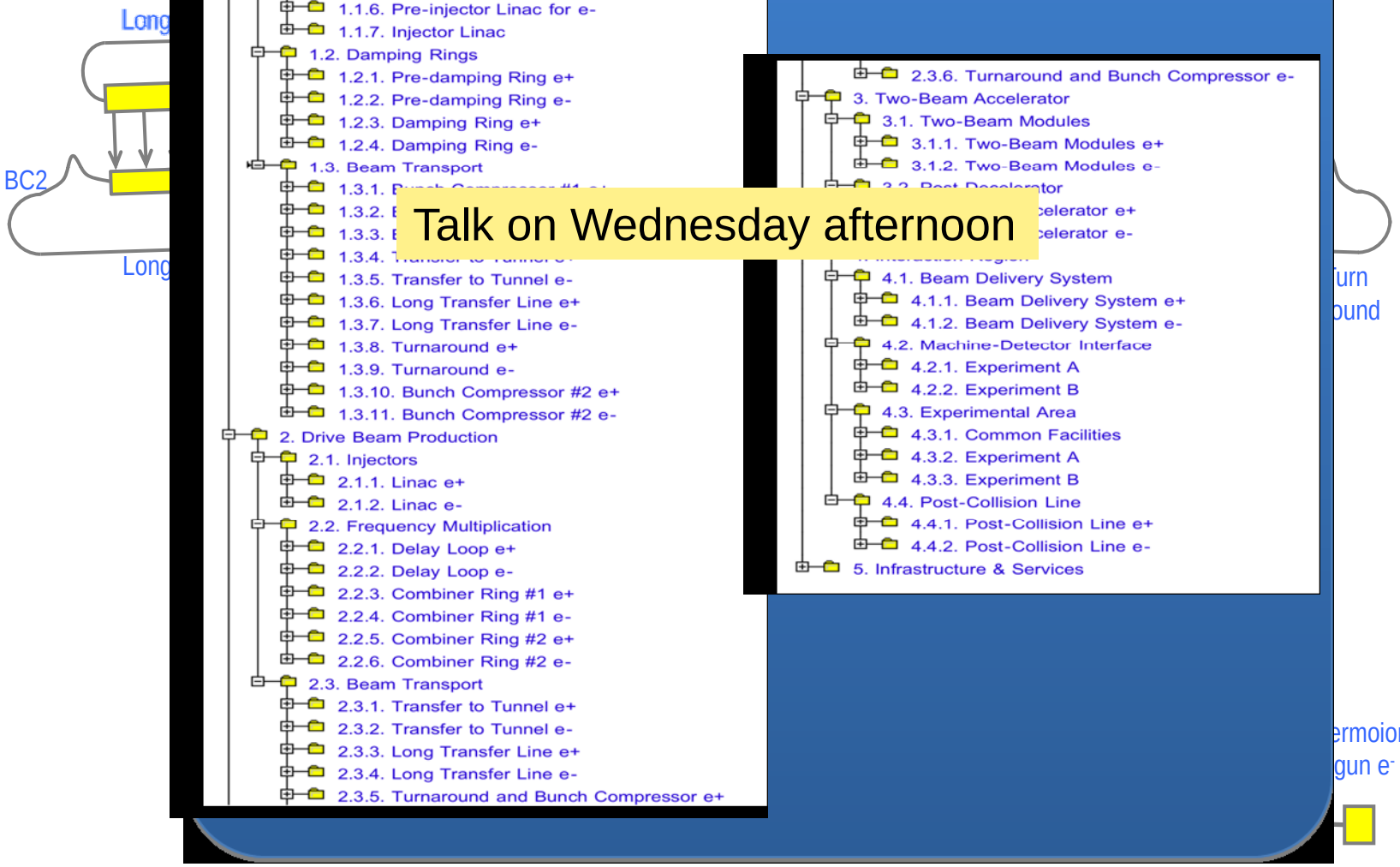
Review on Instrumentation needs and Critical Items

