CLIC Electrical Infrastructure PiP and PBS in preparation for the Internal Review

CEIS Meeting, Friday, 22 June 2018

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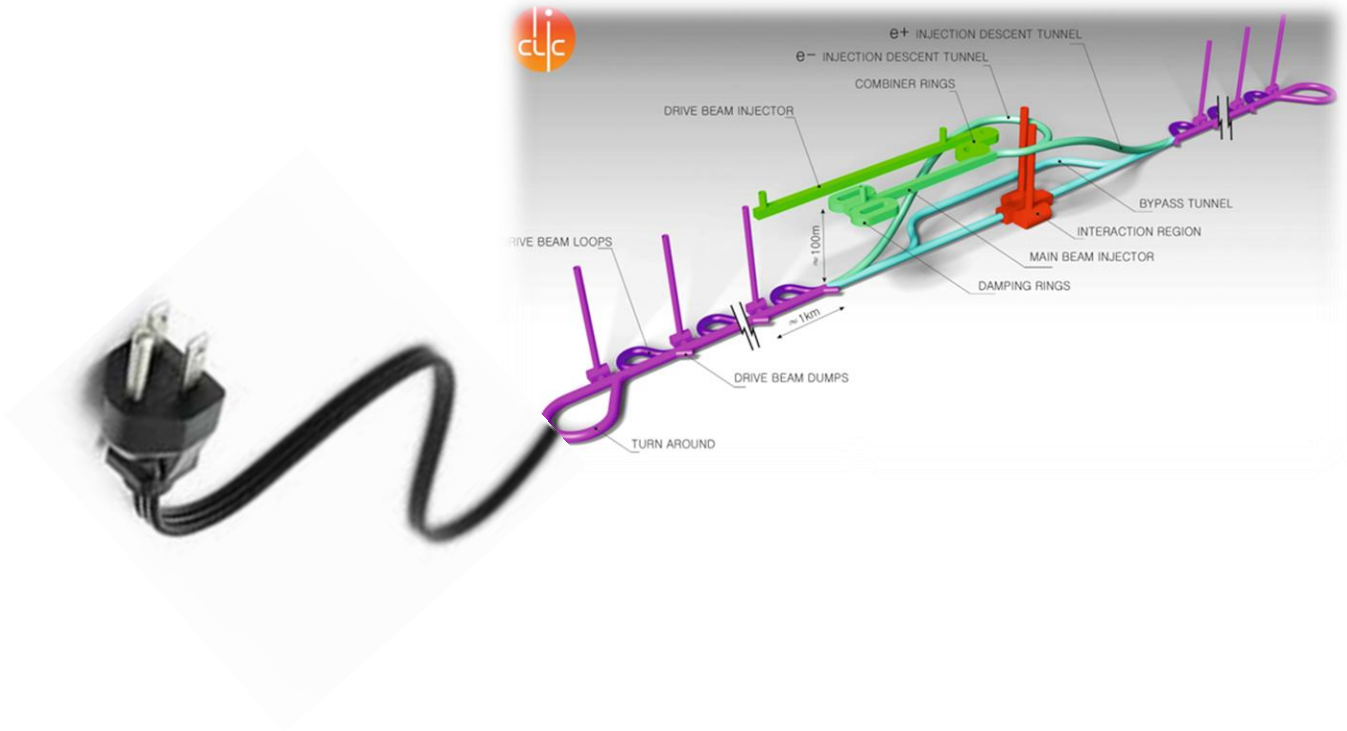

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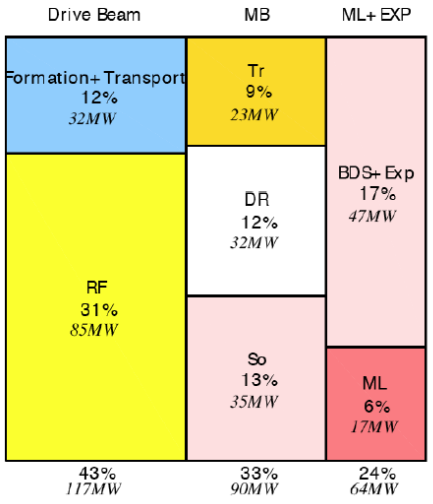
CLIC Power Requirements – Consumption

