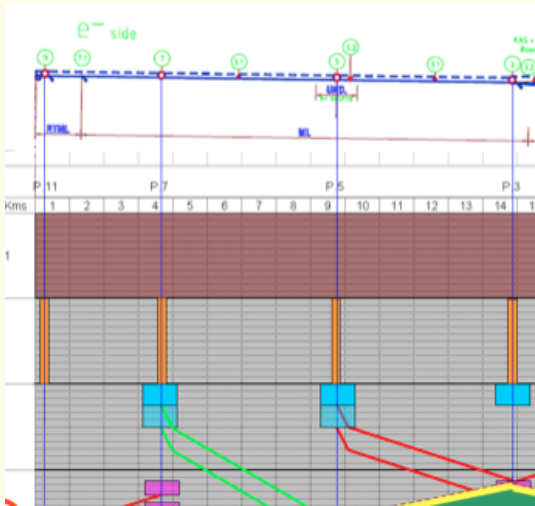


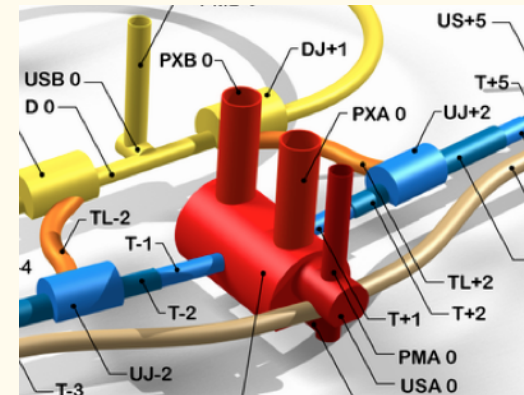
ILC DRAFT CONSTRUCTION SCHEDULE

Flat topography & Mountainous sites



K Foraz & M Gastal

Duration	Hall 1, 2016			Hall 2, 2016			Hall 1, 2017								
	O	N	D	J	F	M	J	A	S	O	N	D	J	F	M
305 days	[Timeline bar]														
0 days	[Timeline bar]														
12 wks	04/01 → 25/03														
3 wks	29/03 → 15/04														
48 wks	18/04 → 03/03														
24 wks	18/04 → 30/09														
75 days	[Timeline bar]														



Many thanks to all contributors

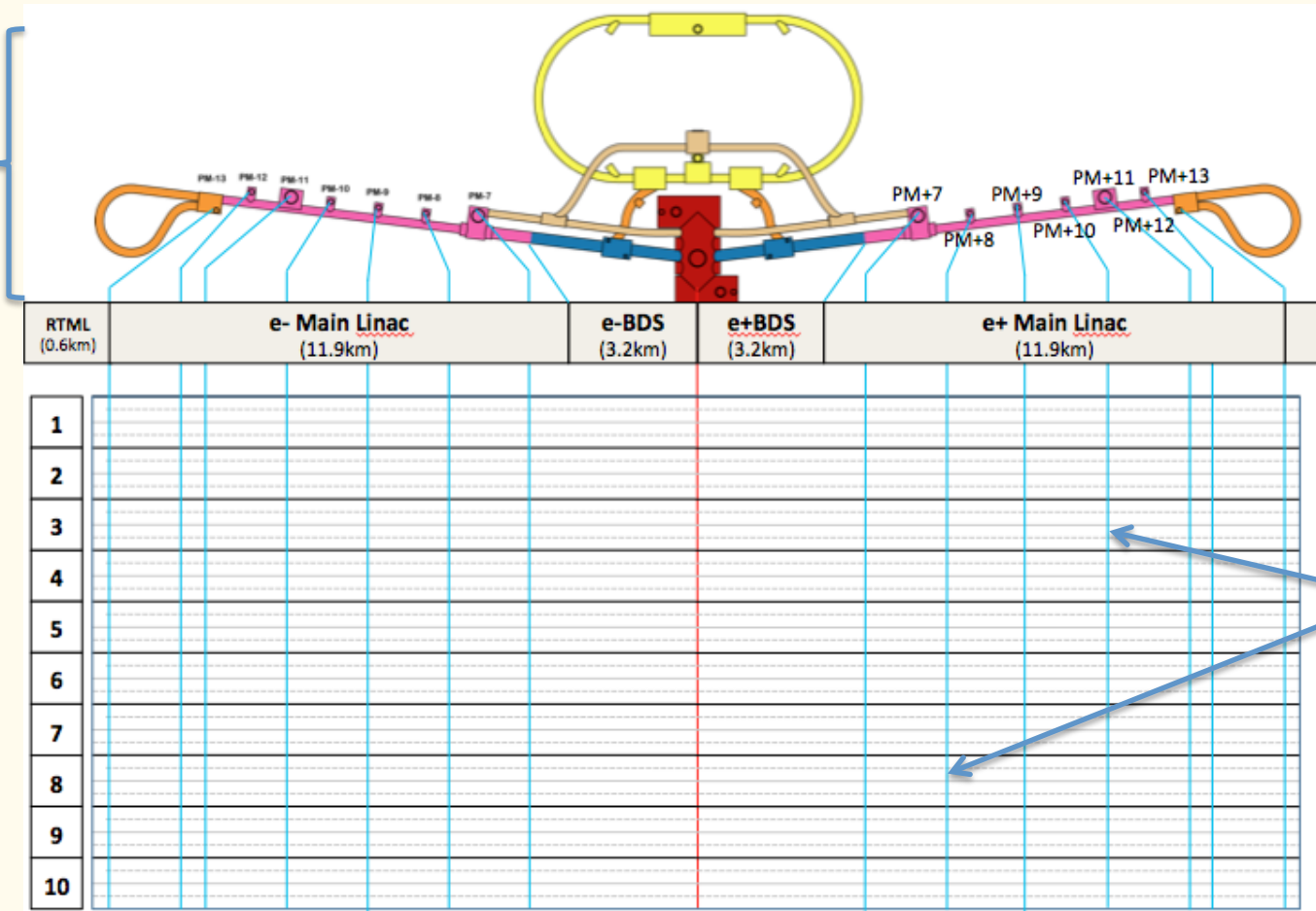
- To provide a consolidated project construction schedule
 - For flat topography sites (Americas, Europe)
 - European site primarily used for flat topography
 - Mountainous region site (Asia)
 - Focus on the critical path
 - From excavation to commissioning of the facilities

- To integrate many data sources
 - ARUP studies for IR
 - Granada 2011 workshop
 - Draft ILC PIP (Project Implementation Planning)
 - Commissioning priorities
 - Output of KILC2012

- To present the TDR section on Project Construction Schedule
 - Many parameters can be tuned and affect this draft scenarios
 - Tolerance to co-activity, number of teams deployed...

→ To follow work progress in time and space

ILC layout
(not to scale)

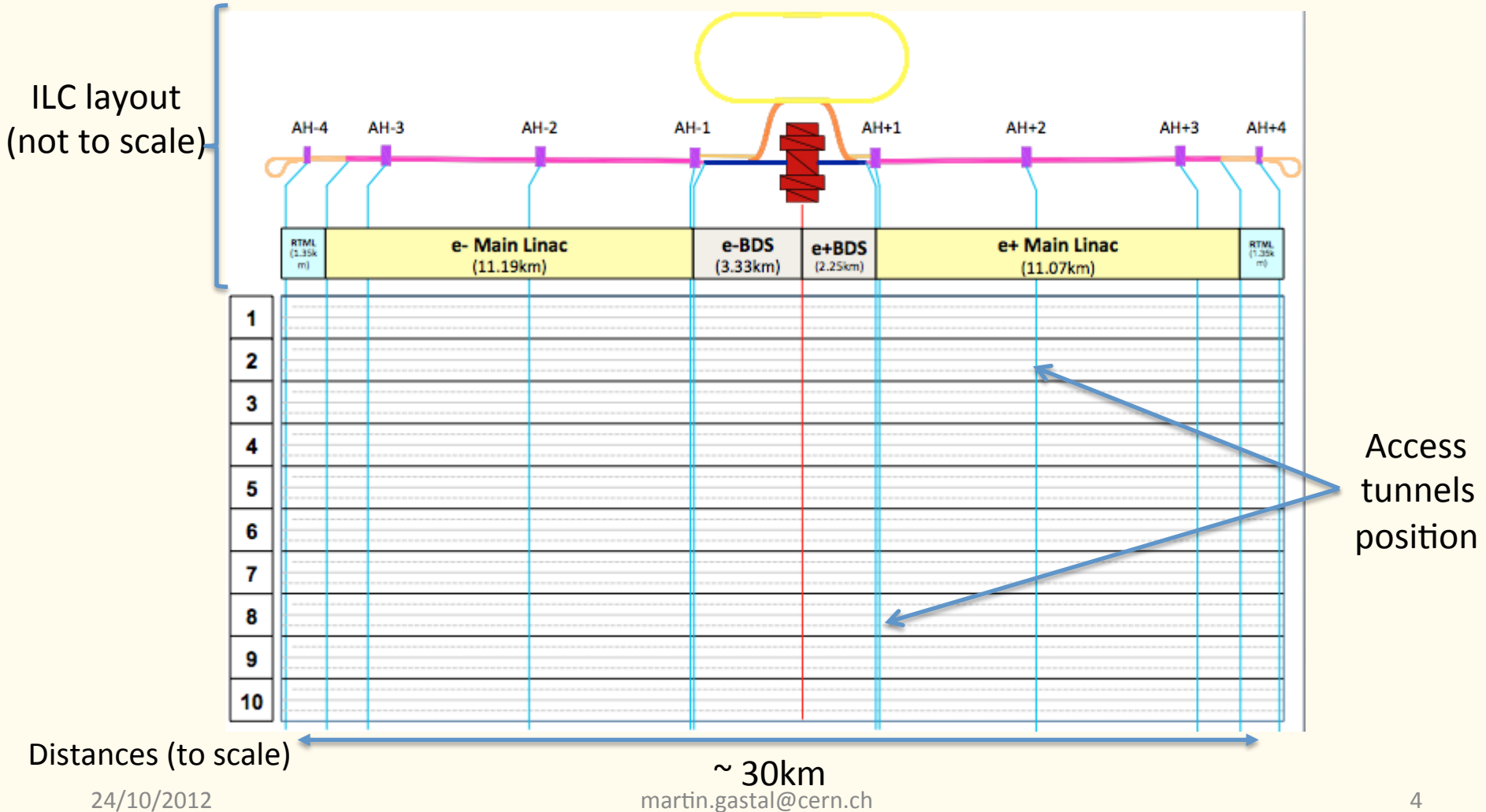


Shafts position

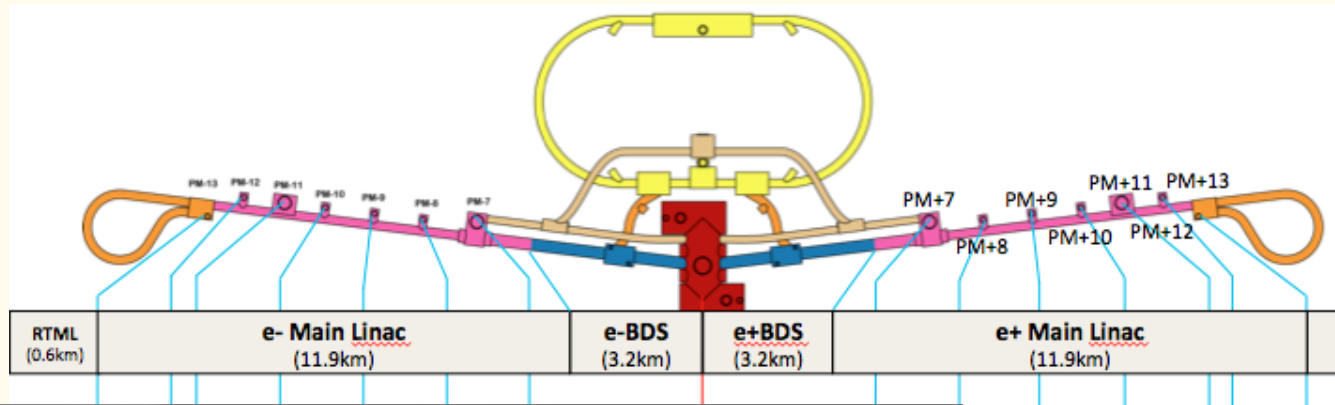
Distances (to scale)

~ 30km

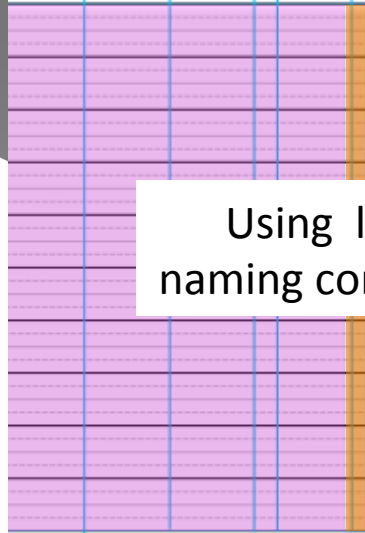
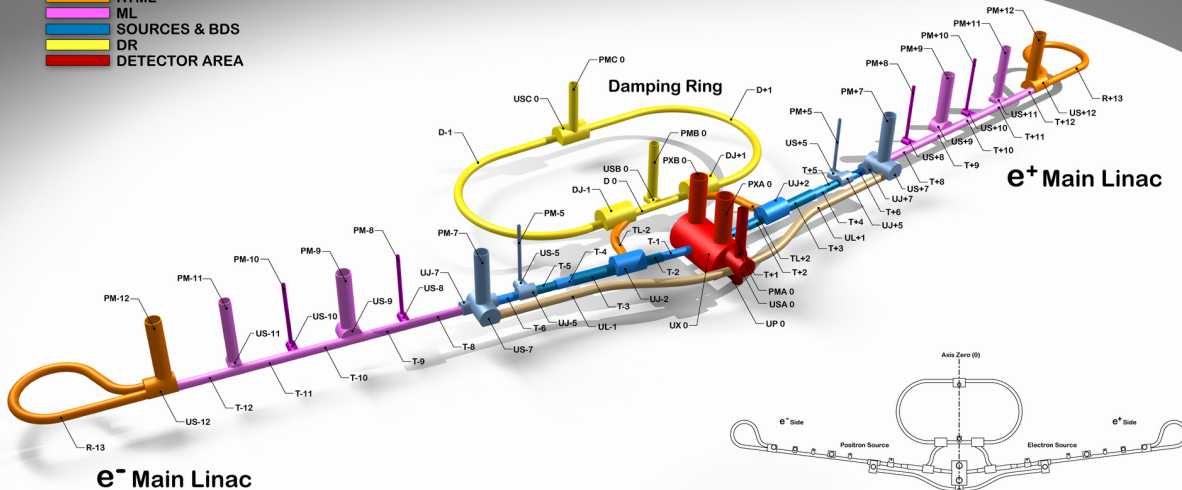
→ To follow work progress in time and space