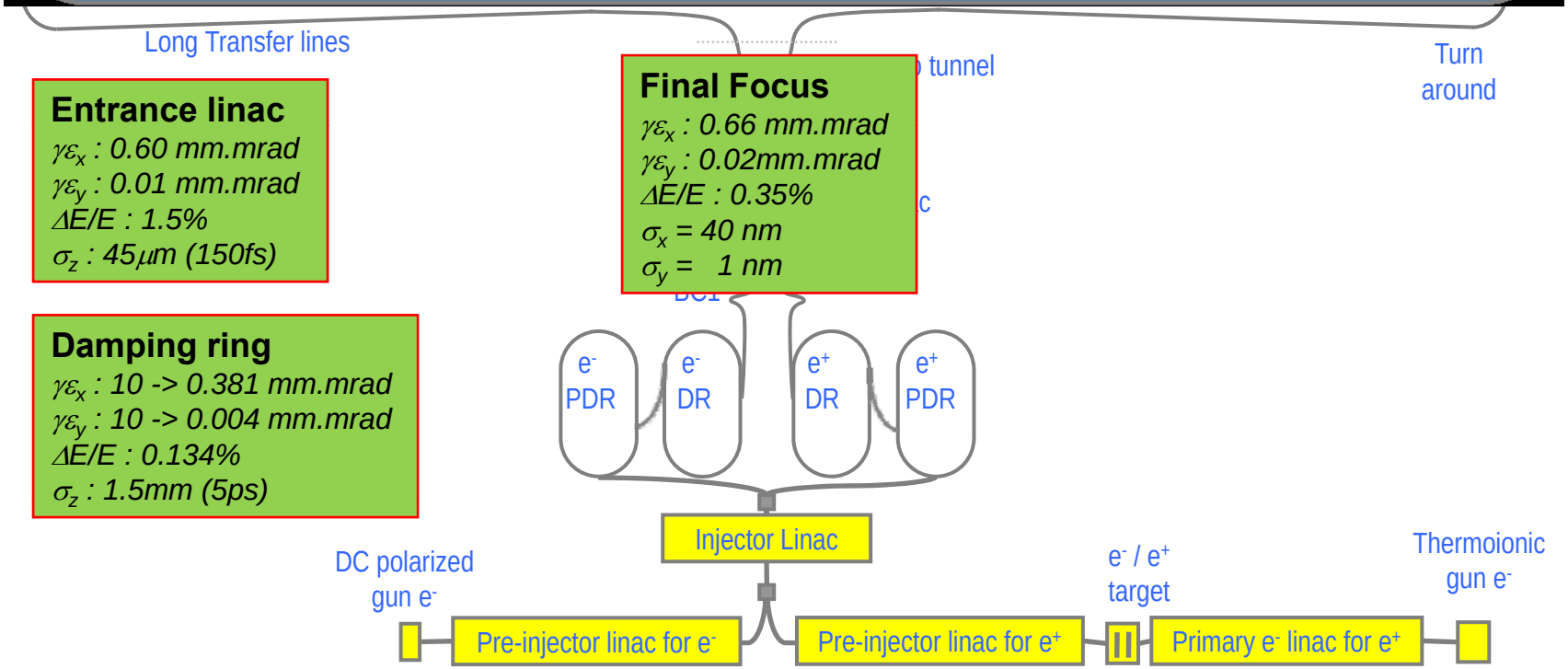
- Overview of the CLIC Machine
- Beam instrumentation requirements by Sub-systems
- Critical Items
- CLIC synergies with other project/ existing machine

CLIC 3TeV

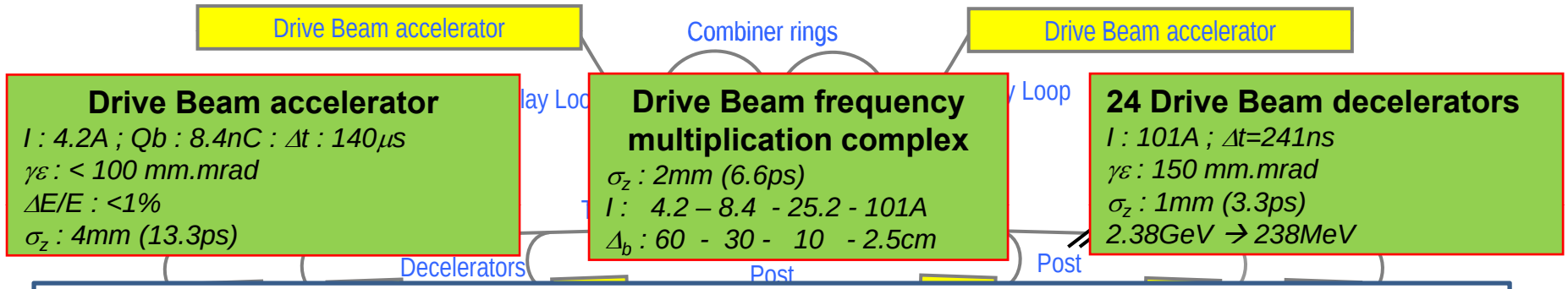

Hardware Baseline
1. Main Beam Production
1.1. Injectors
1.1.1. Thermoionic gun unpolarized e-
1.1.2. Primary e- Beam Linac for e+
1.1.3. e-/e+ Target
1.1.4. Pre-injector Linac for e+
1.1.5. DC Gun Polarised e-
1.1.6. Pre-injector Linac for e-
1.1.7. Injector Linac
1.2. Damping Rings
1.2.1. Pre-damping Ring e+
1.2.2. Pre-damping Ring e-
1.2.3. Damping Ring e+
1.2.4. Damping Ring e-
1.3. Beam Transport
1.3.5. Transfer to Tunnel e-
1.3.6. Long Transfer Line e+
1.3.7. Long Transfer Line e-
1.3.8. Turnaround e+
1.3.9. Turnaround e-
1.3.10. Bunch Compressor #2 e+
1.3.11. Bunch Compressor #2 e-
2. Drive Beam Production
2.1. Injectors
2.1.1. Linac e+
2.1.2. Linac e-
2.2. Frequency Multiplication
2.2.1. Delay Loop e+
2.2.2. Delay Loop e-
2.2.3. Combiner Ring #1 e+
2.2.4. Combiner Ring #1 e-
2.2.5. Combiner Ring #2 e+
2.2.6. Combiner Ring #2 e-
2.3. Beam Transport
2.3.1. Transfer to Tunnel e+
2.3.2. Transfer to Tunnel e-
2.3.3. Long Transfer Line e+
2.3.4. Long Transfer Line e-
2.3.5. Turnaround and Bunch Compressor e+
2.3.6. Turnaround and Bunch Compressor e-
3. Two-Beam Accelerator
3.1. Two-Beam Modules
3.1.1. Two-Beam Modules e+
3.1.2. Two-Beam Modules e-
4.1. Beam Delivery System
4.1.1. Beam Delivery System e+
4.1.2. Beam Delivery System e-
4.2. Machine-Detector Interface
4.2.1. Experiment A
4.2.2. Experiment B
4.3. Experimental Area
4.3.1. Common Facilities
4.3.2. Experiment A
4.3.3. Experiment B
4.4. Post-Collision Line
4.4.1. Post-Collision Line e+
4.4.2. Post-Collision Line e-
5. Infrastructure & Services
Product Breakdown Structure
Talk on Wednesday afternoon