- As specified in CDR

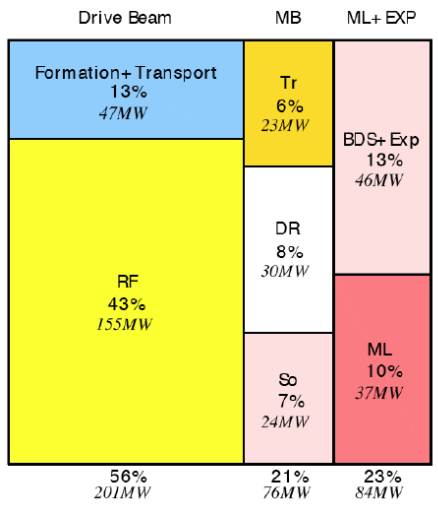
Table 9: Parameters for the CLIC energy stages. The power consumptions for the 1.5 and 3 TeV stages are from the CDR; depending on the details of the upgrade they can change at the percent level.

Parameter	Symbol	Unit	Stage 1	Stage 2	Stage 3
Centre-of-mass energy	$\sqrt{s}$	GeV	380	1500	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		352	312	312
Bunch separation	Δt	ns	0.5	0.5	0.5
Pulse length	τ_{RF}	ns	244	244	244
Accelerating gradient	G	MV/m	72	72/100	72/100
Total luminosity	$\mathcal{L}$	10^{34} cm^{-2}s^{-1}	1.5	3.7	5.9
Luminosity above 99% of $\sqrt{s}$	$\mathcal{L}_{0.01}$	10^{34} cm^{-2}s^{-1}	0.9	1.4	2
Main tunnel length		km	11.4	29.0	50.1
Number of particles per bunch	N	10^9	5.2	3.7	3.7
Bunch length	σ_z	μm	70	44	44
IP beam size	σ_x/σ_y	nm	149/2.9	~ 60/1.5	~ 40/1
Normalised emittance (end of linac)	$\varepsilon_x/\varepsilon_y$	nm	920/20	660/20	660/20
Normalised emittance (at IP)	$\varepsilon_x/\varepsilon_y$	nm	950/30	—	—
Estimated power consumption	P_{wall}	MW	252	364	589

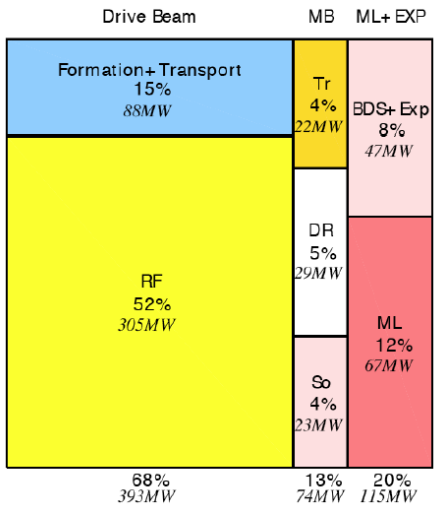
0.38 TeV, 252 MW (265 MVA)