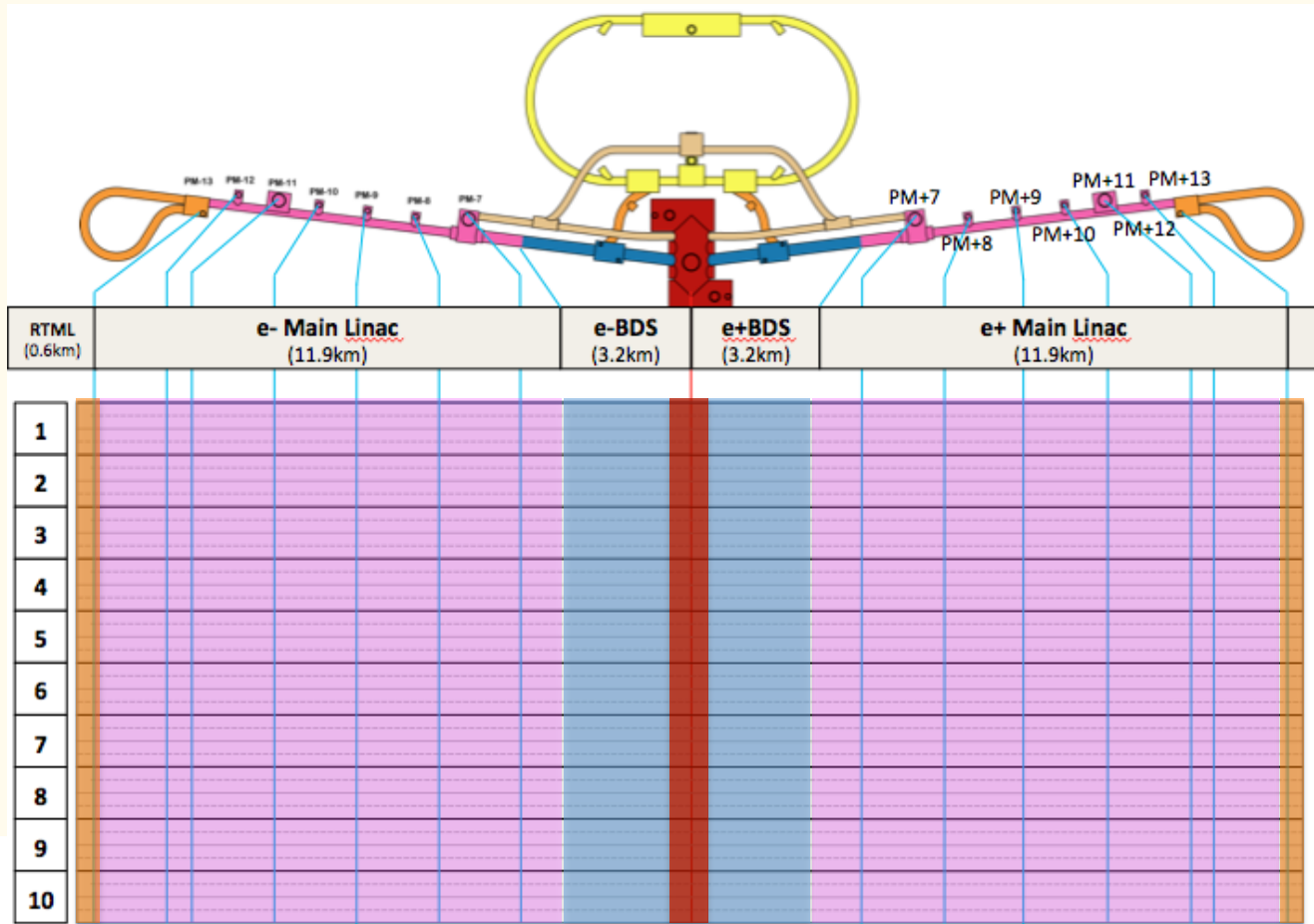
→ To follow work progress in time and space



- █ RTML
- █ ML
- █ SOURCES & BDS
- █ DR
- █ DETECTOR AREA



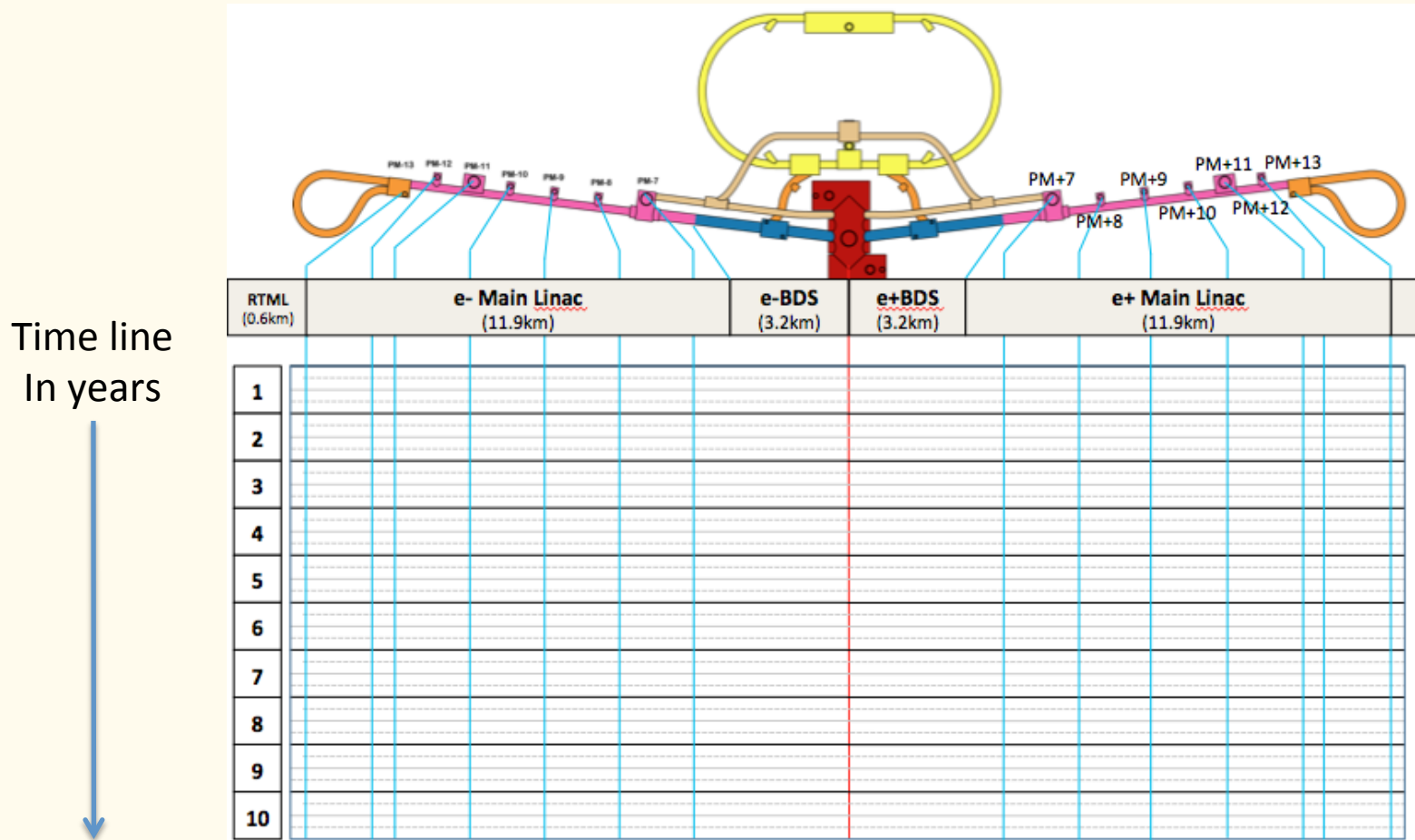
→ To follow work progress in time and space



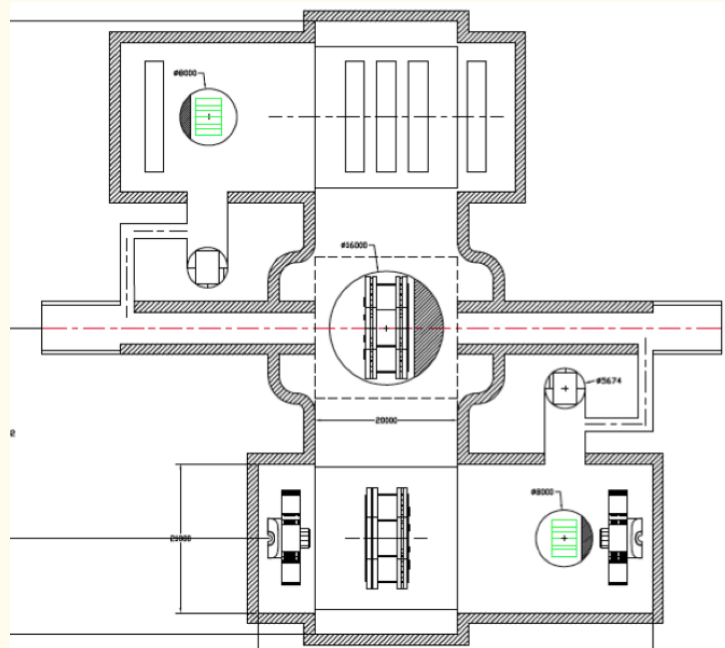
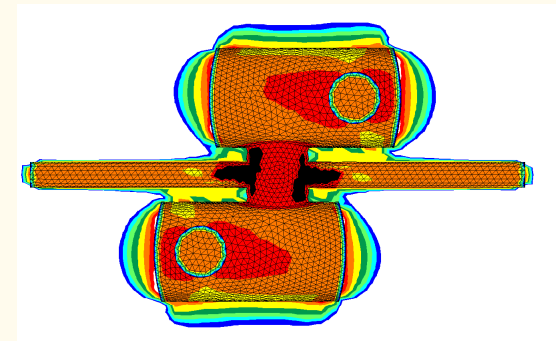
Only for
IR, BDS,
ML & RTML

- Legend :
- RTML
 - ML
 - SOURCES & BDS
 - DR
 - DETECTOR AREA
 - SERVICE TUNNEL

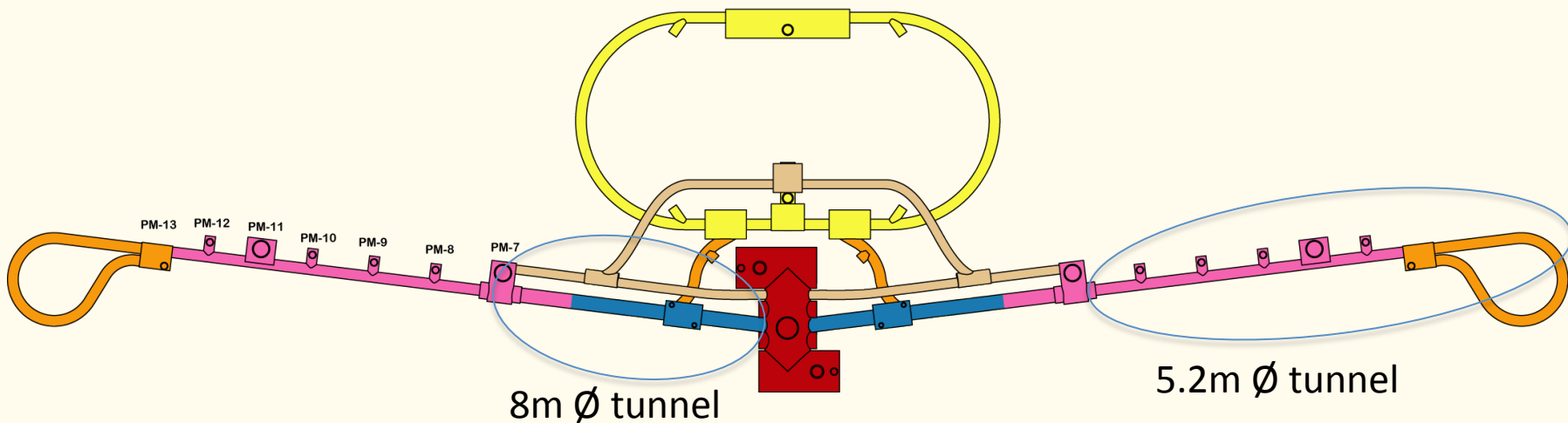
→ To follow work progress in time and space



- Result of the ARUP/J Osborne studies recommends minimising stress concentration on the IP by excavating and finishing the interaction cavern before tackling the tunnels and service caverns
- TBMs launched from adjacent shafts (PM7) and extracted from an IR shaft
 - Allows time for finishing of IR cavern
- Similar recommendations were made for CLIC IR
- Compatible with 3 shaft IR layouts

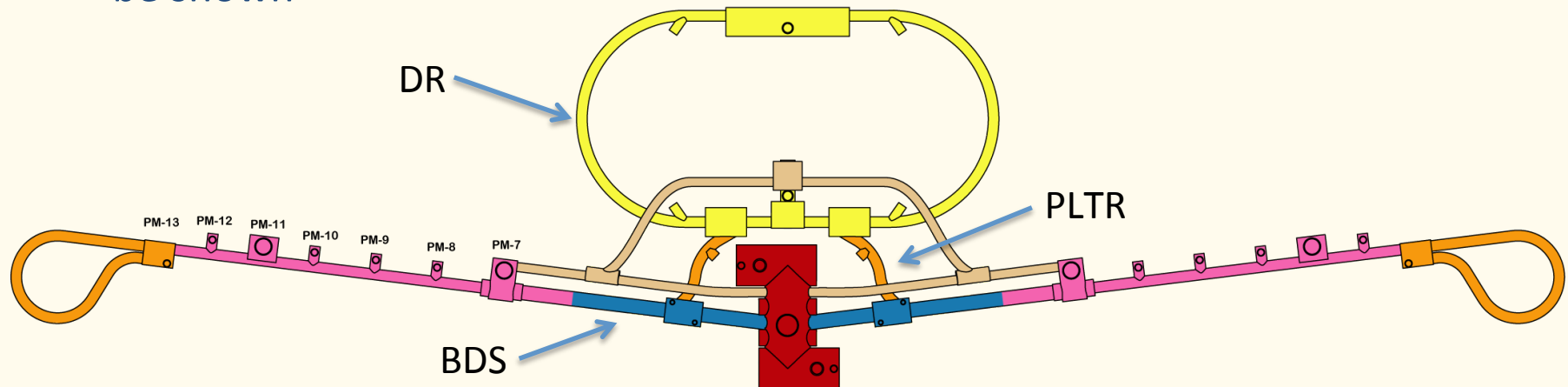


- The BDS tunnel and part of the main linac have a diameter of 8m
 - To minimise cost and speed up excavation
- The rest of the main linac consists of 5.2m diameter tunnel



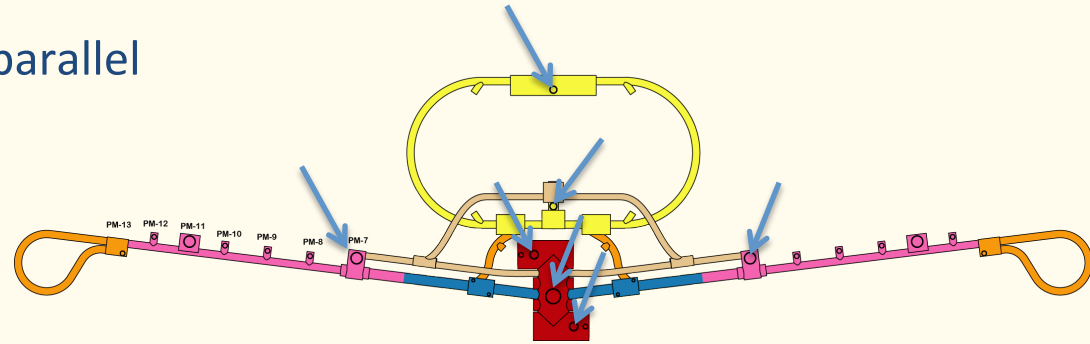
- TBMs cannot be refurbished to accommodate both tunnel sizes
- 2 different machines have to be used
- We are now looking at a 4 TBM scenario in DBS, ML, RTML (2x5.2 + 2x8)

- Requests for early commissioning will set priorities for the delivery of parts of the ILC complex
- When designing the construction schedule, an attempt was made to deliver some components as early as possible:
 - Damping Rings
 - PLTR
 - BDS & ML up to PM7/AH1
- An attempt to design a detailed schedule of the commissioning period will be shown

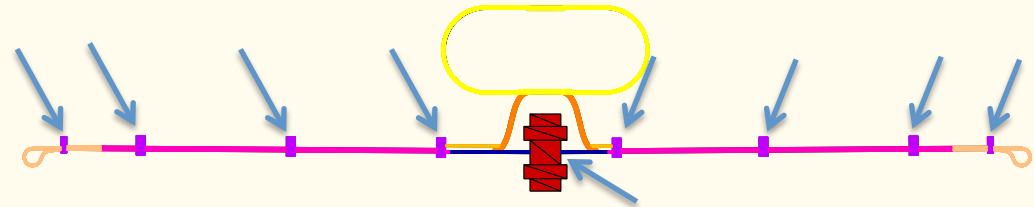


Activity in Main Linac	Region	Progress rates in m/week	For x Shifts
Tunneling using 8m Ø TBM	FT	100	3
	MR	na	
Tunneling using 5.2m or 6m Ø TBM	FT	150	3
	MR	na	
Tunneling using 6-8m Ø road header	FT	30	3
	MR (NATM)	20	3
Concreting, invert and tunnel finishing	FT	50	3
	MR	Concrete lining 25 Invert, drainage 45	3
Ventilation ceiling ducts installation	FT (Europe only)	50	3
	MR	na	
Survey and set out of components supports	All	120	1
Electrics General Services	All	120	1
Piping and ventilation	All	120	1
Cabling	All	120	1
Installation of supports for machine components	All	250	1
Installation of machine components	All	100	1