Challenges for CLIC Main Beam

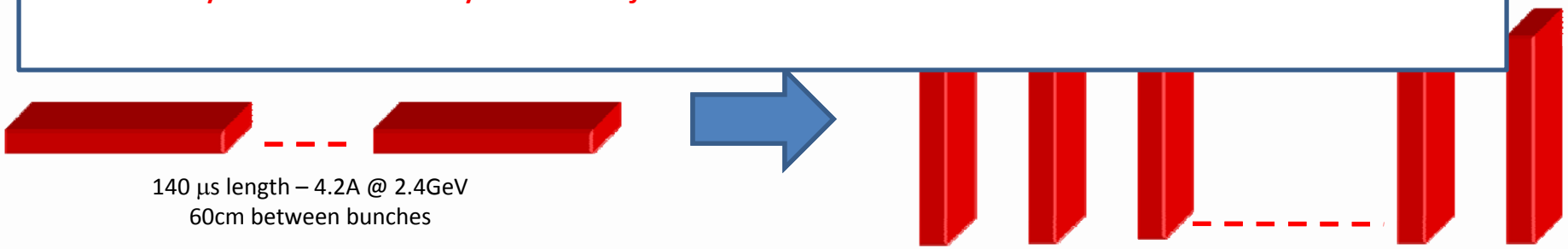
- Producing and measuring **small beam emittance (1micron)**
- Producing and measuring **short Bunches (45microns)**
- Conserving small beam emittance (very strict tolerances/requirements on the **beam position monitor precision and resolution**)



Challenges for CLIC Drive Beam



- Manipulating high charge beams (Machine Protection issues, Radiation level, Non intercepting beam diagnostic, ..)
- In addition, there are very strict tolerances/requirements on the beam phase stability (0.1º@12GHz)
- Reliability and availability : This is 'just' the RF Source !



140 μs length – 4.2A @ 2.4GeV
60cm between bunches

24 x 240ns pulse spaced by 5.8μs
101A, 2.5cm between bunches

CLIC 3TeV

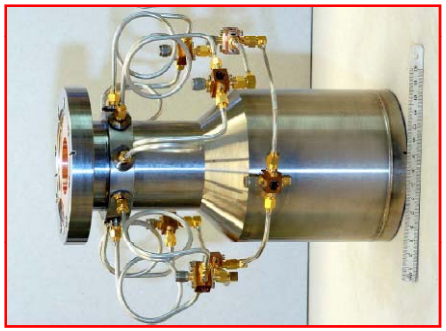
CLIC RF source

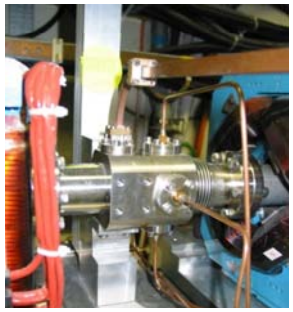
- Electron/positron injectors (600m)
- Damping rings (4x500m)
- Bunch compressor 1 (2x 70m)
- Booster Linac (600m)
- Long transfer lines (2x 21km)
- Turn around (2x 1.6km)
- Bunch compressor 2 (2x 120m)
- Main Linac (2x 20.8km)
- Beam Delivery System (2x 2.75km)
- Post Collision line (2x 250m)