1.5 TeV, 364 MW (383 MVA)



3 TeV, 589 MW (620 MVA)

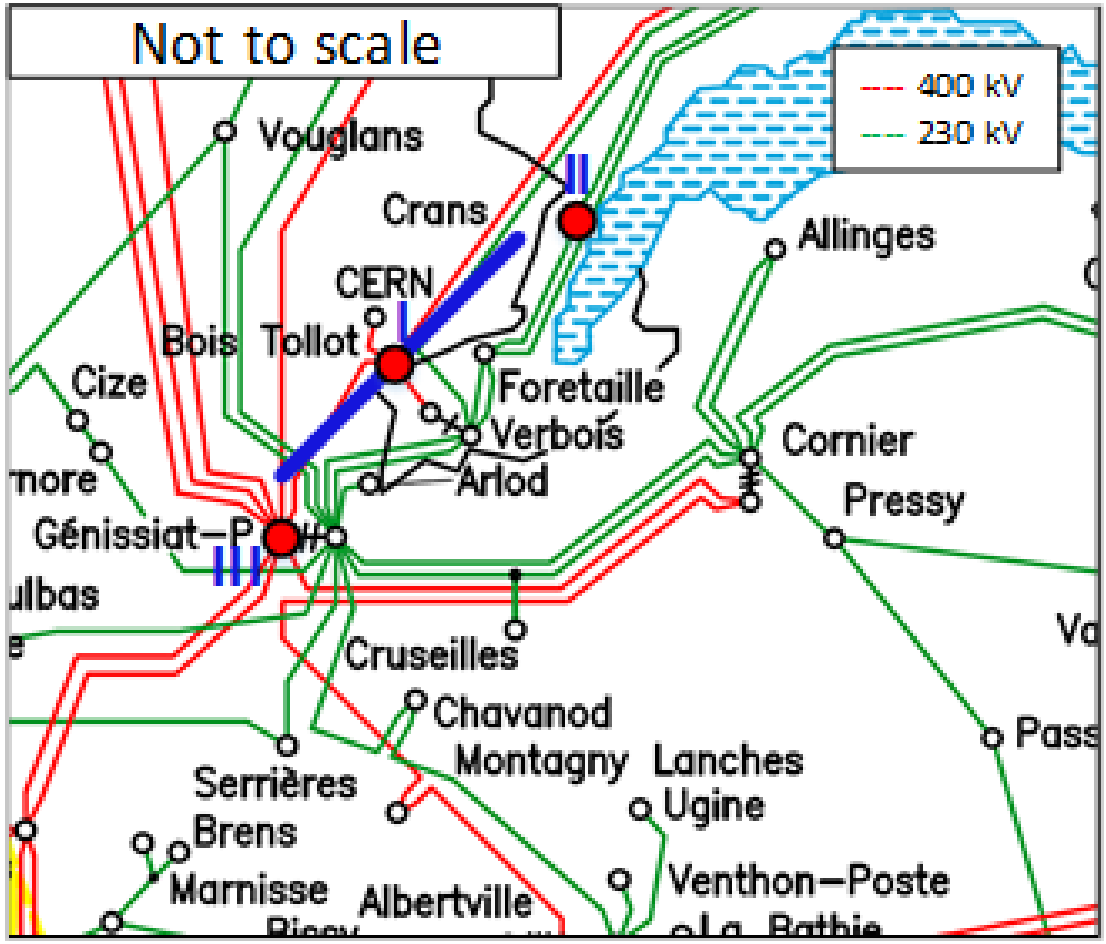


67 %
Of the Bugey-4 Reactor power production capacity

Sources of Energy

- Availability at European Grid level
- Based on mid long term plan of RTE* towards 2030).
- 200 MW (i.e 222 MVA) available at each of the three 400 kV French existing nodes (I,III).
- A 230 kV rated node (II) located on the Swiss side. Power availability unknown.

- **Roughly 70%** of the total power requirements concerns the injection infrastructure **located on the main campus**, identified as point 1 in figure 1.
- The proposed transmission and distribution network **consider the upgrade of the European Grid to** make available to totality of the CLIC power requirements in point 1.



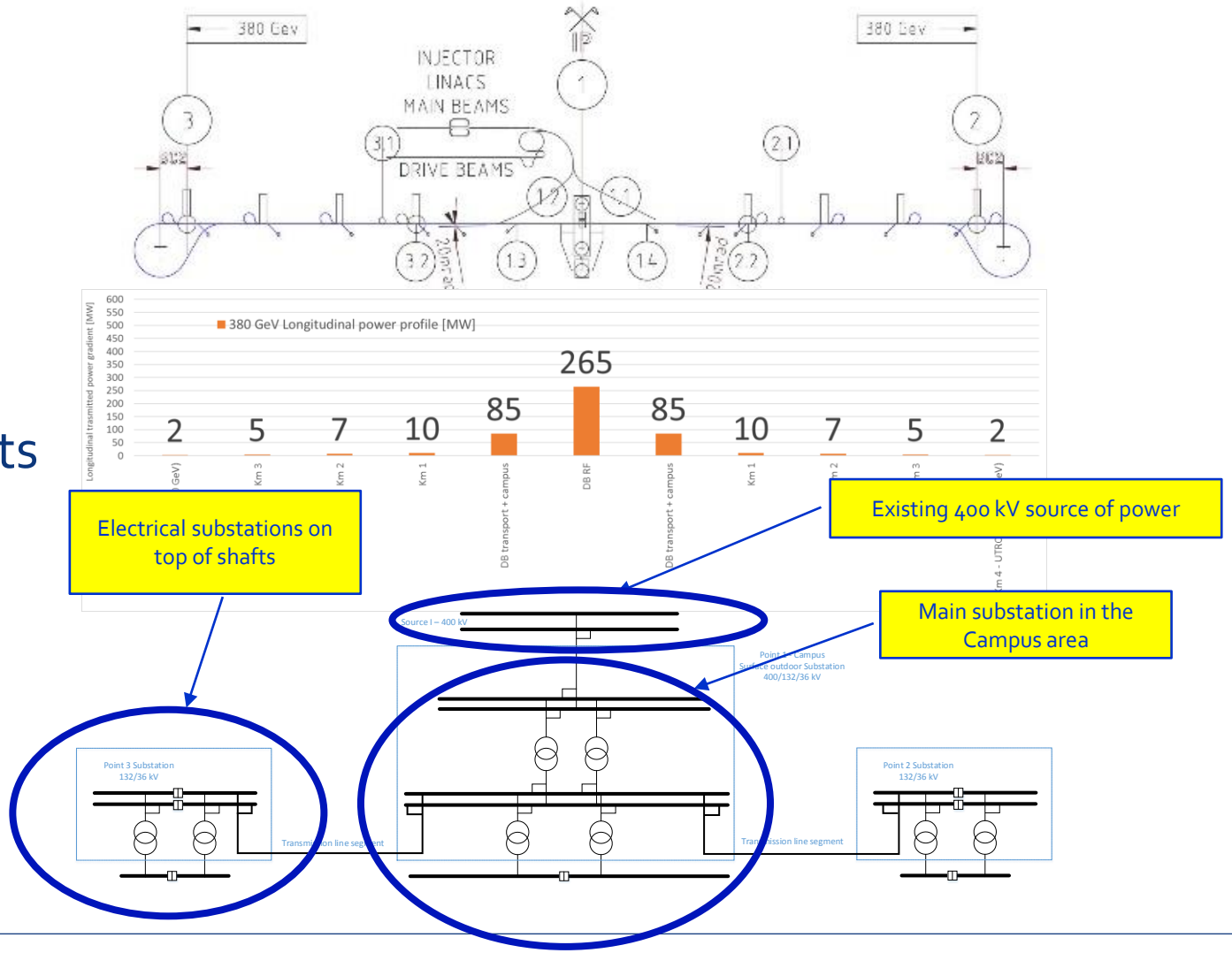
* the French power transmission system operator