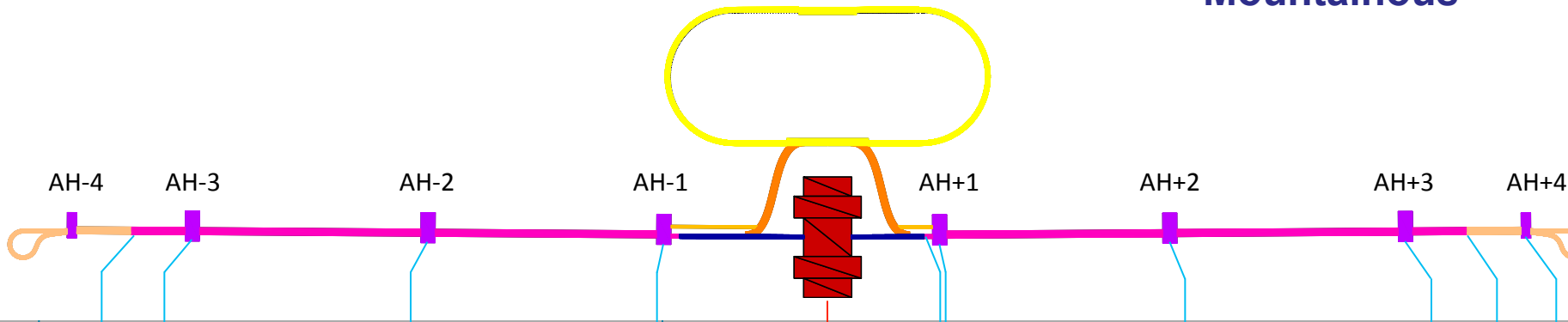
- FT - Excavation of 7 shafts in parallel
 - IR: PX0, PXA0, PXB0
 - ML: PM+7, PM-7
 - DR: PMA0, PMB0
 - 1 year per shaft



- MR – Excavation of 9 access tunnels
 - AH1, AH2, AH3, AH4, IP



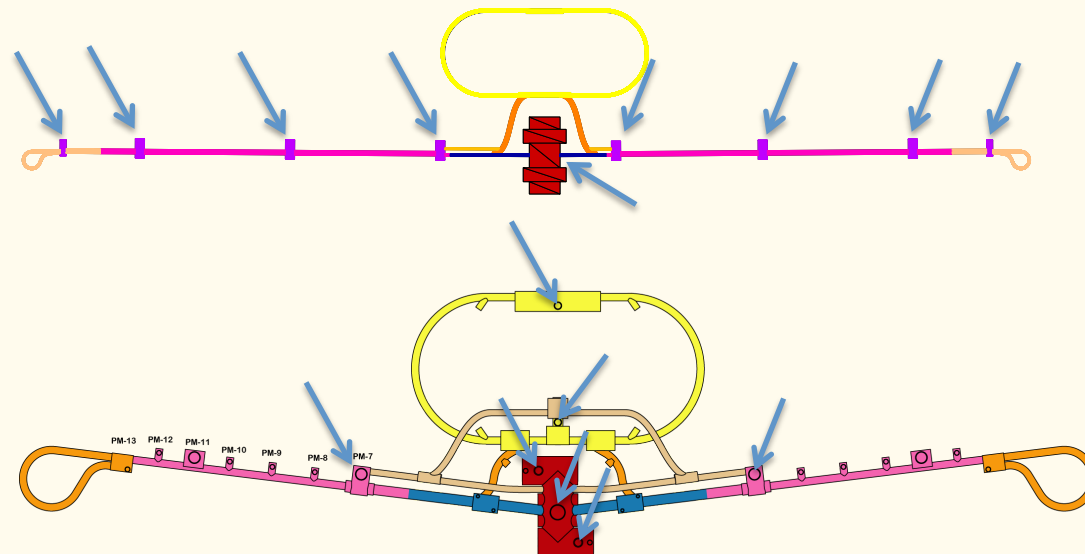
- Launch construction of detector assembly halls on the surface
- Launch construction of service buildings



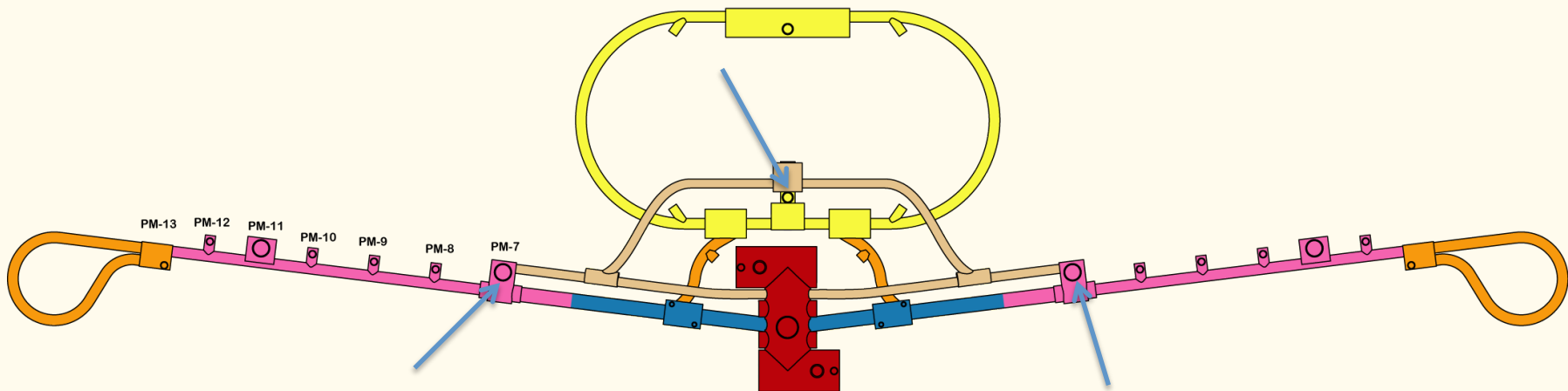
	RTML (1.35k m)	e- Main Linac (11.19km)	e-BDS (3.33km)	e+BDS (2.25km)	e+ Main Linac (11.07km)	RTML (1.35k m)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

→ Launch of works

- Site setup is not included, t_0 is ground breaking
- FT: Not all access shafts to the underground facilities are started together
- FT: 7 excavation crews in action over 4 sites
- MR: Quick deployment of resources to excavate all access tunnels
- MR: 9 excavation crews in action over 9 sites

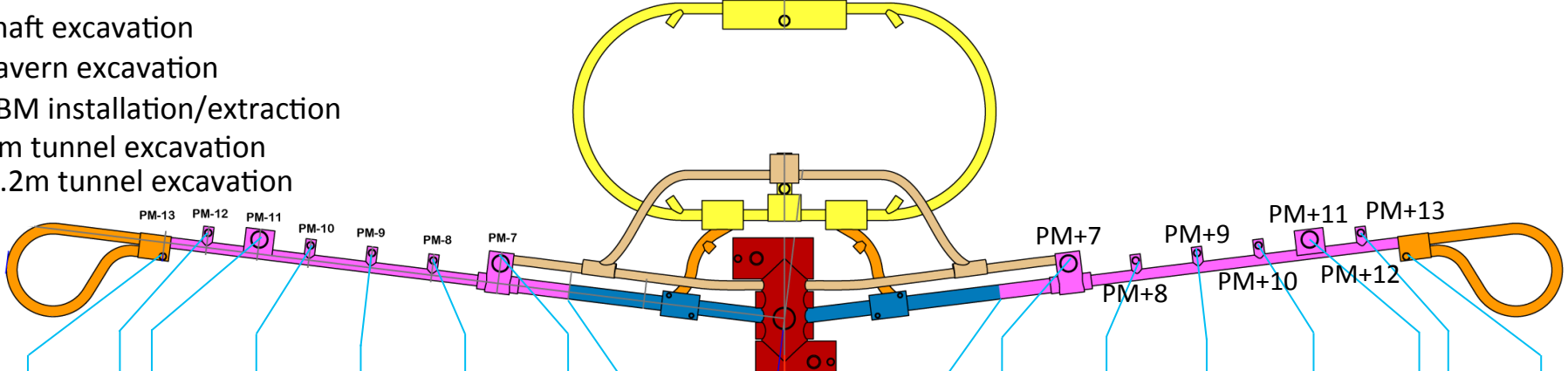


- Tunneling has to start in various parts of the facility (5 TBMs)
 - Shafts excavation of PM8,9,10,11,12,13
 - Shaft based caverns have to be excavated (IR cavern, US-7, US+7, USB0)
 - Two 8m diameter TBMs: ML + BDS
 - Two 5.2m diameter TBMs: ML
 - One 5.2m diameter TBM: DR

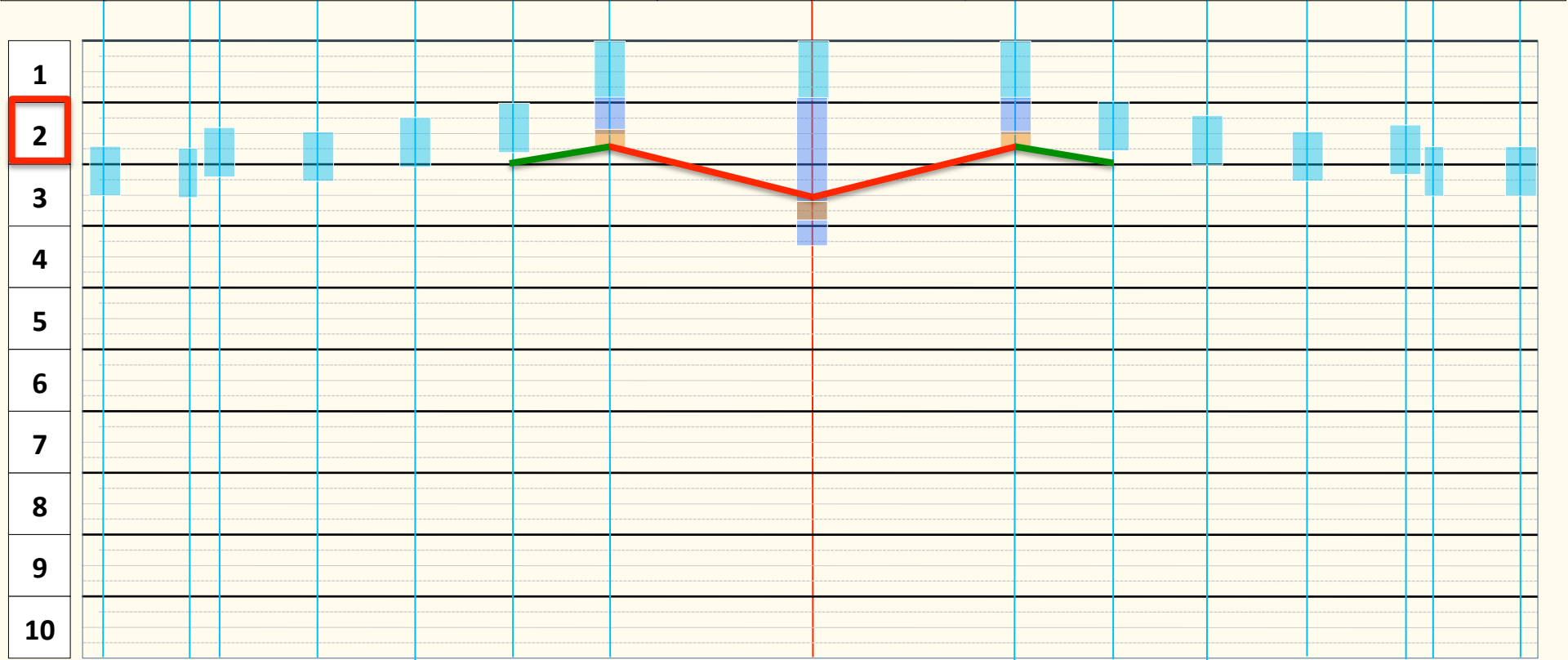


- Progress rates for European site:
 - 8m: 100m/w (3 shifts)
 - 5.2m: 150m/w (3 shifts)

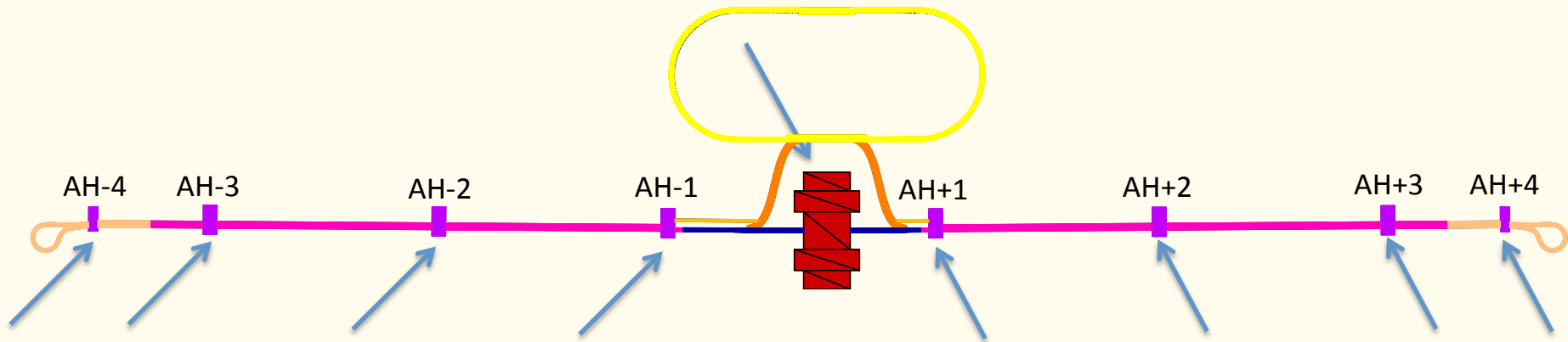
- Shaft excavation
- Cavern excavation
- TBM installation/extraction
- 8m tunnel excavation
- 5.2m tunnel excavation



RTML (0.6km)	e- Main Linac (11.9km)	e-BDS (3.2km)	e+BDS (3.2km)	e+ Main Linac (11.9km)
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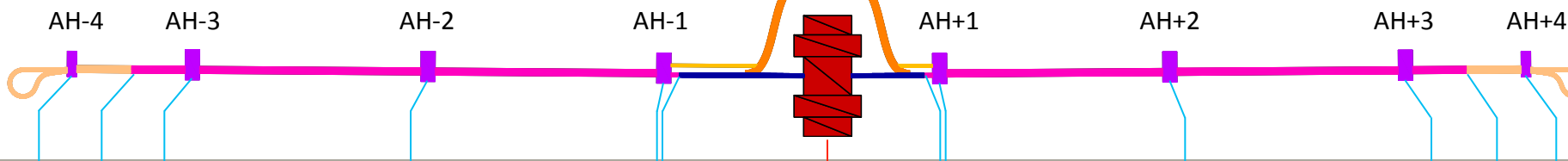
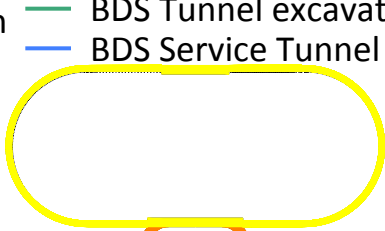


- Tunneling has to start in various parts of the facility
 - 8 Access halls have to be excavated (AH-4, AH-3, AH-2, AH-1, AH+1, AH+2, AH+3, AH+4)
 - 14 tunneling crews are sent from access tunnels AH-3, AH-2, AH-1, AH+1, AH+2, AH+3
 - Excavation of IR Cavern started
 - Start concrete lining in sectors IP-AH-1 and IP-AH+1

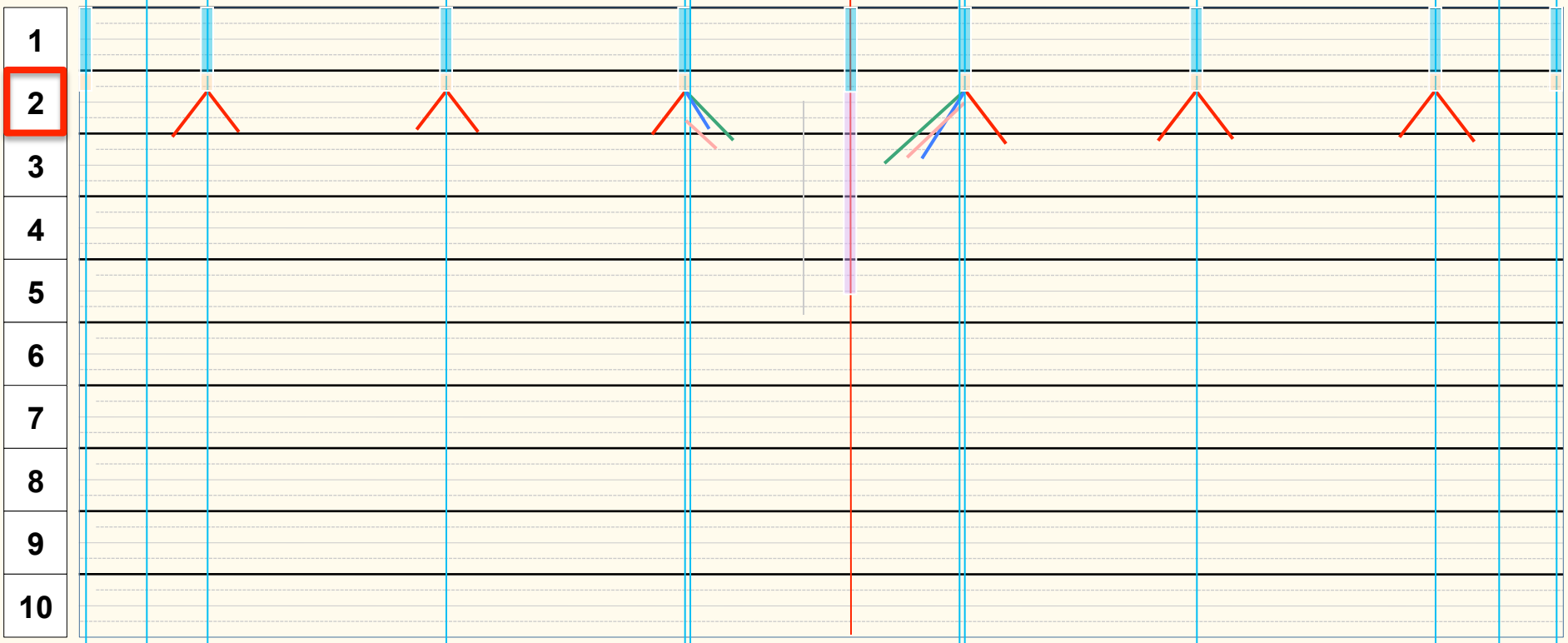


- Progress rates:
 - Tunneling: 20m/week

■ Access Tunnel ex. — Beam Tunnel excavation — BDS Tunnel excavation
■ Cavern ex. — Concrete Lining — BDS Service Tunnel excavation
■ Hall ex.

