on δϕ : feed-forward & back before entering each DECEL

Notional, as for now

Δt to:
injectors
DB & MB
Damp. Rings
MB TA
DB TAs
@50 Hz



Phase from B, Energy jitter δE from A&B,
Phase correction for δE

C&D, Phase error MB/DB , to synchronize
the injector linacs

Open issue:
frequency band of δE correction

Phase control - I

$$\delta\phi_{\mathrm{MB/DB}} = 0.2^o \;/\; 0.8^o \quad [\mathrm{coh}, \mathrm{inc}]$$ At 12 GHz

$$\delta\phi = 0.2^o \;@\mathrm{f}_0 = 12\mathrm{GHz} \;\equiv\; \delta z_{\mathrm{tol}} = 14\ \mu \;\equiv\; \delta t_0 = 46\ \mathrm{fs}$$

Scheme : correct the phase with fast feed-forward in the final chicane and slow feed-back to the injectors

Ingredients

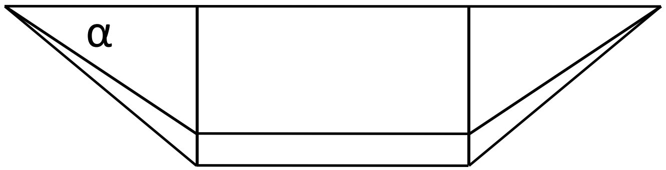
See talk
A. Andersson

- measurement of the 9 GeV MB (keep in memory for T = [0..23] × 6 µs])
- error in the 9 GeV MB from Injector and in the MB-TA
- DB TA length stability ⇔ magnet stability to be specified
- measurement of the DB
- error of the feed-forward adjustement of the chicane
- transmission error in the timing system
- bandwidth limit for correction (30 MHz ← the filling of the MB_ACS) DOABLE ?
- periodic dE/E structure complicating the measurement (slide 13)
- Path-lengths variations to be worked-out in all rings (MB and DB)

Phase control – II : data

$$\delta\phi = 0.2^o\ @f_0 = 12\mathrm{GHz} \equiv \delta z_{\mathrm{tol}} = 14\ \mu \equiv \delta t_0 = 46\ \mathrm{fs}$$

L_0 Chicane after TA



L_0 = 8m α = 0.1 rad

Tolerance on α :
- 1/10 δz_{tol}
- 4 magnets

$$\Delta z_{\mathrm{chicane}} = \alpha^2 L_0$$

$$dz = 2\alpha L_0 d\alpha$$

$$\boxed{d\alpha = \frac{\delta z_{\mathrm{tol}}}{10\sqrt{4}\times 2\alpha L_0} = 4\cdot 10^{-7}}$$

Use static magnets + variable deflectors for range $\delta\phi_r$=10°

$$\Delta\alpha_{\mathrm{defl}} = \frac{c}{2 f_0 \alpha L_0}\frac{\phi_r}{360} = 5\cdot 10^{-4}$$

$$\Rightarrow \frac{\sigma_{\alpha,\mathrm{defl}}}{\Delta\alpha_{\mathrm{defl}}} = \frac{d\alpha}{3\Delta\alpha_{\mathrm{defl}}} = 3\cdot 10^{-4}\ @\ 1/\tau_{\mathrm{fill,MBAS}} = 30\ \mathrm{MHz}$$

$$\Rightarrow \frac{\sigma_{\alpha,\mathrm{static}}}{\alpha_{\mathrm{static}}} = \frac{d\alpha}{3\alpha_{\mathrm{static}}} = 10^{-6}$$