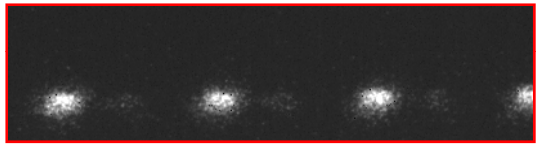
Main Beam

~ 96kms of beam lines

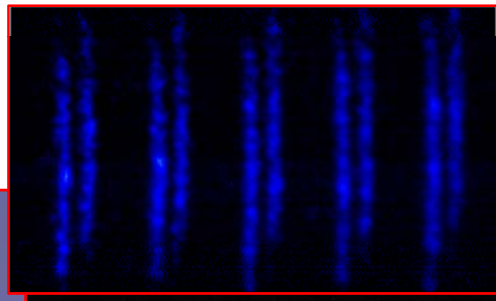
CLIC 3TeV

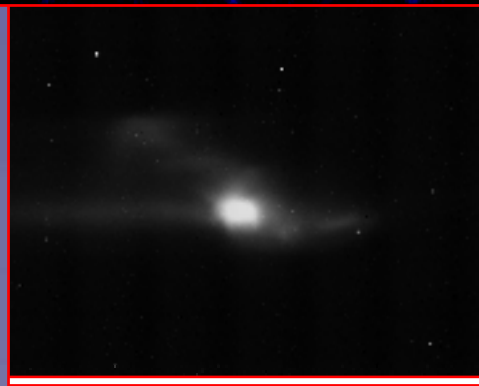




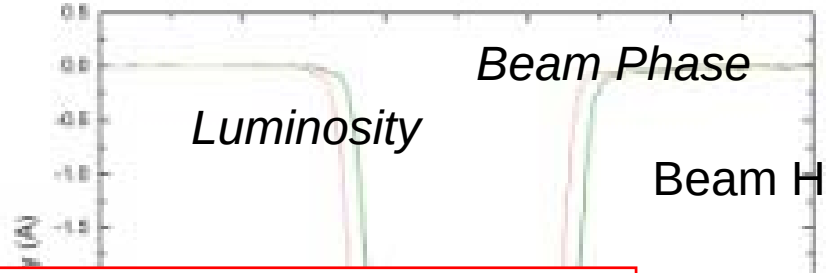


Bunch length (σ_z)





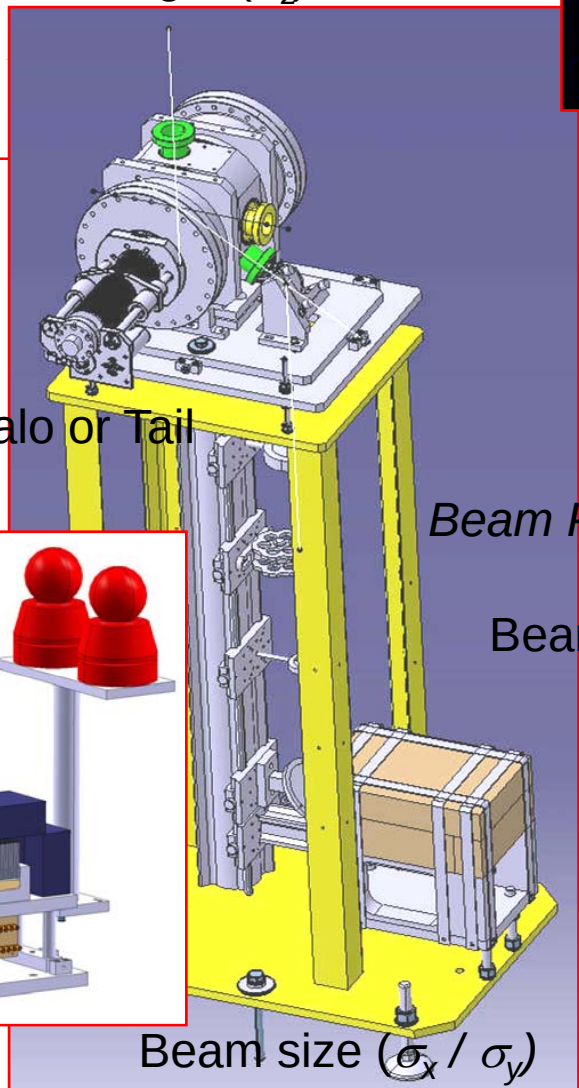
Beam Current *I*



Beam Phase

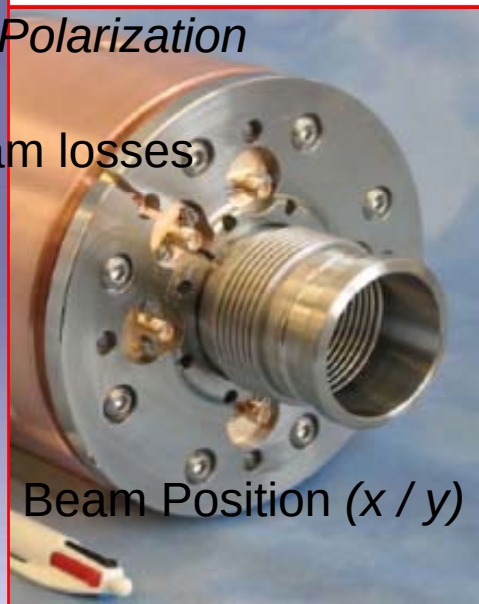
Luminosity

Beam Halo or Tail

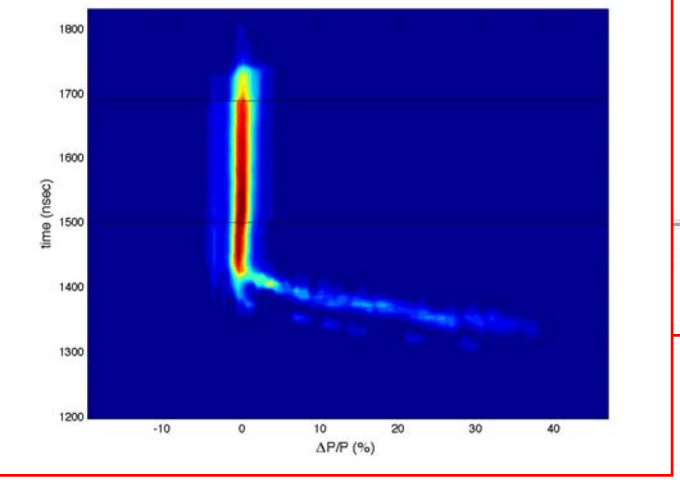


Beam Polarization

Beam losses



Beam Position (*x* / *y*)