Transmission Network for the 380 GeV Stage

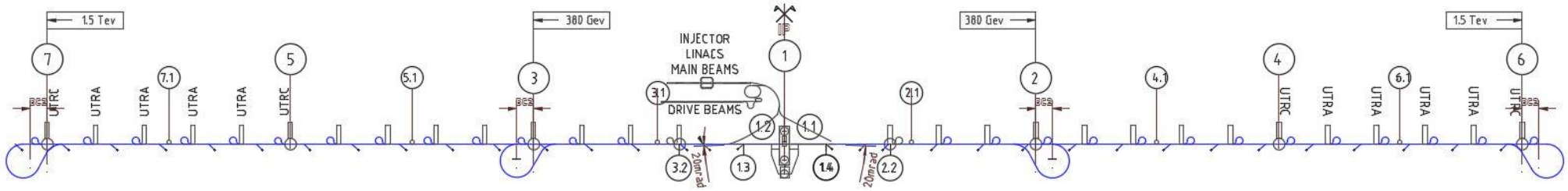
Topology for a staged construction (0.38 to 1.5 to 3 TeV)

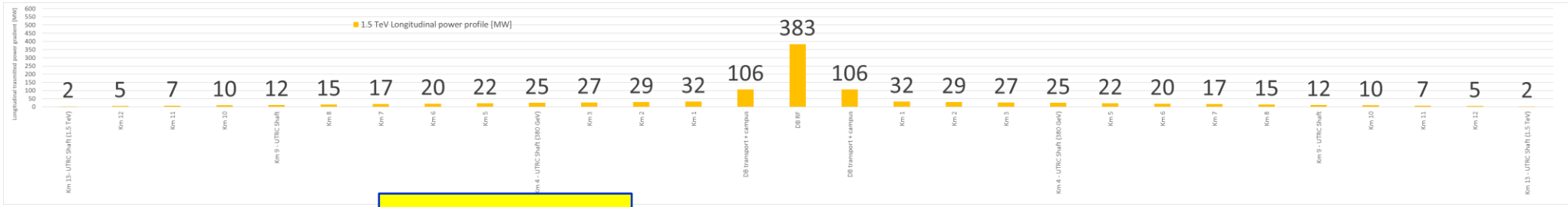
Assumptions taken

- The power will be supplied from **one single source** for the three stages
- **Modularity** to optimize implementation, operability and costs
- Construction of 1.5 and 3 TeV stages **independent** from operation with Beam at lower energy levels