All this being re-worked (less demanding) F.Stulle, D. Schulte

Range inside which correction applies

relax for DB linac →

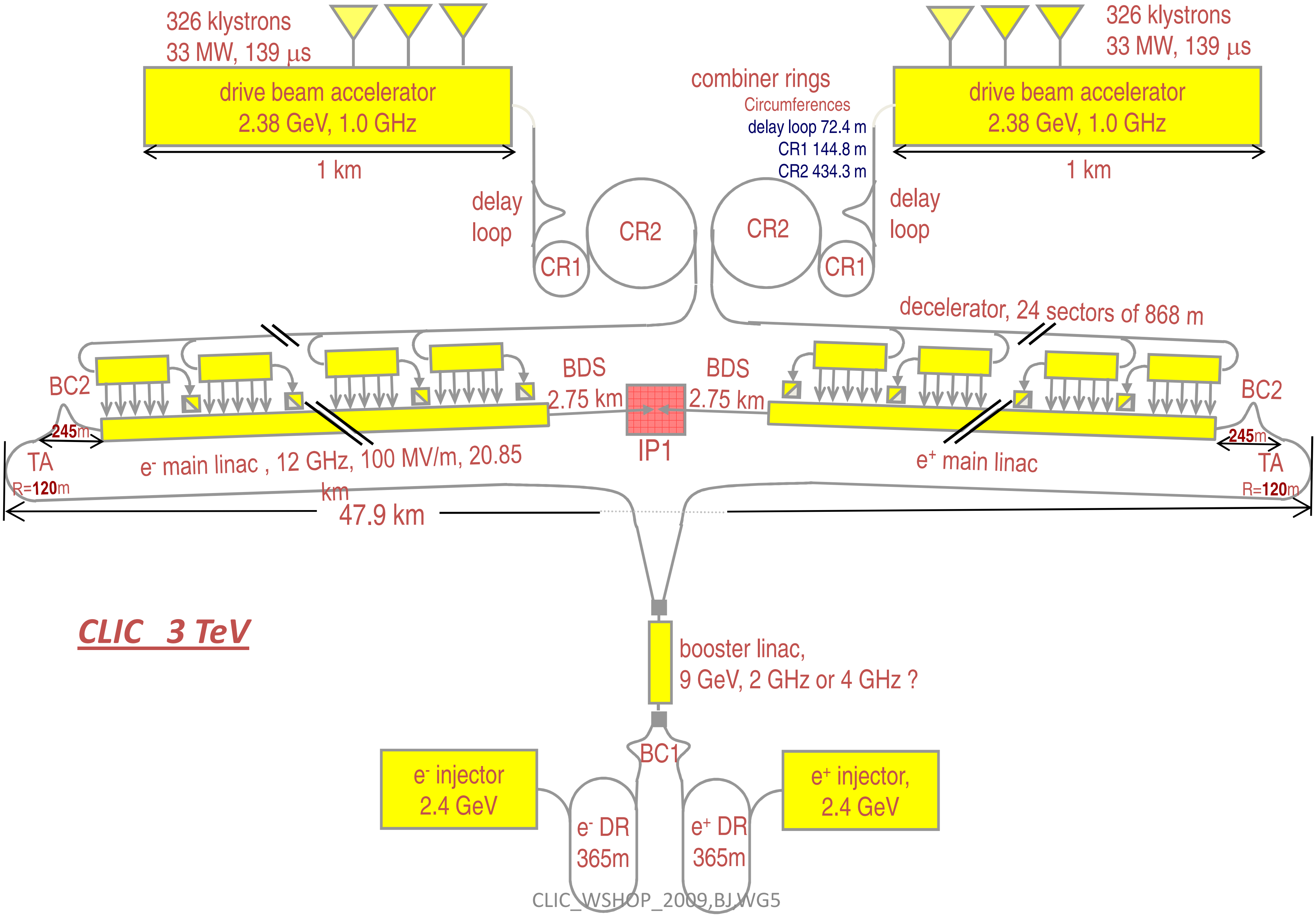
$$\delta z_{\mathrm{Linac}} \simeq 10\,\delta z_{\mathrm{decel}} \Rightarrow \delta\phi_{\mathrm{Linac}} = \frac{10}{12}\delta\phi_{\mathrm{decel}} \simeq 0.2^o\ @\ 1\mathrm{GHz}$$

(Instead of 0.015°)

Fast timing network

- Little (or no) expertise in the project as of today
- Presentations at this workshop : WG3 THURSDAY 11h00-12h30
  - Long distance Optical Fibers with fs resolution
    F. Oemer Ilday / Bilkent Univ. Ankara
  - Overview of the Phase Measurement System at SLS/PSI
    Vladimir Arsov / PSI
  - Femtosecond optical synchronization system for FLASH
    Matthias Felber / DESY