Beam energy *E and* energy spread ΔE

Beam size (σ_x / σ_y)

Parameter specifications

List of instruments for each sub-systems

Instrument	*Accuracy*	*Resolution*	*Bandwidth*	*Beam tube aperture*	*Stability*	*Non-intercepting device?*	*How many?*	*Used in RT Feedback?*	*Machine protection Item ?*
Intensity									
Position									
Beam Size / Emittance									
Energy									
Energy Spread									
Bunch Length									
Beam Loss									
Beam Halo									
Beam Phase									
Beam Po									
Luminos									
Wakefiel									

Identify the critical items in each of the 44 sub-systems (feasibility, cost, performance)

CLIC 3TeV – Numbers of devices

Instrument	N° Devices
Intensity	316
Position	**45242**
Beam Size	**902**
Energy	216
Energy Spread	27
Bunch Length	212
Beam Loss/Halo	0
Beam Phase	96

Drive Beam

47011 devices

No Beam Loss Monitors specified yet

Instr	N° Devices
Intensity	311
Position	**7579**
Beam Size / Emittance	171
Energy	75
Energy Spread	23
Bunch Length	26
Beam Loss/Halo	4
Beam Polarization	23
Tune	8
Beam Phase	2
Luminosity	4
Wakefield monitor	**142812**