Transmission Network for the 1.5 GeV Stage

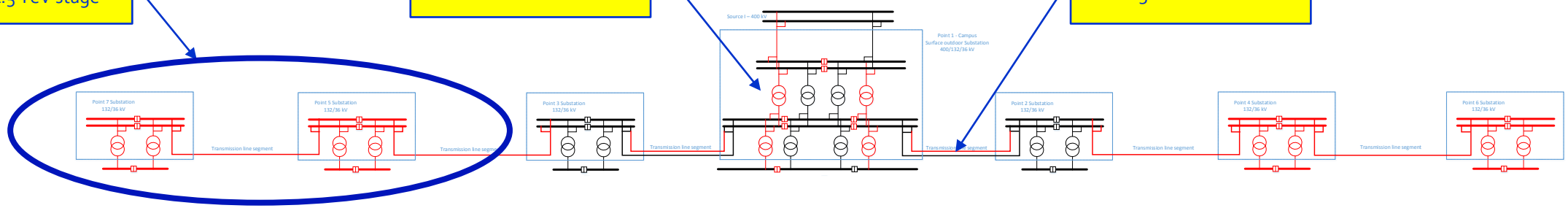




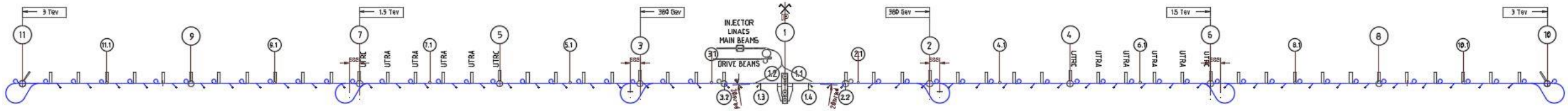
New infrastructure for 1.5 TeV stage

Extension of existing 380 GeV infrastructure for 1.5 TeV stage

Ampacity increase of existing transmission lines



Transmission Network for the 3 GeV Stage



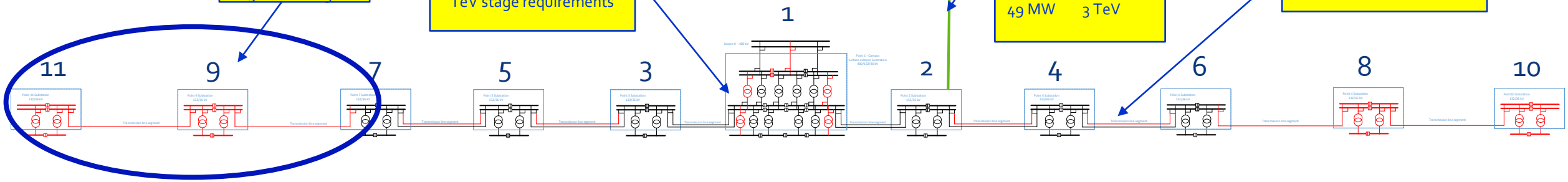
New infrastructure for 3.0 TeV stage

Extension of existing 380 GeV infrastructure for 3.0 TeV stage requirements

Increase of power flowing from point 1 (campus) through point 2 towards point 4

2 MW	0.38 TeV
25 MW	1.5 TeV
49 MW	3 TeV

Ampacity increase of existing transmission lines



Distribution Network

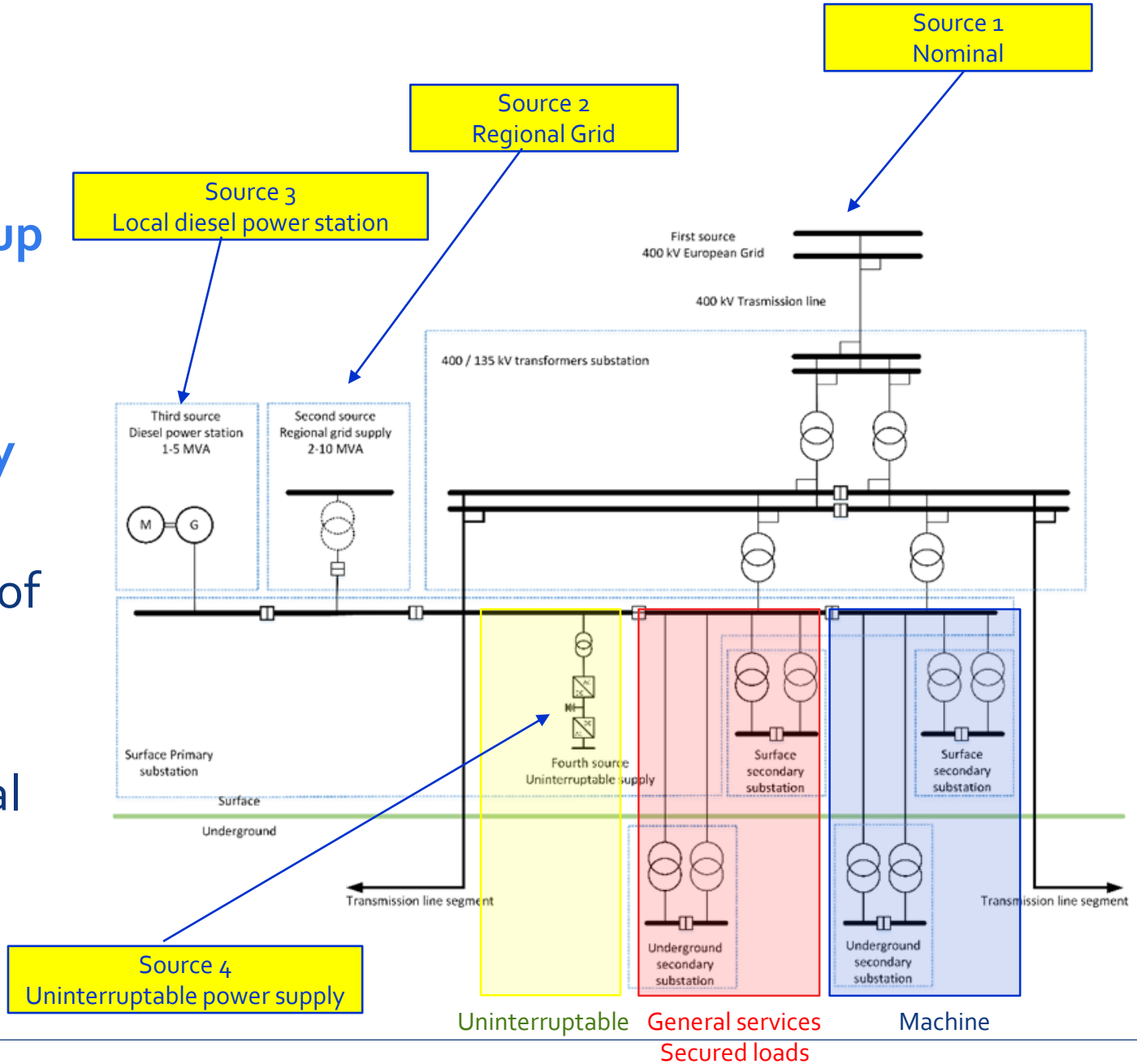
Typical loads for CLIC electrical infrastructure

Type of network	End users voltage level	Loads type	Equipment individual power range	Unavailability duration (in case of main supply outage)	Topology	Network infrastructure complexity
Machine	24 kV 3.3 kV 400 V	Power converters, cooling and ventilation motors, radio frequency	200 W To 20'000 kW	Until return of main supply	- Radial supply - Full redundancy	- Passive components - (MV switchgears, transformers, LV switchboards)
General Services	400 V	Lighting, pumps, vacuum, wall plugs, controls	50 W To 200 kW	Until return of main or secondary supply	- MV distribution loop - LV radial supply - Back-up sources	- Passive components
Secured	400 V	**Personnel safety** Lighting, pumps, wall plugs, elevators	5 W To 100 kW	10 – 30 seconds	- MV distribution loop - LV radial supply	- Active (diesel engine) and passive components
Uninterruptable	400 V	**Personnel safety** : evacuation and anti-panic lighting, fire-fighting system, oxygen deficiency, evacuation **Machine safety** : sensitive processing and monitoring, beam loss, beam monitoring, machine protection	5 W To 100 kW	None (continuous service)	- MV or LV distribution radial distribution	- Active and passive components - Local energy storage (batteries)

Distribution Network

Conceptual Diagram

- Typical voltage rating **400 V, 3.3 kV up to 36 kV**
- **Indoor** substations
- All distribution networks **supplied by the transmission** network
- **Redundancy** to grant required level of availability, operability and maintainability
- **Secured loads** are part of the general services
- **Four sources of** supply