CLIC 3 TeV



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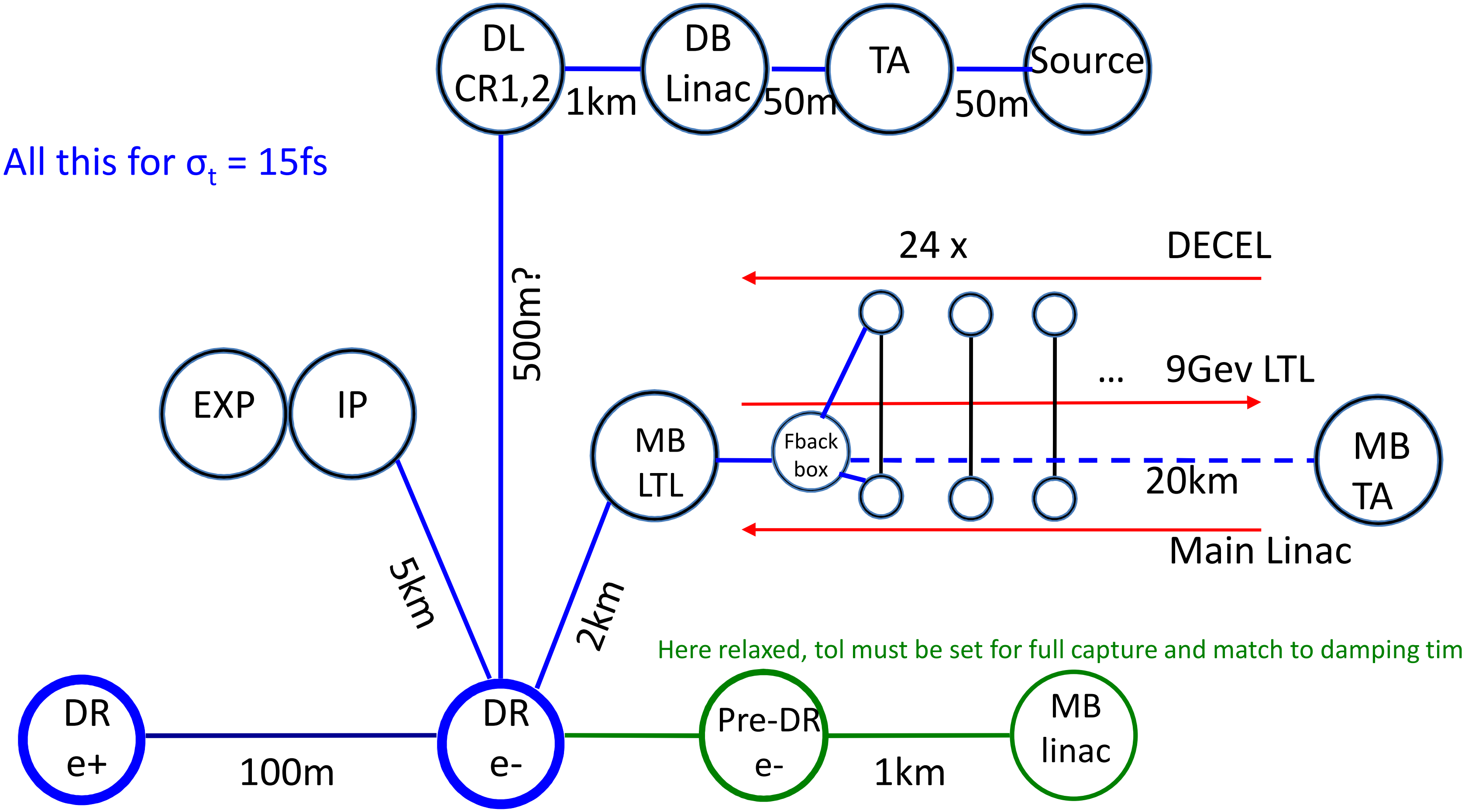


All this for σ_t = 15fs

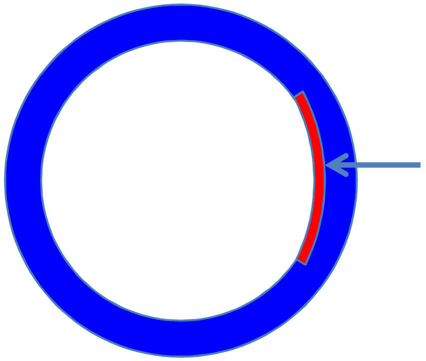
Here relaxed, tol must be set for full capture and match to damping time