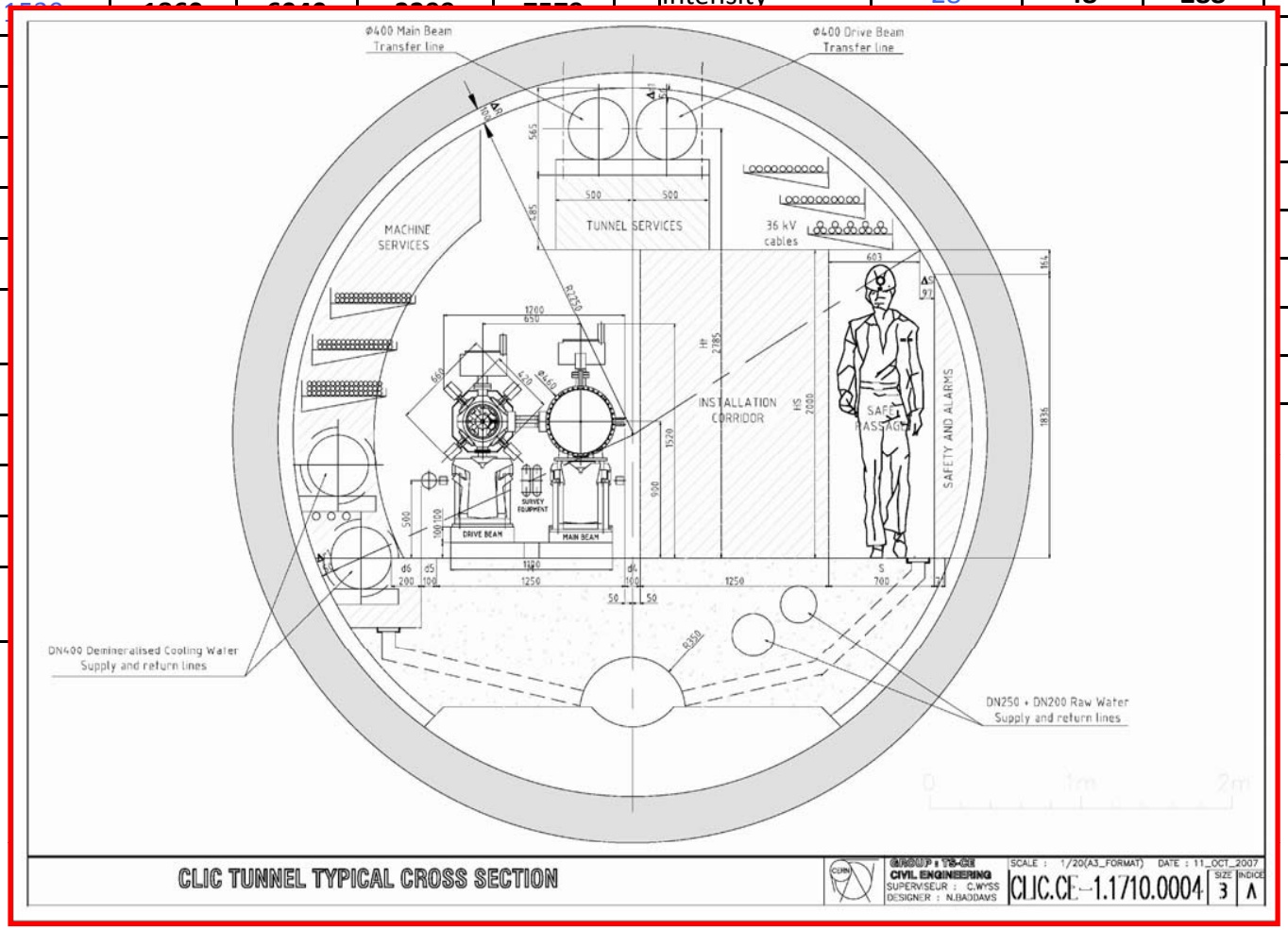
Main Beam

8226 devices
+ 142812 wakefield monitors

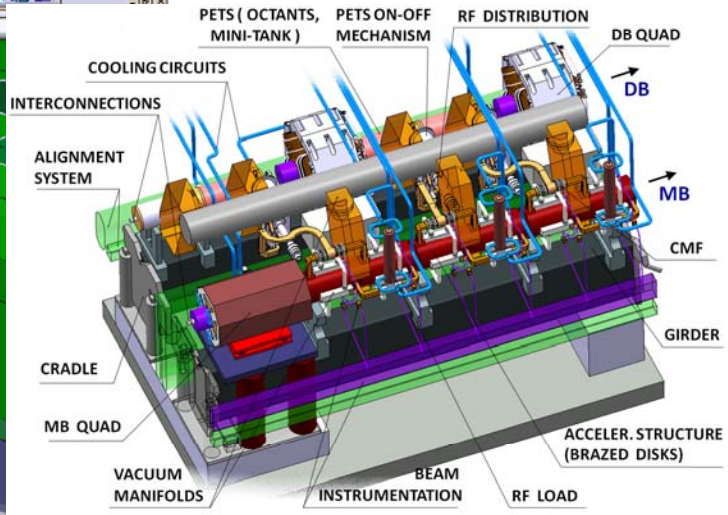
From 500GeV to 3TeV

Instrument	Main Beam injector	Main Beam Tunnel		Main Beam Total	
		500GeV	3TeV	500GeV	3TeV
Intensity	225	36	86	261	311
Position					
Beam Size					
Energy					
Energy Spread					
Bunch Length					
Beam Loss/Halo					
Beam Polarization					
Tune					
Beam Phase					
Luminosity					
Total					
Wakefield monitor					

Instrument	Drive Beam injector	Drive Beam Tunnel		Drive Beam Total	
		500GeV	3TeV	500GeV	3TeV
Intensity	28	48	288	76	316
				8282	45242
				172	902
				56	216
				27	27
				52	212
				0	0
				16	96
				8681	47011



CLIC Tunnel



Courtesy of J. Osborne and A. Samoshkin

List of Critical Items

- **Very tight requirements** for measuring micrometer **beam size**, 40-75microns short **bunch length** and **beam position** with a 50nm resolution

- **Reliability and availability** of roughly 5000 high resolution (50nm) BPMs, 40000 BPM's for the Drive Beam Decelerator and 150000 wakefield monitors with 5µm accuracy

- Need to study the **Machine Protection System** for both the Drive and Main beams and to develop a **Beam loss monitoring system along the CLIC linac** (both beams)

- Beam **synchronization** implies a **0.1deg at 12GHz phase measurement** with an adequate feed-forward system (a **stability of the Drive Beam energy and intensity of 3.10^{-5}**): need a non destructive energy measurements between each CLIC Main Beam sectors

Several steps for the CDR

1- Collect the beam instrumentation requirements for each CLIC sub-systems and identify Critical Items and the need for new R&D

2- Evaluate the performance of already-existing technologies

- **CLIC specific instruments**
  - Luminosity monitors
  - 20-50fs timing synchronization

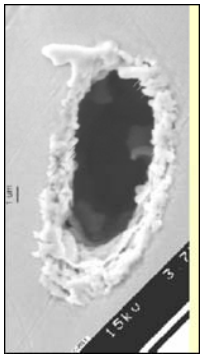
- **CTF3 beam diagnostics – importable to CLIC**

- **ILC instruments with similar requirements as for CLIC**
  - Laser Wire Scanner or Cavity BPM
  - Beam Delivery System instrumentation
    Ex: Polarization monitor, Beam Energy measurements
  - Damping ring instrumentation developed at ATF2

- **3rd and 4th generation light sources**
  - Damping ring instrumentation
  - Bunch Compressor instrumentation very similar to XFEL projects

CLIC vs CTF3

	CTF3	CLIC
Beam Energy (GeV)	0.15	2.4
RF Frequency (GHz)	3	1
Multiplication Factor	8	24
Initial Beam Current (A)	3.75	4.2
Final Beam Current (A)	30	100
Initial Pulse length (us)	**1.2**	**140**
Final Pulse Length (ns)	140	240
Total Beam Energy (kJ)	**0.7**	**1400**
Repetition Rate (Hz)	5	50
Average Beam Power (MW)	**0.0034**	**70**
Charge density (nC/cm^2)	**$0.4\ 10^6$**	**$2.3\ 10^{10}$**



The thermal limit for 'best' material (C, Be, SiC) is 10^6 nC/cm^2

- Still considerable extrapolation to CLIC parameters
- Especially total beam power (loss management, machine protection)
- Development of non-destructive instruments
- Stability and reliability