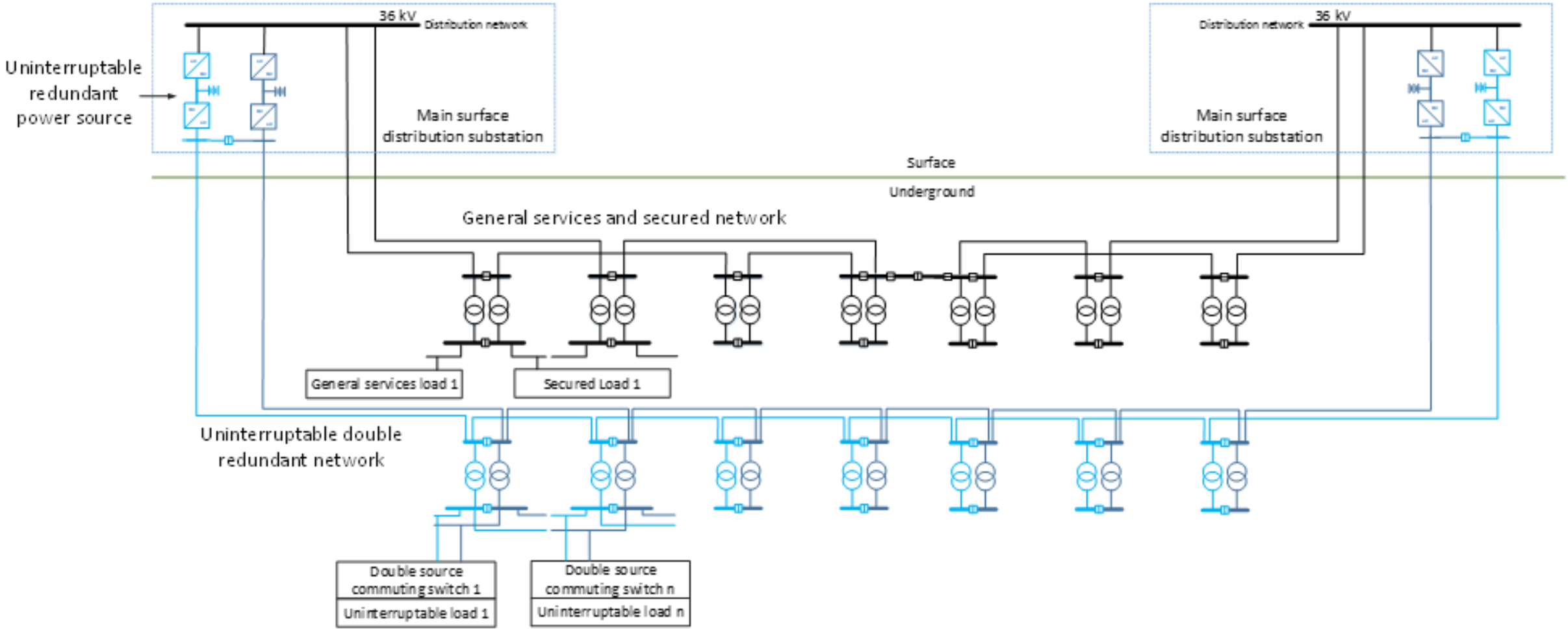


Emergency Power

- Based on the requirement to **keep essential parts** of the accelerator infrastructure operational if the **normal power source fails**.
- Particular emphasis is put on loads related to **personnel and machine safety during degraded situations**.

Load class	Loads type (non-exhaustive list)	Power unavailability duration in case of degraded scenario
Machine	Power converters, cooling and ventilation motors, radio frequency	Until return of main supply
General Services	Lighting, pumps, vacuum, wall plugs	Until return of main or secondary supply
Secured	Personnel safety Lighting, pumps, wall plugs, elevators	10 – 30 seconds
Uninterruptable	Personnel safety : evacuation and anti-panic lighting, fire-fighting system, oxygen deficiency, evacuation Machine safety : sensitive processing and monitoring, beam loss, beam monitoring, machine protection	Interruptions not allowed, continuous service mandatory

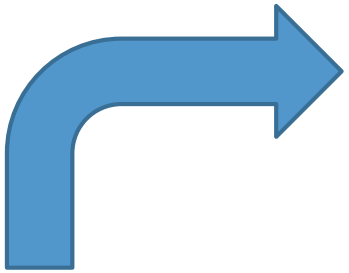
Emergency Power



PBS

Structure

- Updated proposal wrt 2011
- One PBS covering all CLIC configurations
- Only quantities are changing
- Reflects better the needs for the cost and schedule model