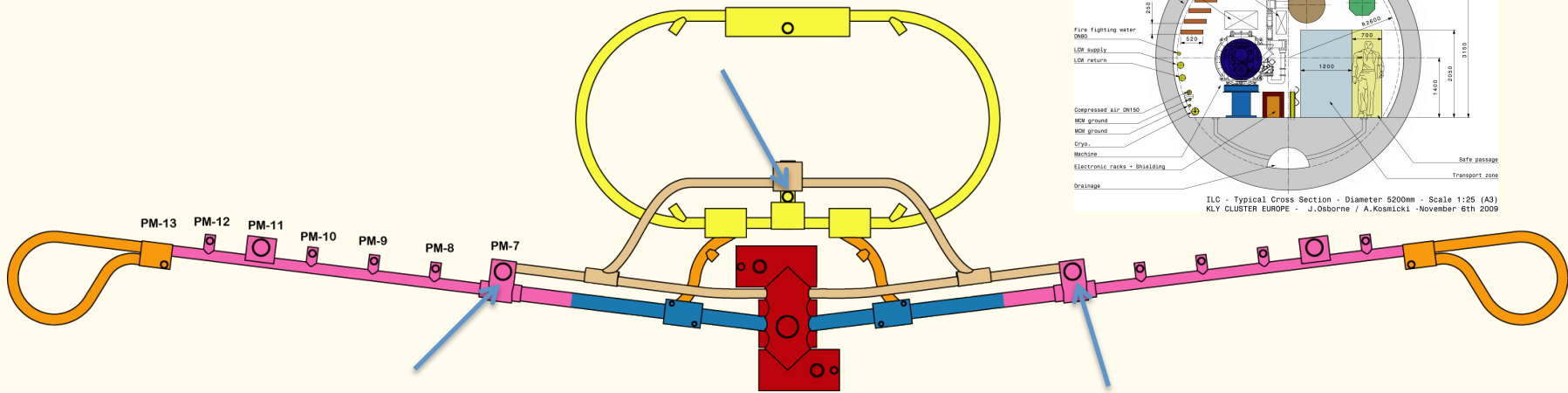


RTML (1.35k m)	e- Main Linac (11.19km)	e-BDS (3.33km)	e+BDS (2.25km)	e+ Main Linac (11.07km)	RTML (1.35k m)
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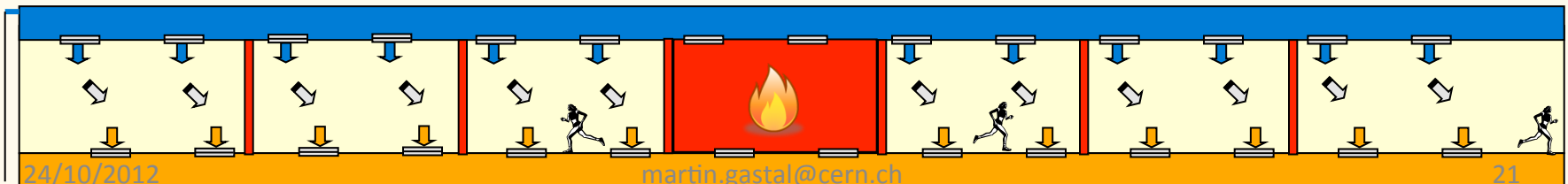


- Tunneling effort is intensive in the Asian region
 - Construction of 14 tunnels in parallel
- During Year 2 the Flat topography regions would be still providing access to the underground worksite by excavating shafts
- The Asian worksite looks a lot more labor intensive with 8 access halls excavation proceeding in parallel with the IP cavern excavation

- Tunneling will proceed in BDS, ML and DR
 - Spoil to be evacuated through PM8
- Invert concreting and tunnel finishing will start as soon as spoil management allows
 - Progress rate: 50m/d for 3 shifts



- Ceiling ducts for fire safety purposes
 - Progress rate: 50m/d for 3 shifts

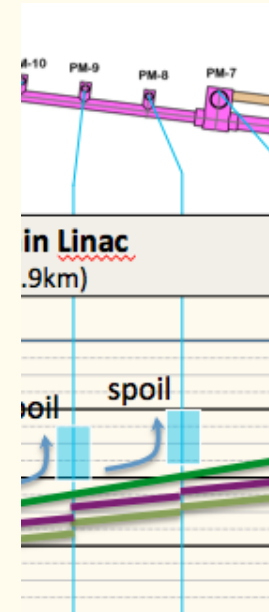


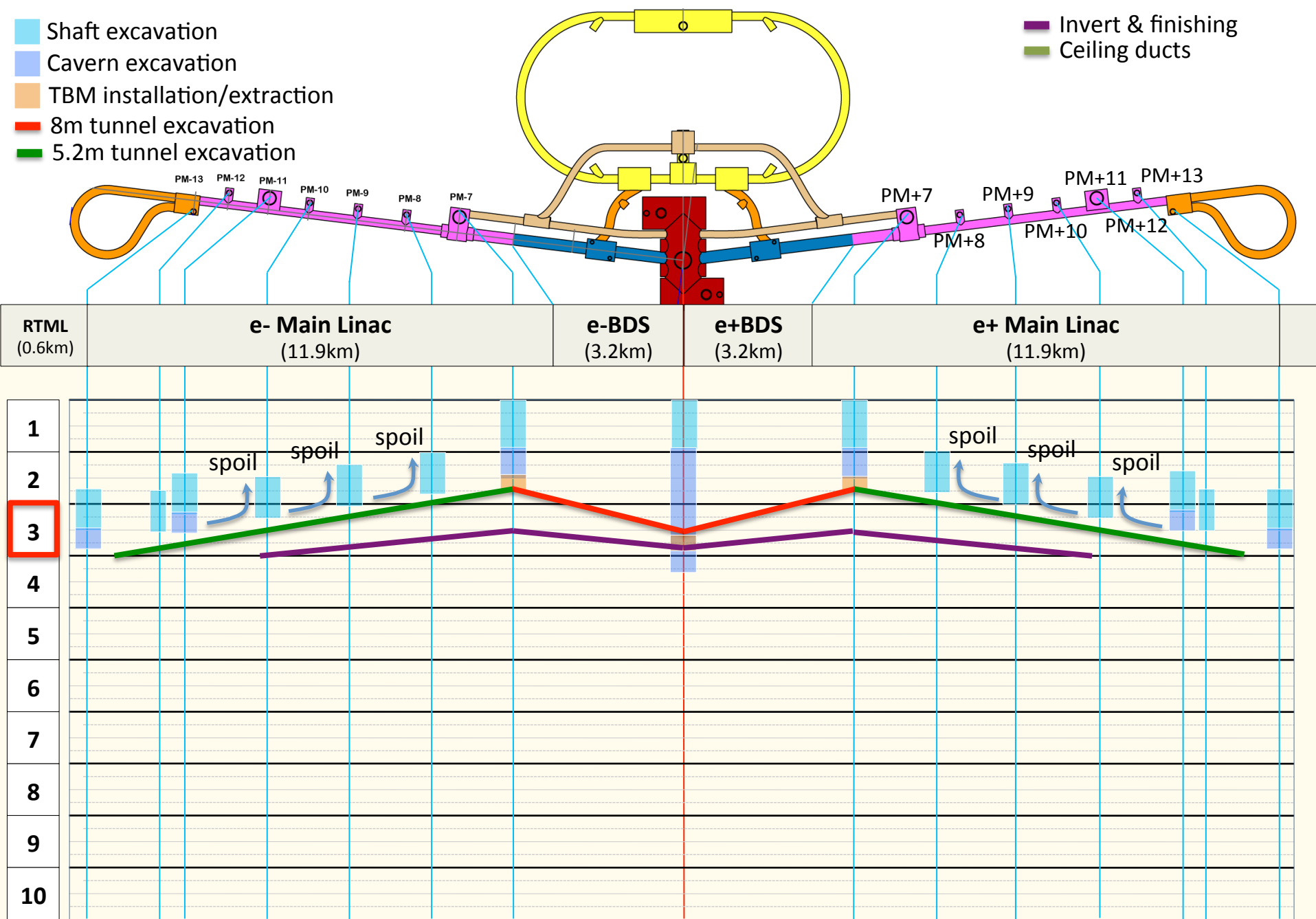
→ Work in a tunnel section, e.g. T-8, can only start once the conveyor belt evacuating the spoil produced by the TBM is redirected to the nearest shaft



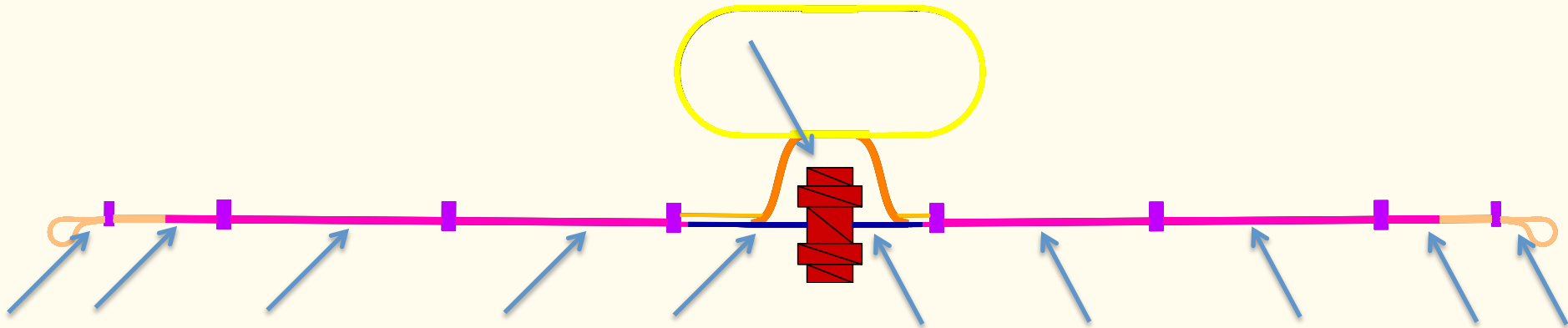
24/10/2012

martin.gastal@cern.ch

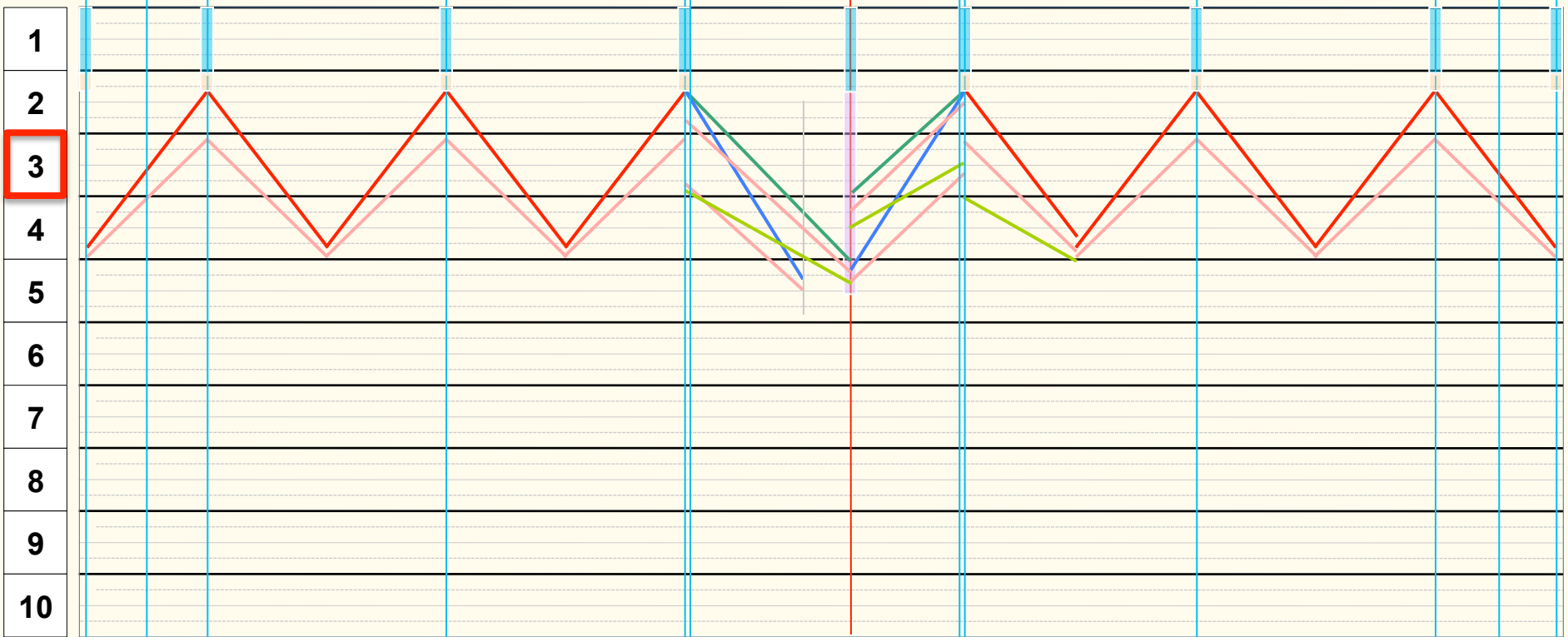
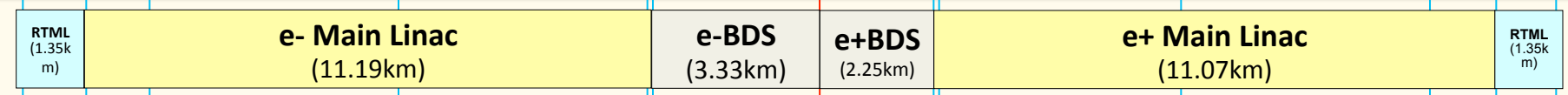
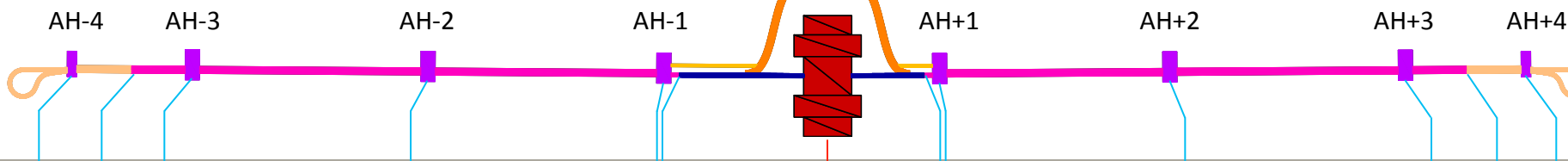
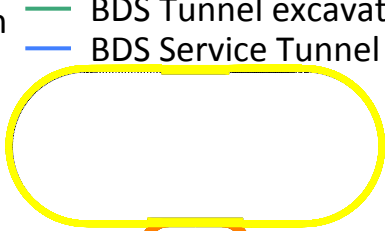




- Excavation of IP cavern
- Tunneling will proceed in all 14 tunnels sections
- Concrete lining to follow
 - Progress rate: 25m/week
 - Spoil to be carefully managed once concrete lining starts in the same tunnel section