CLIC vs ILC

	CLIC 3TeV	CLIC 500GeV	ILC
Center of mass energy (GeV)	3000	500	500
Main Linac RF Frequency (GHz)	12	12	1.3
Luminosity (10^{34} cm^{-2} s^{-1})	5.9	2.3	2
Linac repetition rate (Hz)	50	50	5
Accelerating gradient (MV/m)	100		33.5
Proposed site length (km)		13	31
Total power consumption (MW)	415	129.4	216
Wall plug to main beam (%)	6.8	7.5	9.4

Requirements for CLIC are always tighter

Critical Beam Parameter

	CLIC 3TeV	CLIC 500GeV	ILC
Bunch Length in the Linac (fs)	150	230	900
Typical Beam Size in the Linac (μm)	**1**	**1**	**5**
Beam Emittance H/V (nm.rad)	**660/20**	**2400/25**	**10^4/40**
Beam size at IP : σ_x / σ_y (nm)	40/1	202/2.3	640/5.7

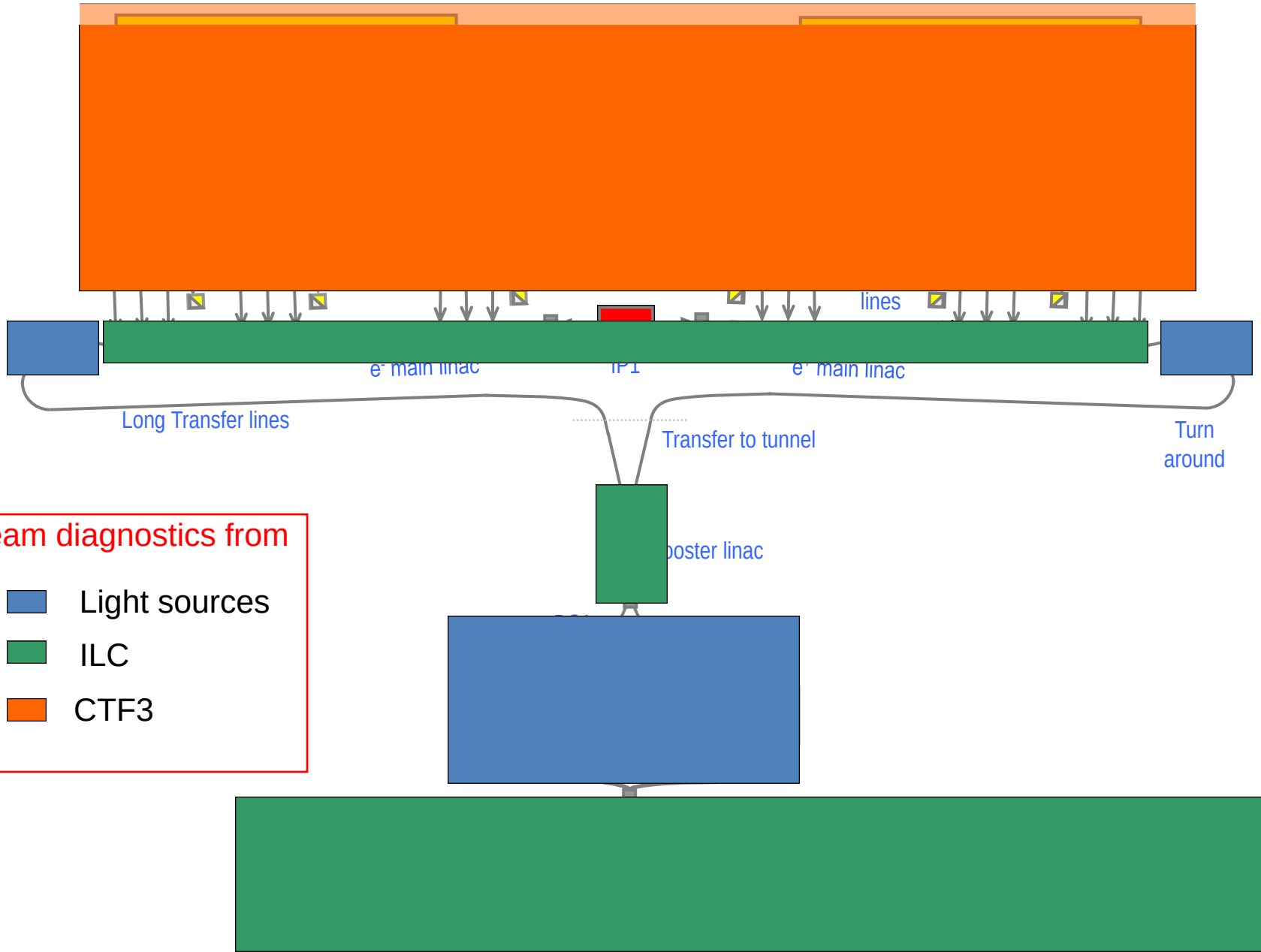
CLIC vs Light Sources

	CLIC DR	SLS	Diamond	Soleil
Beam Energy (GeV)	2.86	2.4	3	2.75
Ring Circonfrence (m)	493	288	561.6	354
Bunch charge (nC)	0.6	1	1	0.5
Energy Spread (%)	0.134	0.09	0.1	0.1
Damping times (x,y,E) (ms)	2,2,1	9,9,4.5	-	6.5,6.5,3.3
Orbit stability (um)	1	1	1	1