2018

Element	Unit
Connection to EU grid	sources
Connection EU grid to CLIC point	km
Incoming EHV-HV substation	substation
Transmission line	km
HV-MV substation	substation
Back-up source	point
Diesel generator system	point
UPS system	point
Surface main substation (MV & LV)	point
Surface distribution network (MV & LV)	point
Surface buildings electrical infrastructure	buildings
Underground distribution network (MV)	km
Tunnel electrical infrastructure	km
Injectors electrical infrastructure	km
Experimental area electrical infrastructure	Substation
Alcove UTRA	alcove
Alcove UTRC	alcove
Technical shaft electrical infrastructure	km
Experimental cavern infrastructure	experiment

2011

Code	New Code*	Name*	Multiplicity*	Date Of Estimate	Tech. Uncertainty	Expected Offers	Type	Unit	Industrial Index	Technical Responsible
5.2.	5.2.	Electricity	1.00						Machine index	Davide.Bozzini@cern.ch
5.2.1.	5.2.1.	400 kV Equipment	1.00	6/16/2011	C1	5				
5.2.2.	5.2.2.	36 kV Equipment	1.00	6/16/2011	C1	5				
5.2.3.	5.2.3.	400/230 V Equipment	1.00	6/16/2011	C1	5				
5.2.4.	5.2.4.	Emergency Power System	1.00	6/16/2011	C1	5				
5.2.5.	5.2.5.	Power Network Monitoring	1.00	6/16/2011	C1	5				

Status and Future Steps

Status

- Transmission and distribution networks **concepts are available for CDR**.
- **No imminent showstoppers** on the feasibility of electrical powering of the CLIC 380 GeV.
- Availability of required power at point 1 for 1.5 TeV and 3 TeV require upgrade of European Grid.

Future Steps

- Integration of the electrical infrastructure in the different tunnel cross sections.
- Develop functional scheme for the drive beam distribution network.
- Develop a functional scheme for the drive beam 380 GeV Klystron based distribution network.

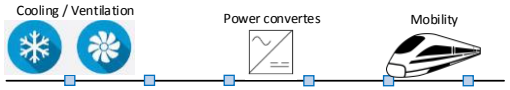
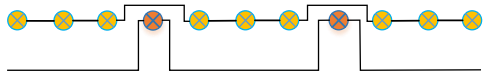
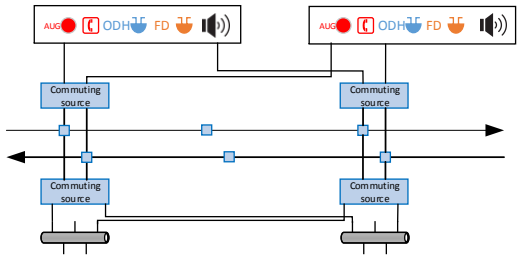
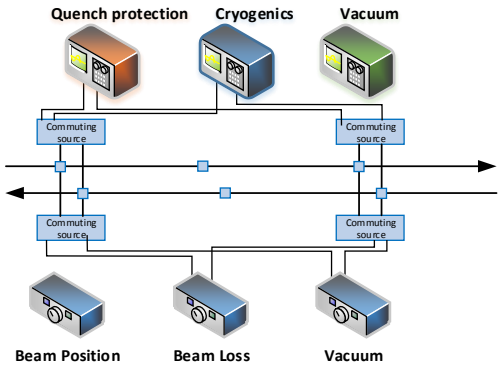
Thank you

Back-up slides

Distribution Network

Users and Systems

- Loads **homogeneously distributed** over the tunnel length
- End users supplied at low voltage **400 V ac**
- **Four types of network** required:
  - Machine (Typically supplied radially - not listed in this table)
  - General services
  - Secured
  - Uninterruptable
- **Critical systems** related to:
  - Personal safety
  - Machine safety
- Critical systems may require **uninterrupted double redundant supply**

Users	Network type	Schematic layout
Generic power sockets	General Services	
Users power sockets	Secured	
Controlled lightning	General Services	
Permanent lightning	Secured	
Evacuation lightning	Uninterruptable	
Antipanic lightning	Uninterruptable	
Safety systems	Uninterruptable	
Communication / Star points	Double redopundancy	
Machine Protection	Uninterruptable	
Beam protection	Double redopundancy	

Drive Beam Supply

Drive Beam RF powering proposal
Courtesy: D. Aguglia

Conceptual requirements @ 3 TeV

- 6 sectors for RF power distribution requiring ~ **300 MW**
- Each sector require ~ 50 MW
- Each sector feeds ~220 modulators and needs an indoor substation of (very roughly) ~ 1500 m2 x 10m height for:
  - AC transformers, bus bars and grid switchgear at medium voltage
  - 4 x Modular Multilevel AC/DC converter rated at 16 MW each