- Access Tunnel ex.
- Cavern ex.
- Hall ex.
- Beam Tunnel excavation
- Concrete Lining
- Invert & Drainage
- Shield Wall
- BDS Tunnel excavation
- BDS Service Tunnel excavation
- Survey & supports set-out
- Electrical general services
- Piping & ventilation
- Cabling
- Supports
- Machine installation

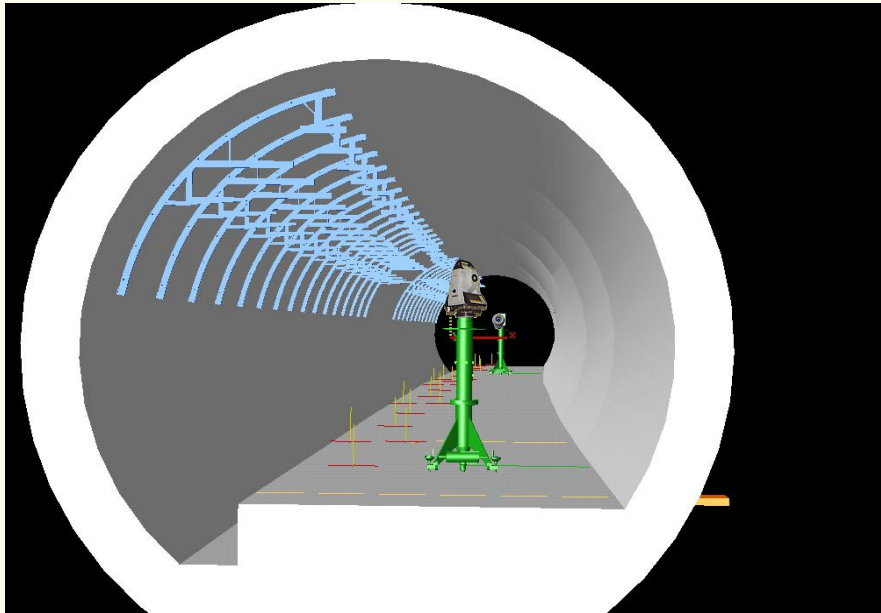


- Thanks to a higher progress rate the tunneling in the FT site is catching up with the MR.
- Spoil management will be a critical challenge

- End of CE phase
 - BDS: Q2 ; ML: Q4 ; RTML: Q4
- Start of infrastructure installation
 - Survey and set out of components supports
 - Electrics General Services
 - Piping and ventilation
 - Cabling

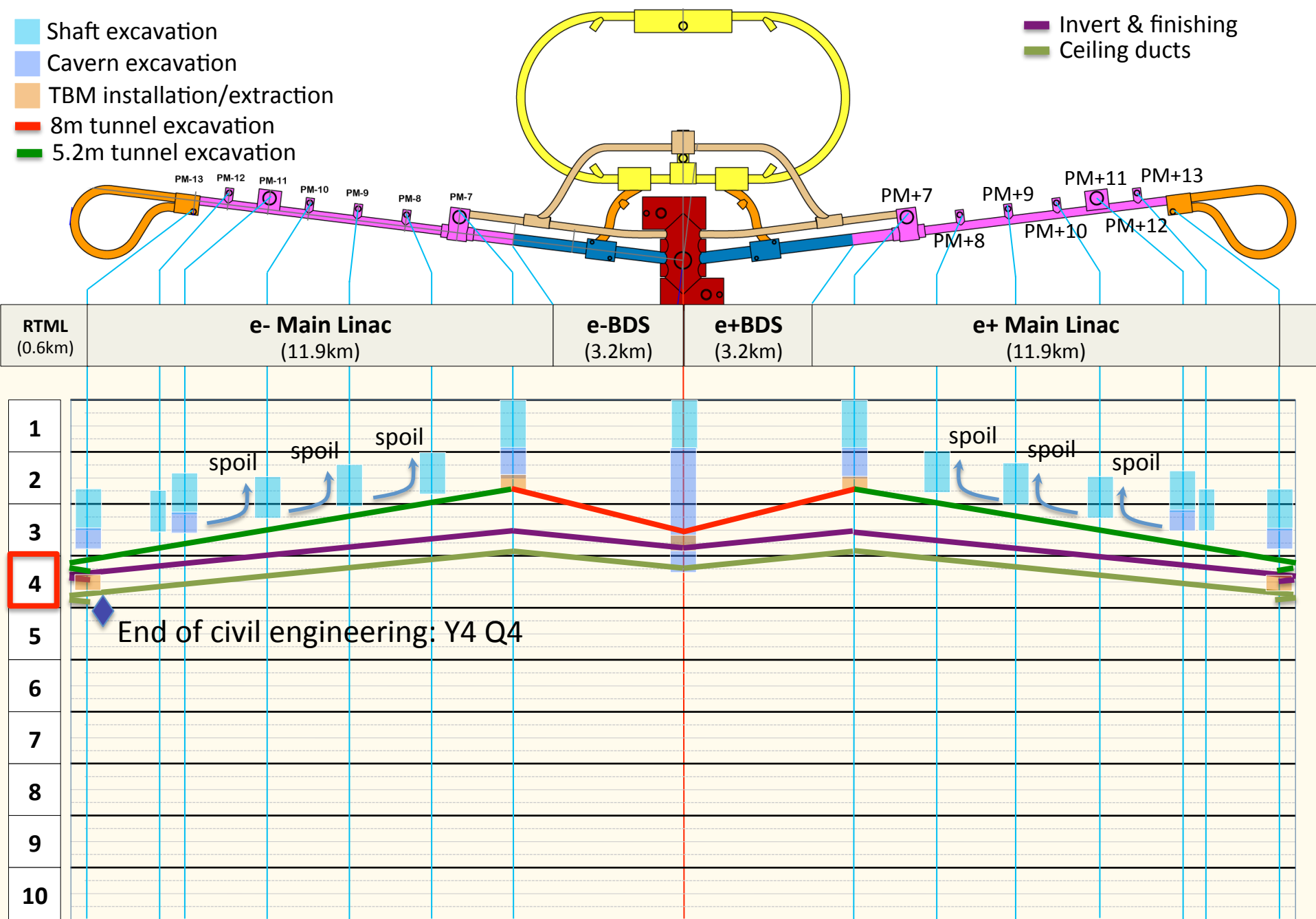


Progress rate 120m/w for 1 shift

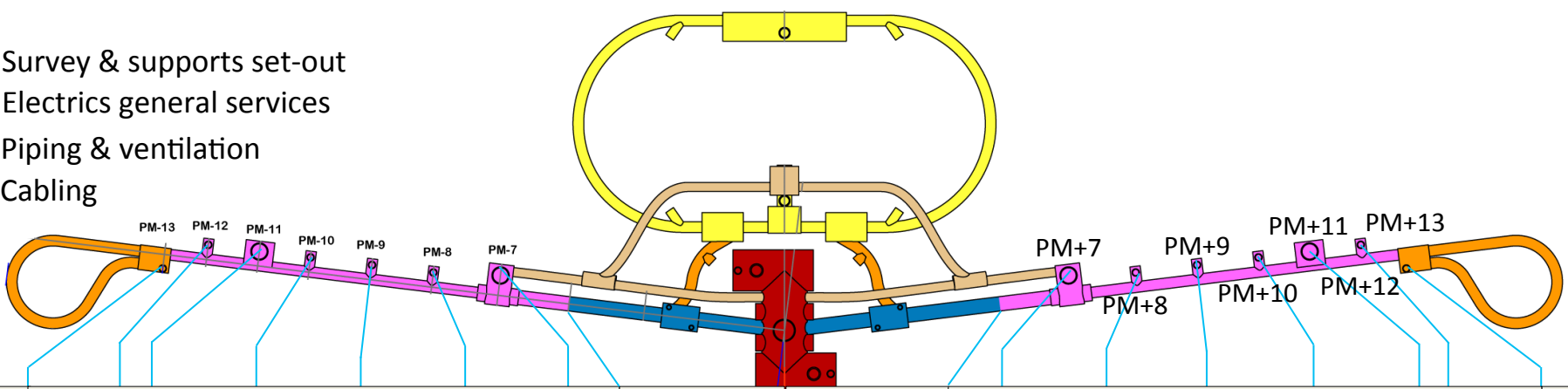


Courtesy of BE-ABP-SU

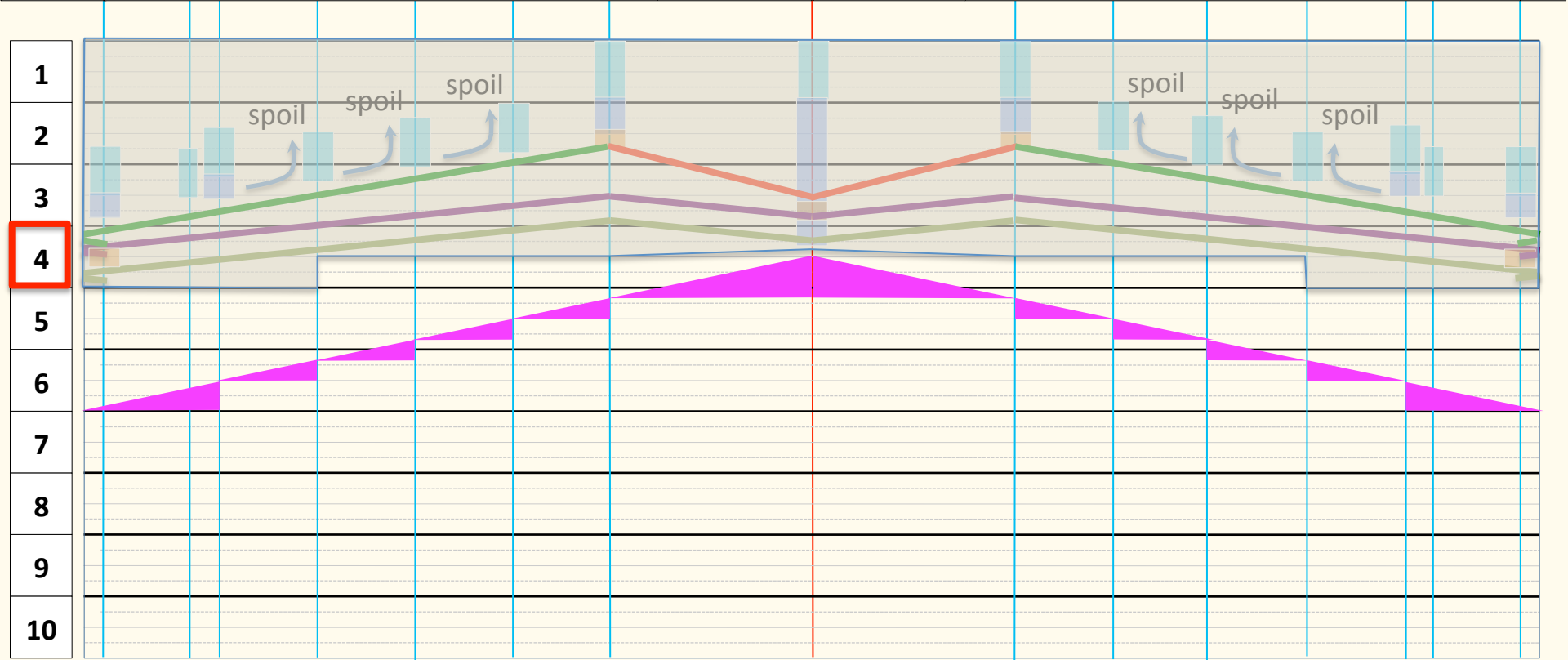




- Survey & supports set-out
- Electrics general services
- Piping & ventilation
- Cabling

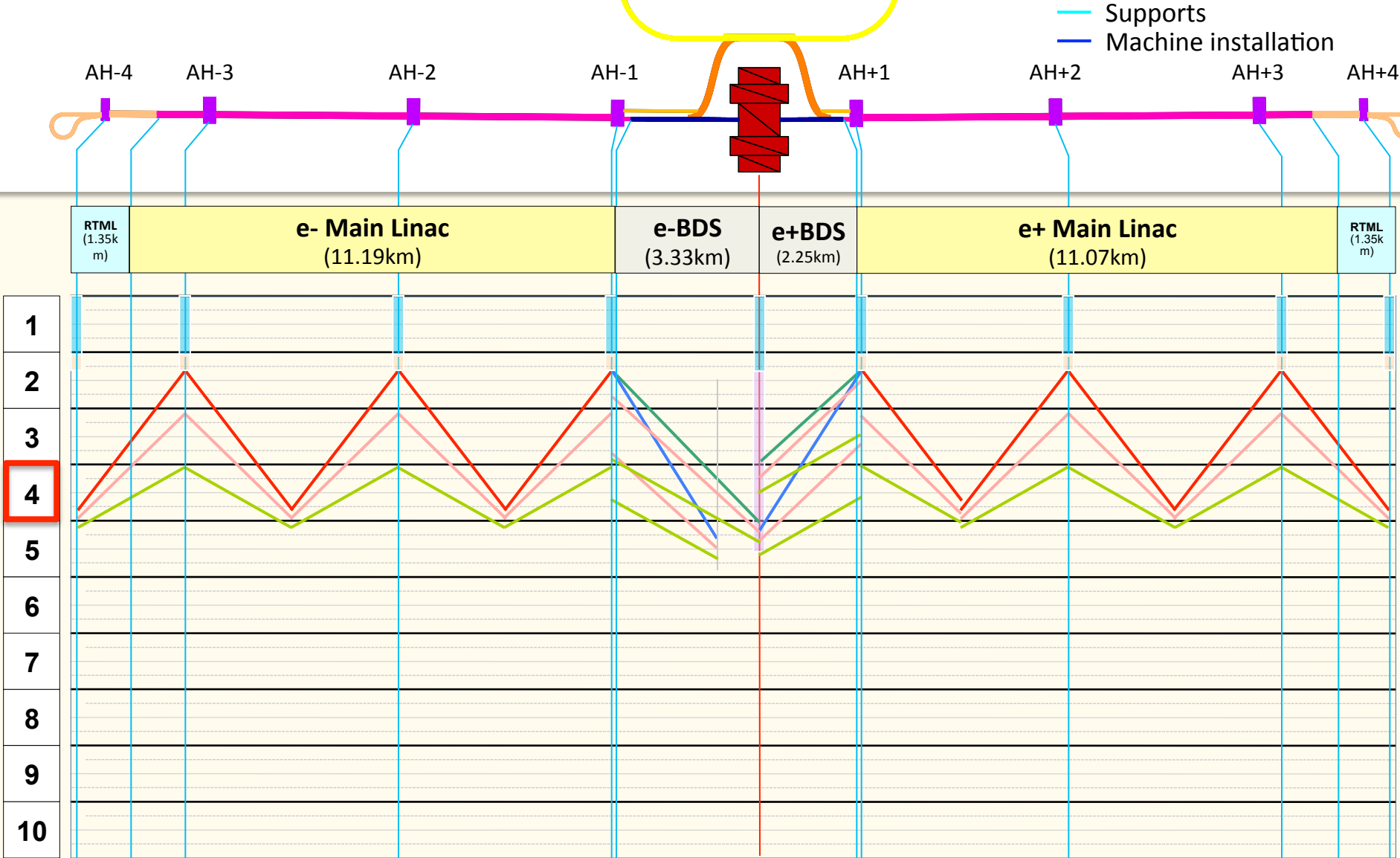


RTML (0.6km)	e- Main Linac (11.9km)	e-BDS (3.2km)	e+BDS (3.2km)	e+ Main Linac (11.9km)
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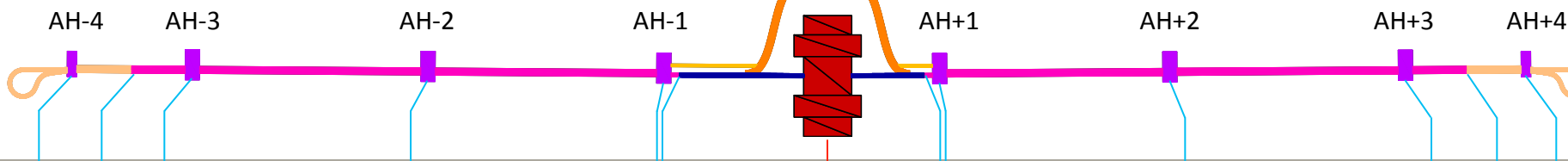
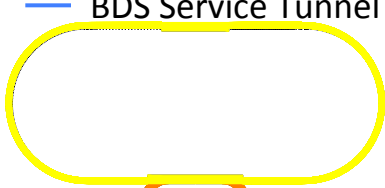
- End of tunneling phase in Beam Tunnel and BDS Tunnel
- Tunneling to proceed in BDS service tunnel
- Concrete lining to proceed in Beam Tunnel
- Invert and drainage work to start
 - Progress rate: 45m/week