	CLIC linac	XFEL	LCLS
Beam Energy (GeV)	3000	[illegible]	15
Linac RF Frequency (GHz)	12	[illegible]	2.856
Bunch charge (nC)	[illegible]	1	1
Bunch Length (fs)	150	80	73

Development of BLM for long linac

CLIC Instrumentation



Beam diagnostics from

- Light sources
- ILC
- CTF3

Perspectives

- Huge amount of work: *200000 Instruments over 190kms of beamlines*
- R&D on Critical Items has started and the status is presented during the next two sessions
- Big potential for collaborations with light sources community
- Discussion sessions on Wednesday Afternoon
  - Define the frame of the work for the CDR
  - Review Plans & Milestones for every Critical Instruments
  - Work to be done for a Cost estimate

CLIC Instrumentation and ressources

- Development on **Beam loss monitors**
  - Recent collaboration with **University of Liverpool** - Cockcroft Institute for Beam loss detection technique based on Optical fiber
  - Recent collaboration with **Greece** : Students for beam loss shower simulations

- Development of **micrometer beam size monitor**
  - **JAI-RHUL** and **Oxford University** colleagues involved in ATF2 laser wire scanner program

- Development of **short bunch length monitoring techniques**
  - **INFN-Frascati** for RF deflector techniques
  - **Northwestern University** using RF pick-up techniques
  - **JAI-RHUL** for Coherent Diffraction radiation techniques
  - Recent interest from **University of Dundee** for Electro-optics techniques

- Development of **Beam Position Monitors**
  - **FNAL** collaboration for 50nm resolution BPM
  - **JAI-RHUL** for BPM development
  - **IFIC Valencia** for Drive Beam Decelerator BPM
  - **CEA/IRFU** for re-entrant cavity BPM
  - **INFN-Frascati** for Drive Beam delay loop and combiner rings

- Development of **Wakefield monitors** by **CEA/IRFU**

- Development of emittance and energy spread measurement devices with **PSI**

- Development of **post collision line monitor (luminosity monitor)** by **Uppsala university**

- Beam synchronization implies a 0.1deg at 12GHz phase measurement with an adequate feed-forward system
  Activity not follow-up by the BI group (RF group and FP7)

- **Electronic development** for **Large distributed systems**:
  - **LAPP** for the acquisition system (rad-hard analog and digital solutions)
  - **University Politecnica de Catalunya** for rad-hard analog electronic

EuCARD WP9 "NCLinac"

- Full name: ***"Technology for normal conducting higher energy linear colliders"***
- 5 tasks:
  - NCLinac Coordination and Communication
  - Normal conducting High Gradient Cavities
    PETS, alignment & HOM's, breakdown simulation, BD diagnostics, precise assembly
  - Linac and Final Focus Stabilisation
    Quadrupole mock-up, FF test-stand
  - Beam Delivery System
    tuning procedures at ATF2, high-precision BPM's, Laser-wire
  - Drive Beam Phase control
    20 fs RF monitor, electro-optical monitor
- Partners: CERN, CIEMAT, CNRS, INFN, PSI, RHUL, STFC, UNIMAN, UOXF-DL, UU
- **Resources: 6.5 MEuros, 540 persons-years**

Damping Rings diagnostics

- **300PUs**, turn by turn (every **1.6μs**)
  - **10μm** resolution, for linear and non-linear optics measurements.
  - **2μm** resolution for orbit measurements (vertical dispersion/coupling correction + orbit feedback).
- WB PUs for bunch-by-bunch (bunch spacing of **0.5ns** for **312** bunches) and turn by turn position monitoring with high resolution (**1μm**) for injection trajectory control, and bunch by bunch transverse feed-back.
- PUs for extraction orbit control and feed-forward.
- Tune monitors and fast tune feed-back with precision of 10^{-4}, critical for resolving instabilities (i.e. synchrotron side-bands, ions)
- Turn by turn transverse profile monitors (X-ray?) with a wide dynamic range:
  - Hor. geometrical emittance varies from 11nm.rad @ injection to 90pm.rad @ extraction and the vertical from 270pm.rad to 0.9pm.rad.
  - Capable of measuring tails for IBS
  - This would probably be the most challenging item
- Longitudinal profile monitors
  - Energy spread of 0.5% to 0.1% and bunch length from 10 to 0.1mm.
  - Note that the dispersion around the ring is extremely small (<12mm).
- Fast beam loss monitoring and bunch-by-bunch current measurements
- E-cloud + ion diagnostics

Intro: ILC Beam Instruments

- ~ 2000 Button/stripline BPM's (10-30 / 0.5 µm resolution)
- [illegible], 0.
- [illegible] part
- [illegible] s (0
- [illegible] tion
- [illegible] 13 Deflecting Mode Cavities (bunch length)
- ~ 1600 BLM's
- Other beam monitors, e.g. toroids, bunch arrival / beam phase monitors, wall current monitors, faraday cups, OTR & other screen monitors, sync light monitors, streak cameras, feedback systems, etc.
- Read-out & control electronics for all beam monitors

ILC
~ 6000 Devices

CLIC@500GeV
~32000 Devices