Here to synchronize the two complex

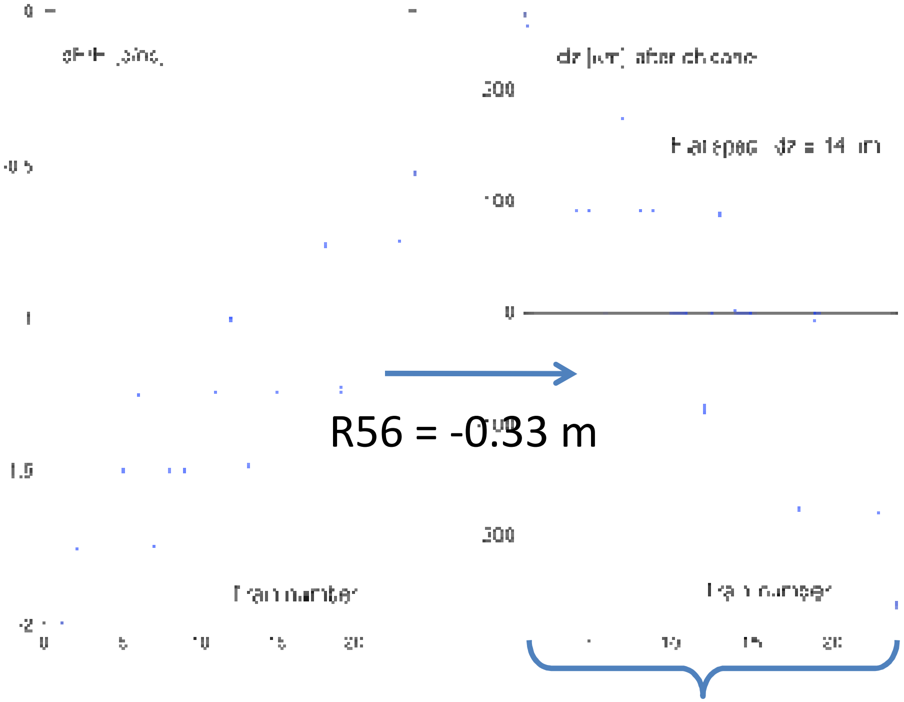
Tolrance : σ_t = 7.5fs

Fast longitudinal measurement

A complication : Incoherent synchrotron radiation



- X-ray @ 6 keV : $L_{absorption}$ = 50 μm (Aluminium)
- Impact angle : ~ 0.2 rad
- ΔT = 80 °K @ 50 Hz
- Risk of rapid ageing



R56 = -0.33 m

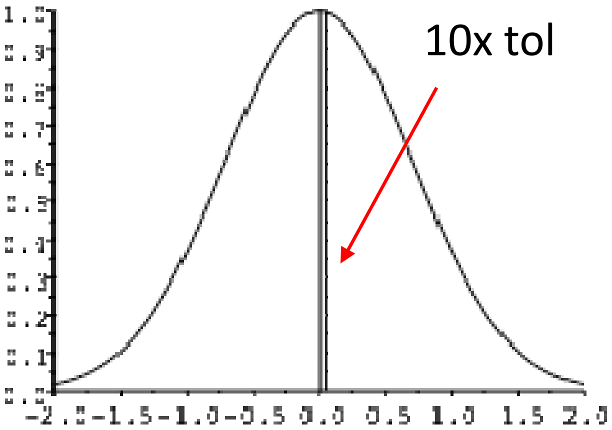
24 bunches x 121

TIME STRUCTURE

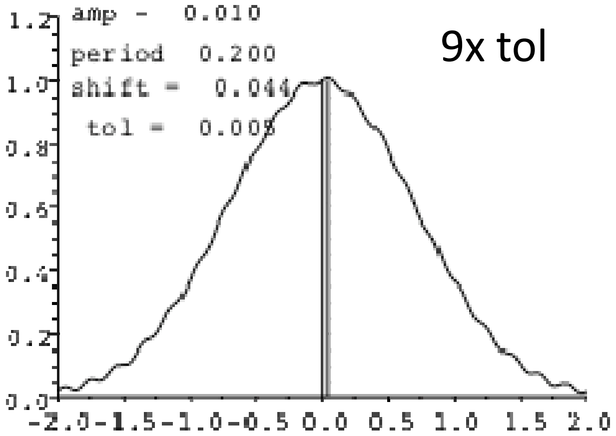
Overall dE/E of ISR varies between
Trains travelling :
- MIN : No DL, 1×CR1, 1×CR2
- MAX : 1×DL, 3×CR1, 4×CR2
- Max dE/E = 2 o/oo
- Converts to dz after last chicane before DECEL
- 1% longitudinal z-pitch modulation

Cure :
- make the DL, CR1,CR2 longer accordingly
- complicates the feed-forward ϕ–correction (see slide 20)

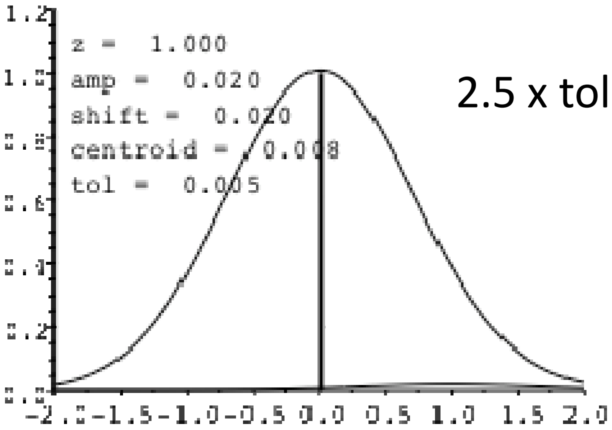
Detection of the bunch centroid



10x tol



9x tol



2.5 x tol

A gaussian bunch,
with sσ_z = 1mm
And tol $\sigma(\delta z)$ = 0.005mm
($\sigma(\delta t)$ = 15fs)

- Existing CTF3 data ?

Summary

- Timing and feed-back in the femto-second range not trivial
- Much work in many areas
- Multi-group issue (RF,detectors,network?,beam)
- Long distance (km) & precise (10fs,5µm) new for us