- Access Tunnel ex.
- Cavern ex.
- Hall ex.
- Beam Tunnel excavation
- Concrete Lining
- Invert & Drainage
- Shield Wall
- BDS Tunnel excavation
- BDS Service Tunnel excavation
- Survey & supports set-out
- Electrical general services
- Piping & ventilation
- Cabling
- Supports
- Machine installation

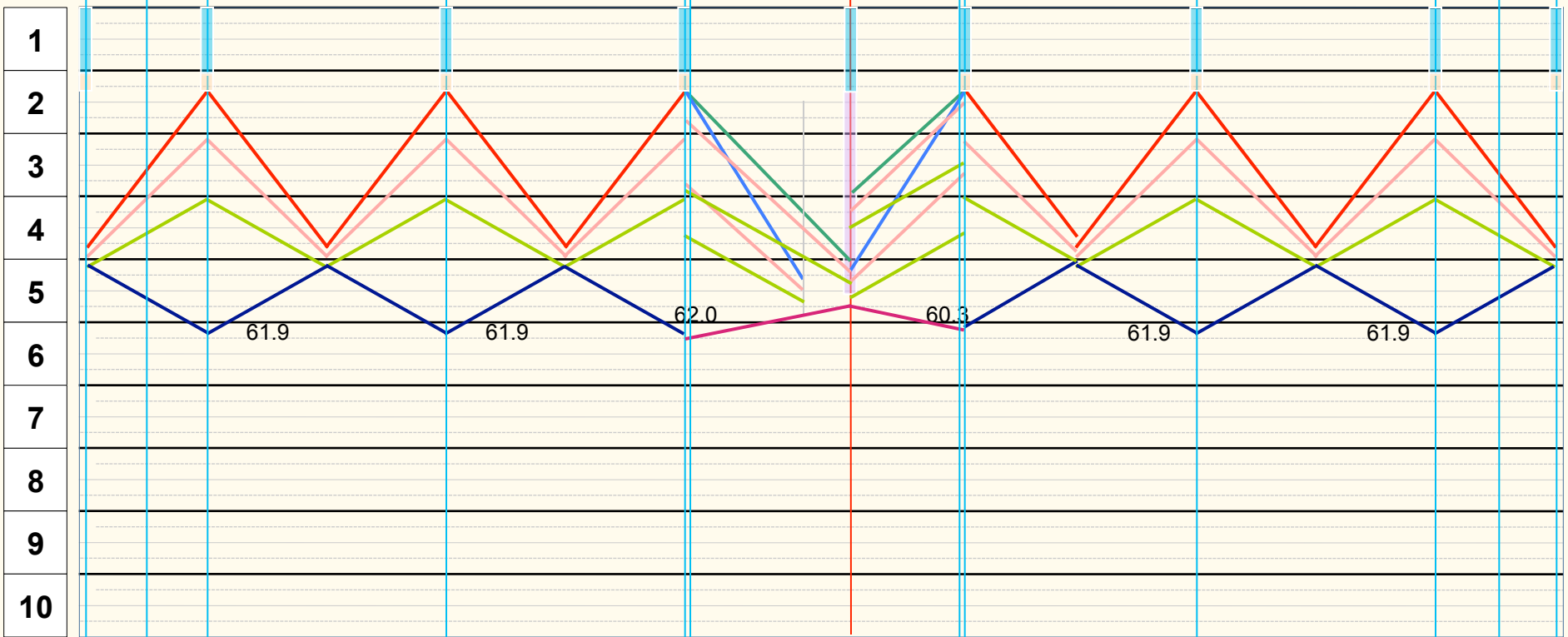


- The civil engineering work reaches completion during Year 4 in the flat topography site
- Due to slower tunneling progress rates the MR civil engineering work will need one more year to reach completion
- Year 5 for MR is dominated by the construction of the Shielding Wall
 - Progress rate: 45m/week
- Milestones: Civil engineering work complete
 - FT: Y4 Q4
 - MR: Y5 Q1

- Access Tunnel ex.
- Beam Tunnel excavation
- BDS Tunnel excavation
- Cavern ex.
- Concrete Lining
- BDS Service Tunnel excavation
- Hall ex.
- Invert & Drainage
- Shield Wall



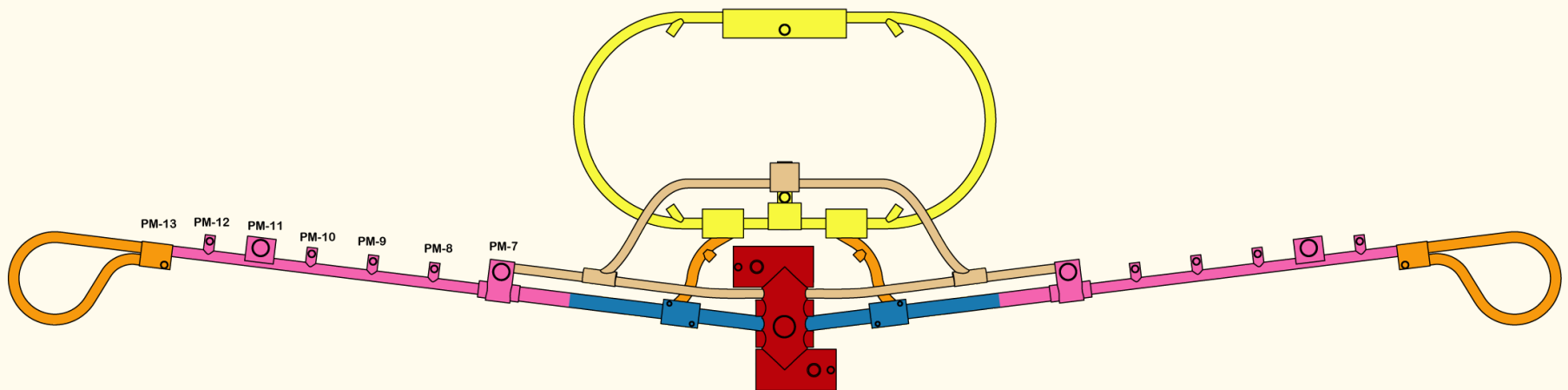
	RTML (1.35k m)	e- Main Linac (11.19km)	e-BDS (3.33km)	e+BDS (2.25km)	e+ Main Linac (11.07km)	RTML (1.35k m)
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→ Installation of infrastructure

- Survey and set out of components supports
- Electrics General services
- Piping and ventilation
- Cabling

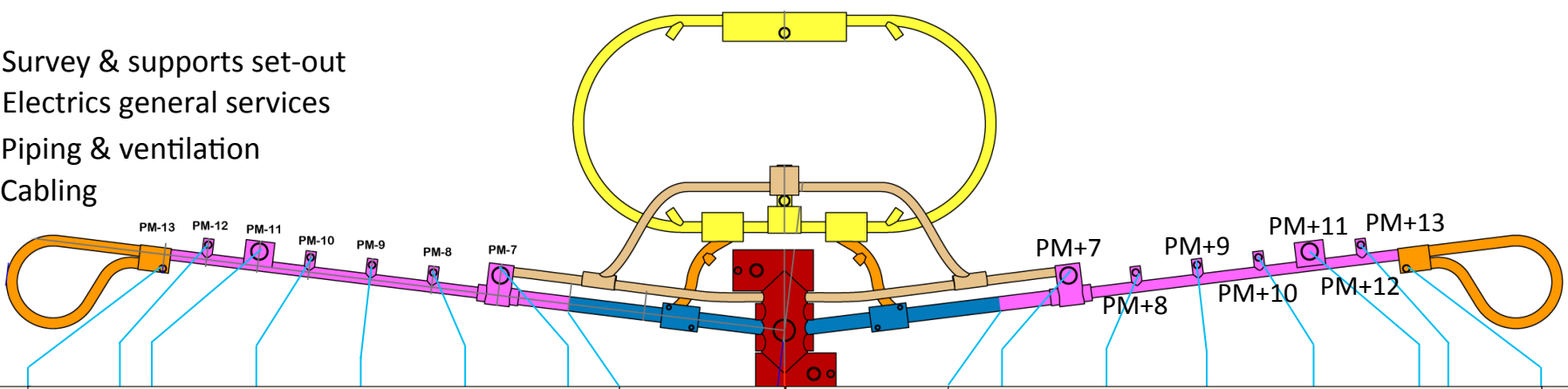
Progress rate 120m/w for 1 shift



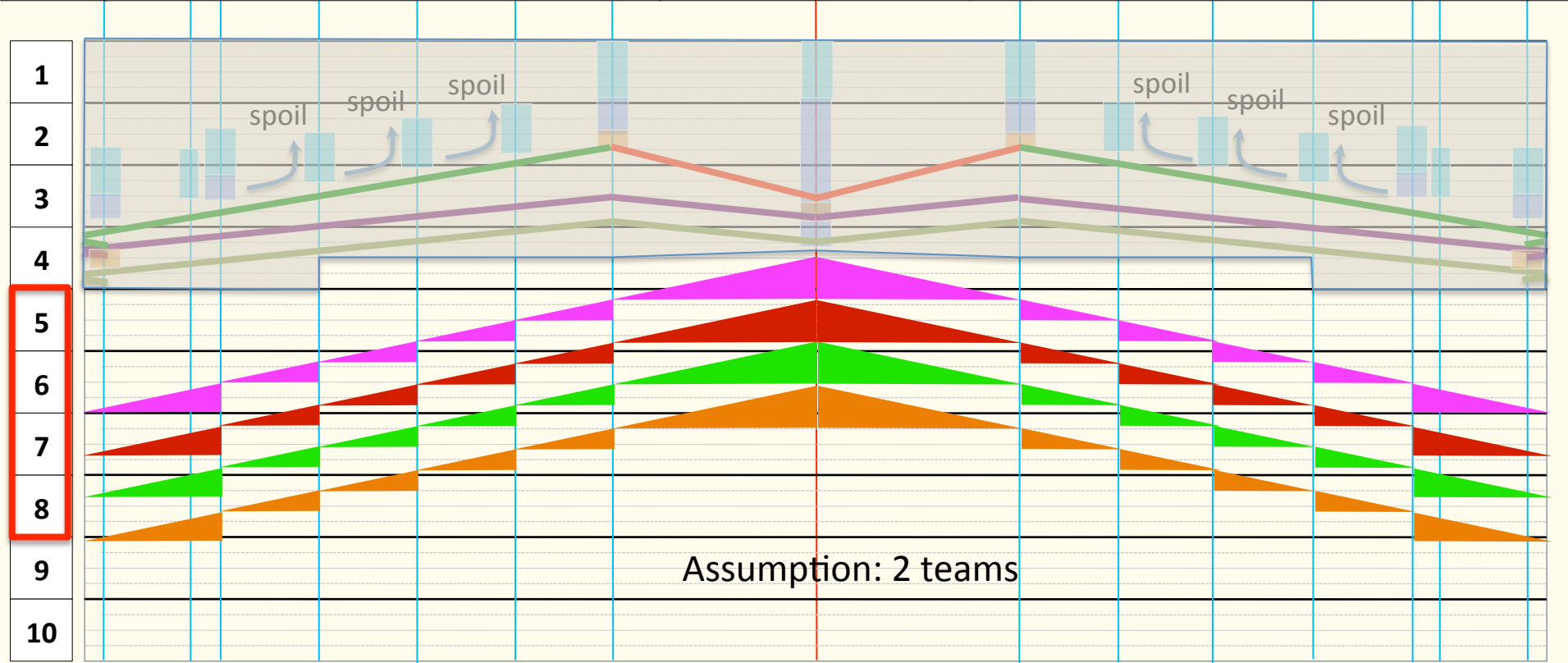
→ Impact of the number of teams deployed is significant

- Baseline: 2 teams
- Option: 4 teams

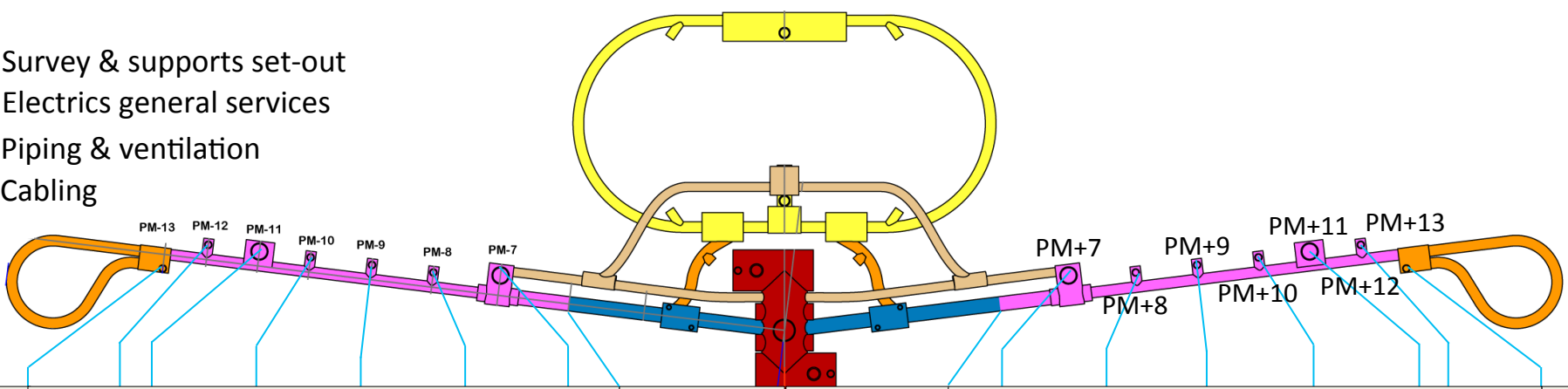
- Survey & supports set-out
- Electrics general services
- Piping & ventilation
- Cabling



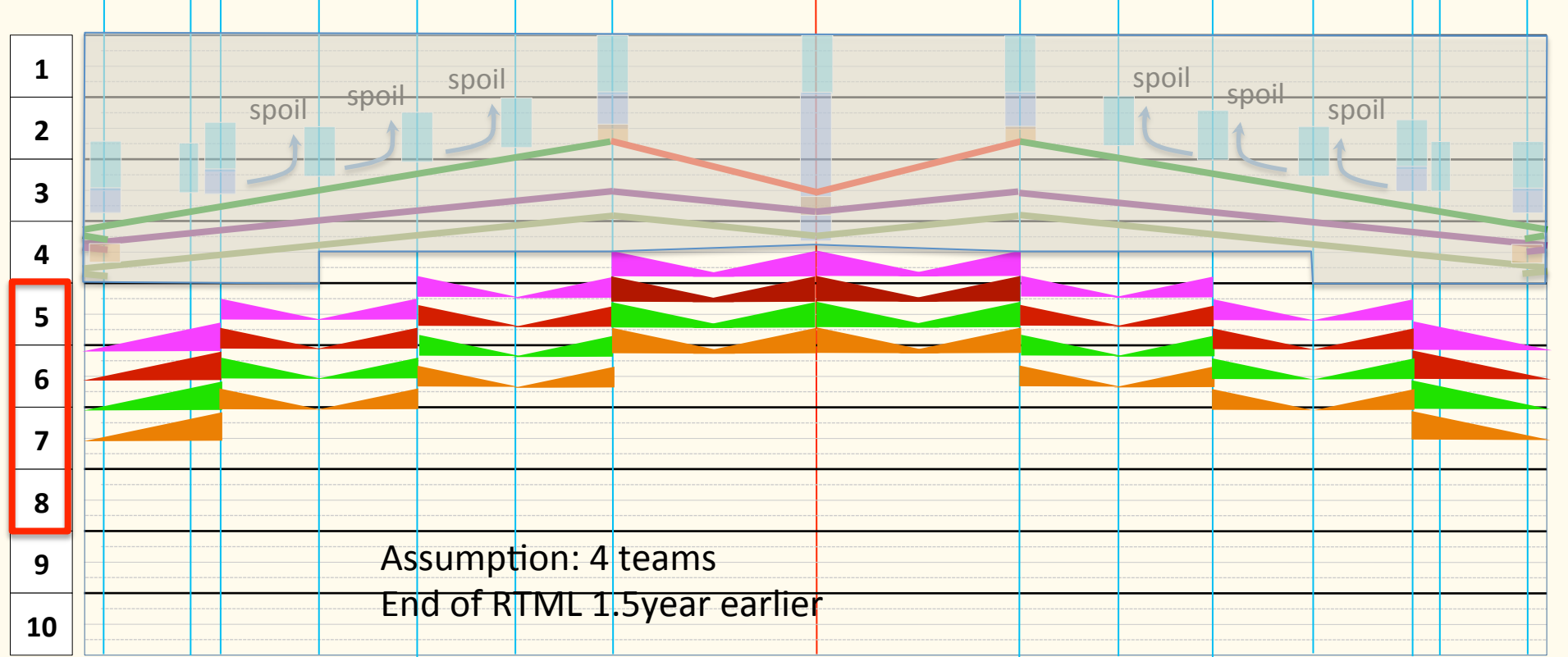
RTML (0.6km)	e- Main Linac (11.9km)	e-BDS (3.2km)	e+BDS (3.2km)	e+ Main Linac (11.9km)
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- Survey & supports set-out
- Electrics general services
- Piping & ventilation
- Cabling



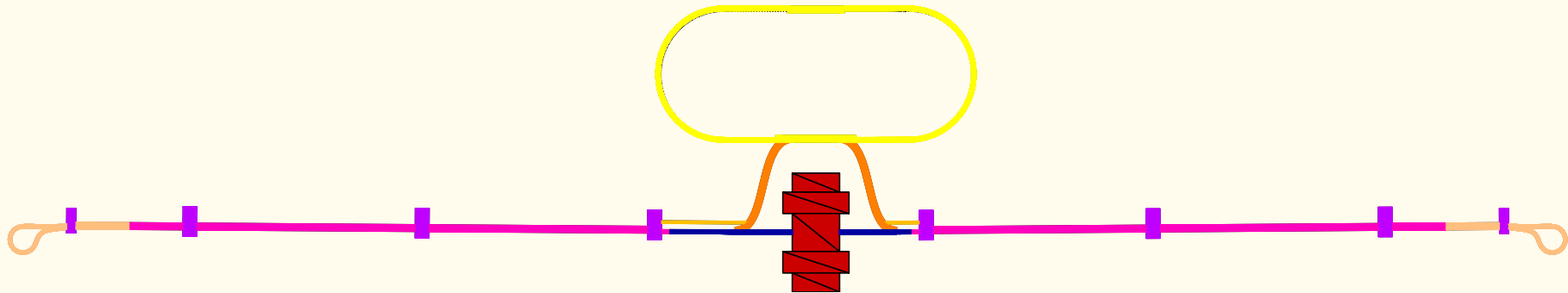
RTML (0.6km)	e- Main Linac (11.9km)		e-BDS (3.2km)	e+BDS (3.2km)	e+ Main Linac (11.9km)
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→ Installation of infrastructure

- Survey and set out of components supports
- Electrics General services
- Piping and ventilation
- Cabling

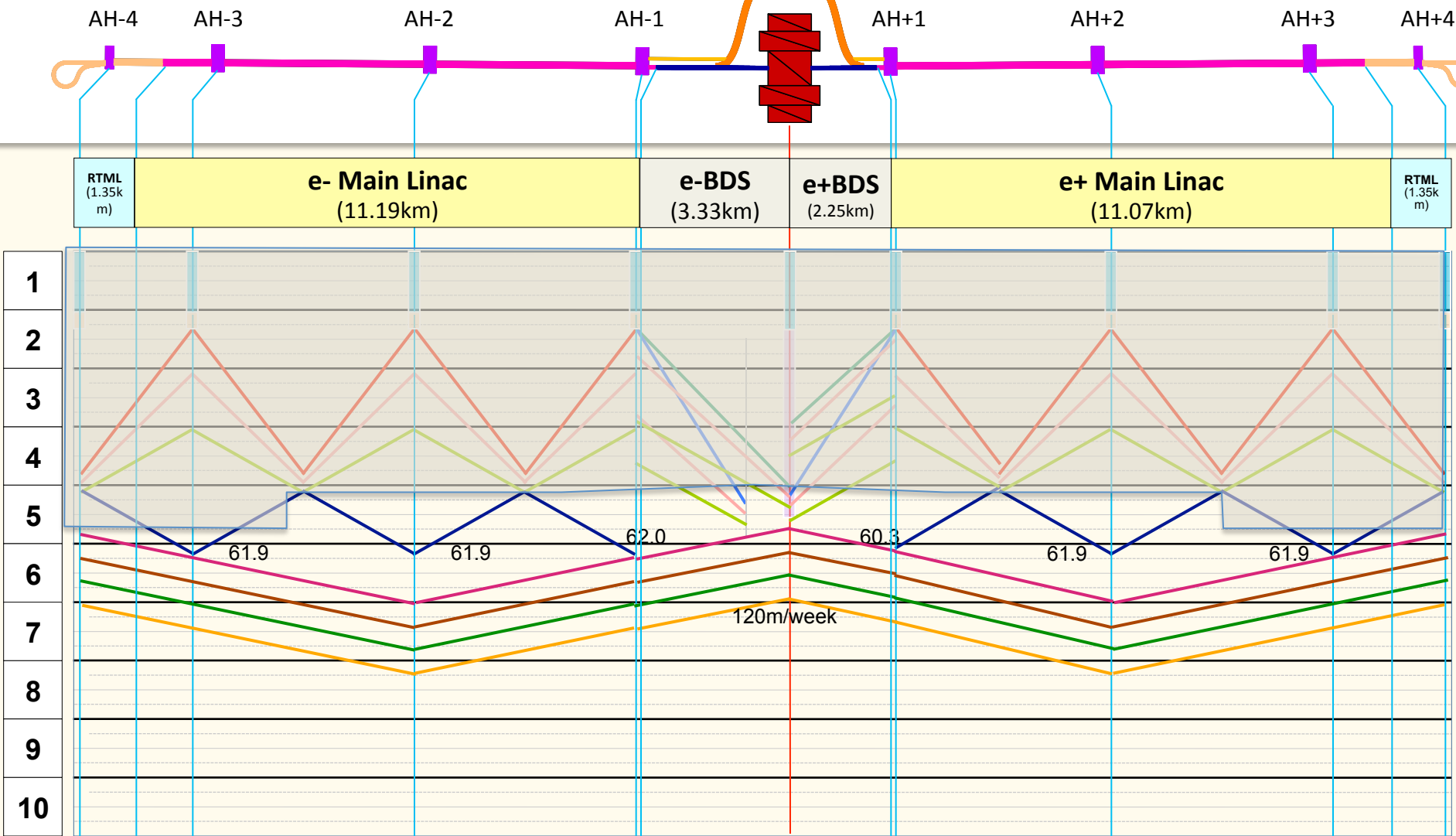
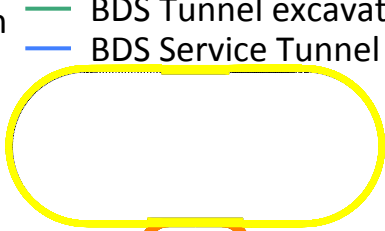
Progress rate 120m/w for 1 shift



→ 4 teams deployed

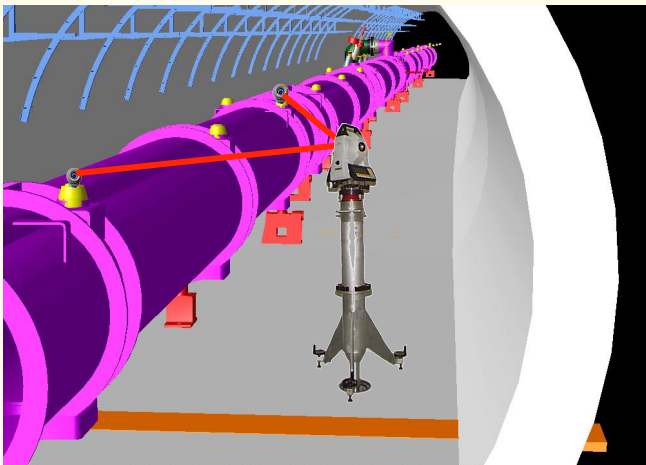
- In the Asian schedule, teams from different activities are allowed to work in one same sector ex in e-BDS between electrical teams and piping teams
- Having shielding wall make this possible

- Access Tunnel ex.
- Beam Tunnel excavation
- BDS Tunnel excavation
- Survey & supports set-out
- Cavern ex.
- Concrete Lining
- BDS Service Tunnel excavation
- Electrical general services
- Hall ex.
- Invert & Drainage
- Shield Wall
- Piping & ventilation
- Cabling



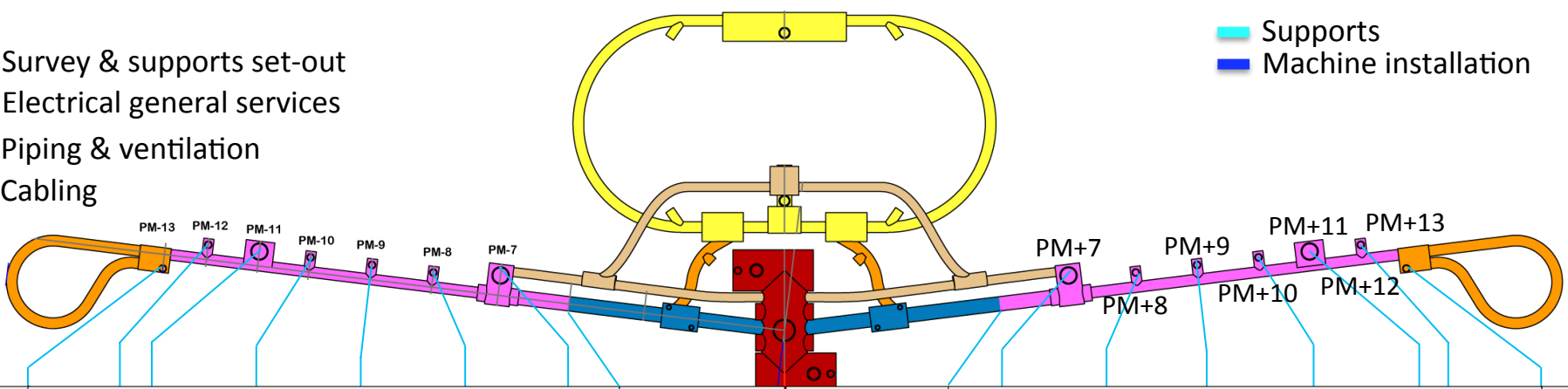
- Progress rates used for the Installation of infrastructure are the same for both regions
 - Survey and set out of components supports
 - Electrics General services
 - Piping and ventilation
 - Cabling
- Allowing multiple types of activities in a same tunnel section allows the MR schedule to catch up slightly with the FT one
- Milestones: Installation of infrastructure complete
 - FT: Y7 Q3
 - MR: Y8 Q1
- Milestone: Installation of machine components in BDS started
 - FT: Y6 Q1
 - MR: Y7 Q2

- Installation of supports for machine components
 - Progress rate: 250m/w for 1 shift
- Installation of machine components
 - Transport
 - Interconnections
 - Alignment
 - Progress rate: 100m/w for 1 shift (Average value from LHC)
- 2 teams for each activity for FT; 4 teams for each activity for MR

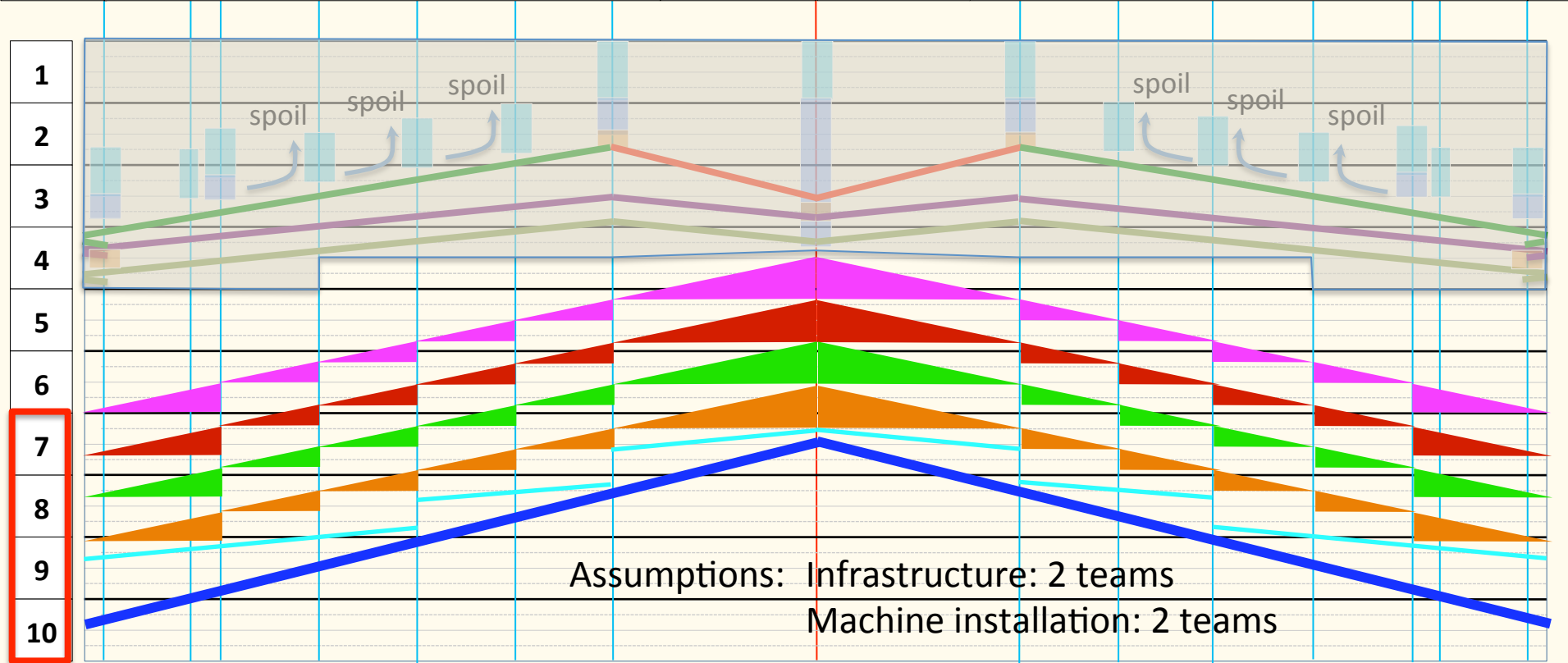


- Survey & supports set-out
- Electrical general services
- Piping & ventilation
- Cabling

- Supports
- Machine installation

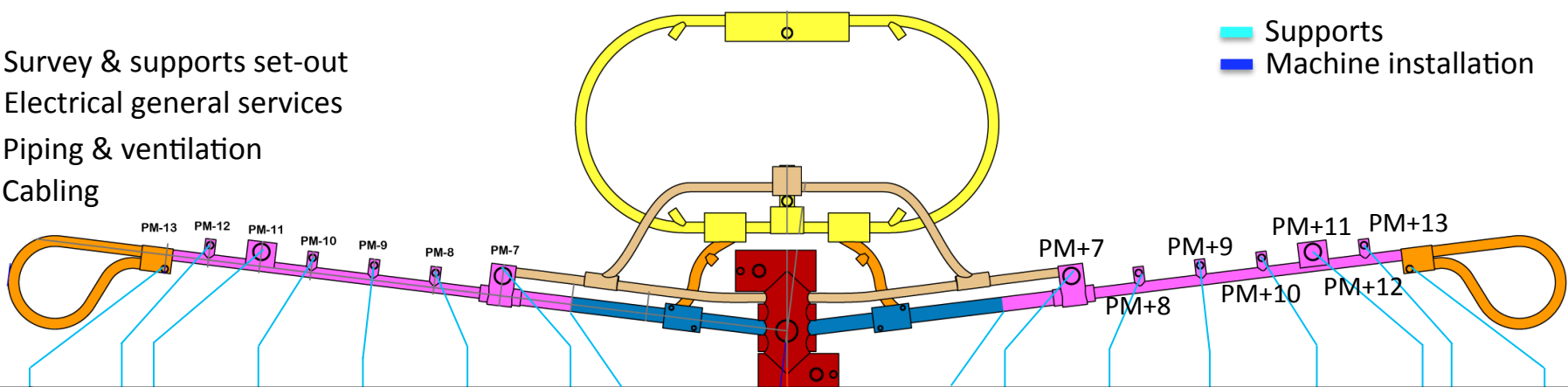


RTML (0.6km)	e- Main Linac (11.9km)	e-BDS (3.2km)	e+BDS (3.2km)	e+ Main Linac (11.9km)
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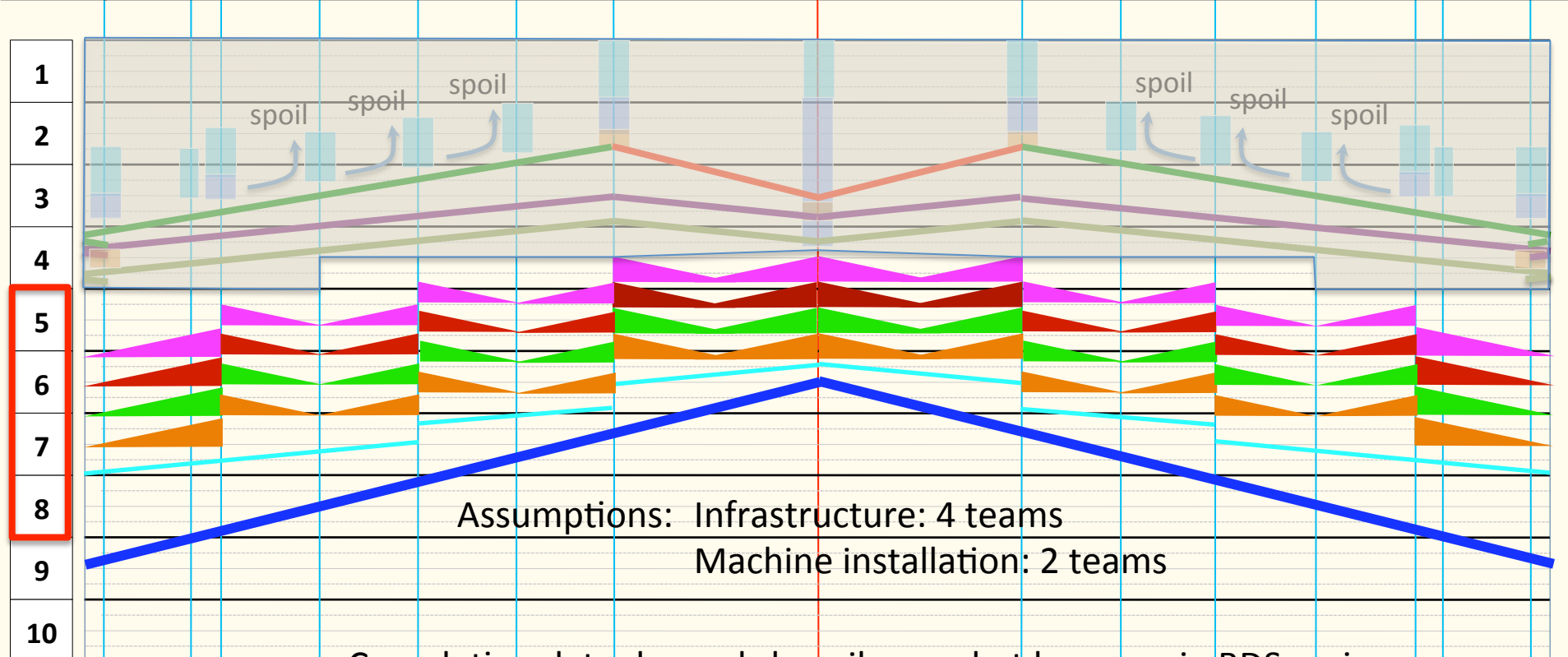


- Survey & supports set-out
- Electrical general services
- Piping & ventilation
- Cabling

- Supports
- Machine installation



RTML (0.6km)	e- Main Linac (11.9km)	e-BDS (3.2km)	e+BDS (3.2km)	e+ Main Linac (11.9km)
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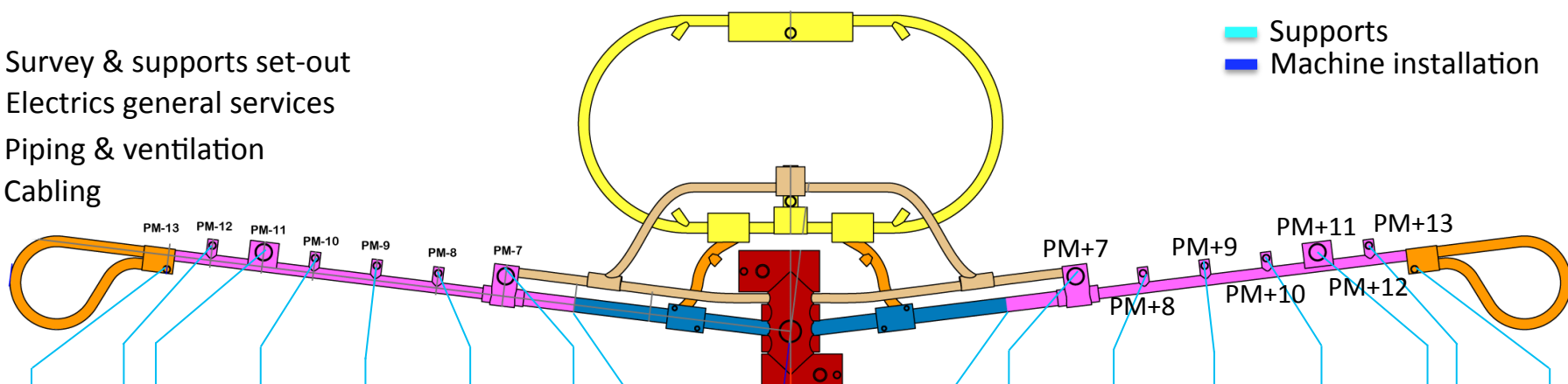


Assumptions: Infrastructure: 4 teams
Machine installation: 2 teams

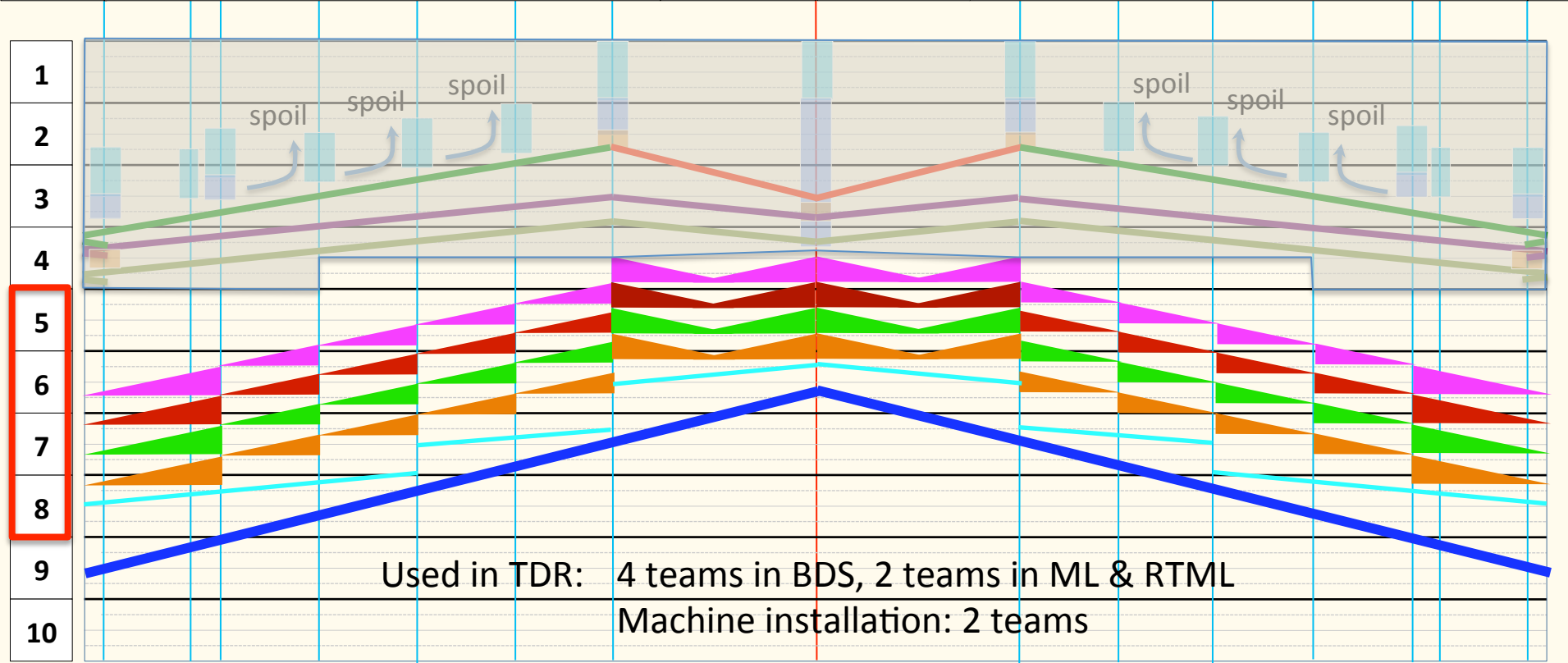
Completion date depends heavily on what happens in BDS region

- Survey & supports set-out
- Electrics general services
- Piping & ventilation
- Cabling

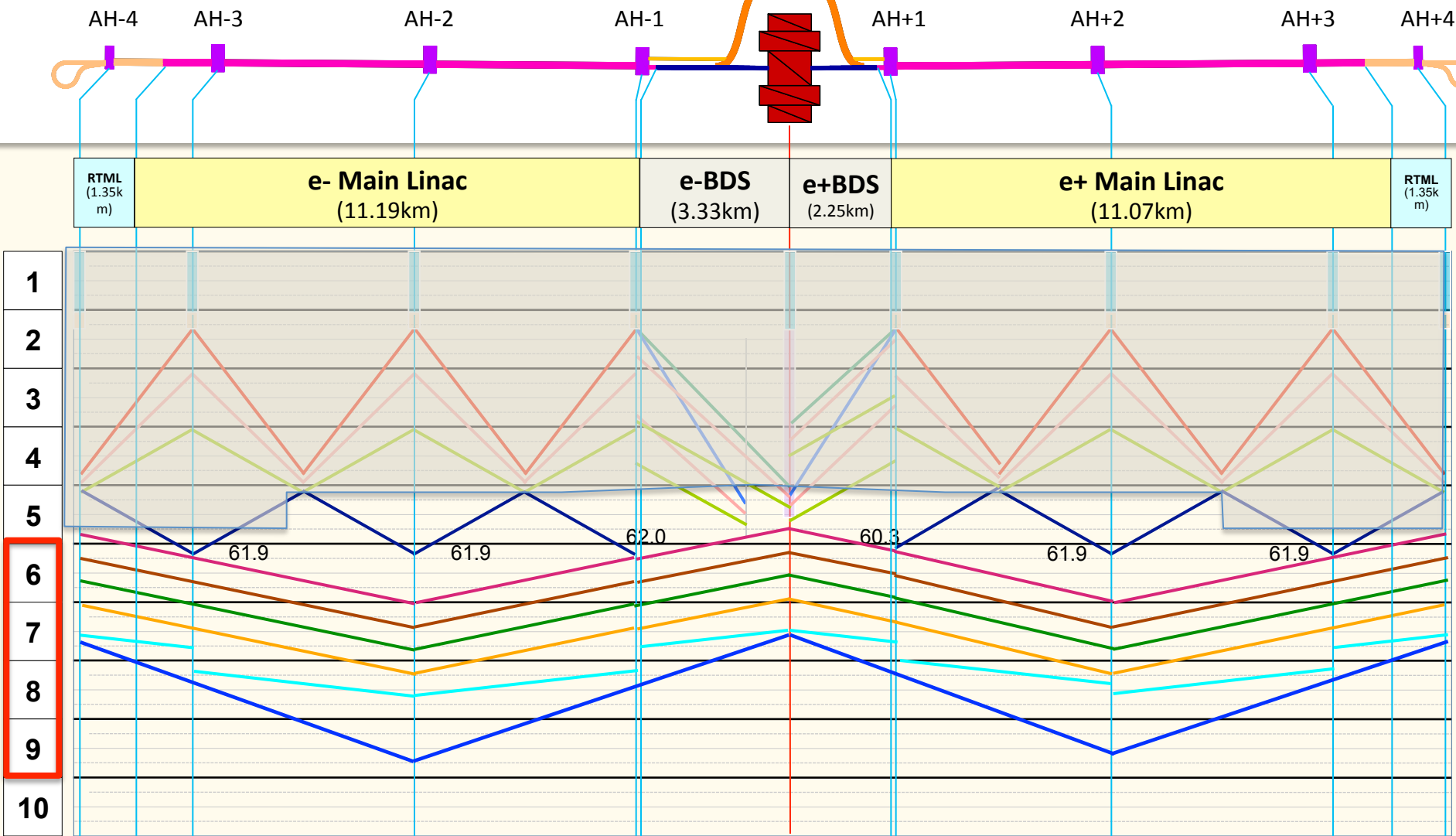
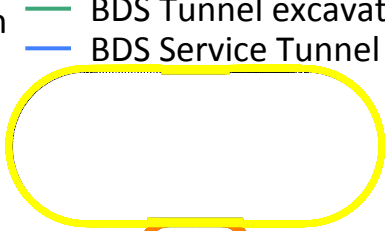
- Supports
- Machine installation



RTML (0.6km)	e- Main Linac (11.9km)	e-BDS (3.2km)	e+BDS (3.2km)	e+ Main Linac (11.9km)
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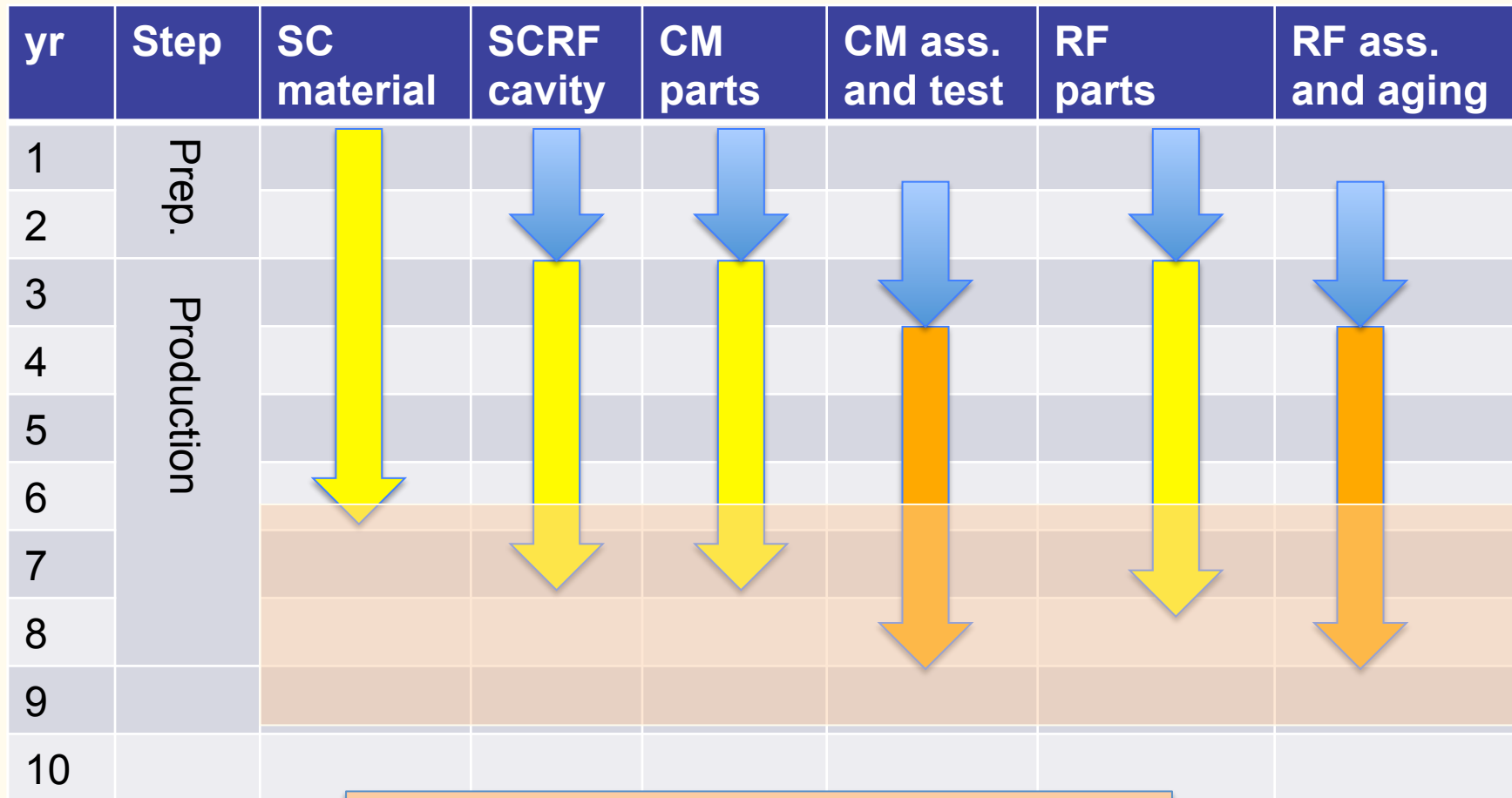


- Access Tunnel ex.
- Cavern ex.
- Hall ex.
- Beam Tunnel excavation
- Concrete Lining
- Invert & Drainage
- Shield Wall
- BDS Tunnel excavation
- BDS Service Tunnel excavation
- Survey & supports set-out
- Electrical general services
- Piping & ventilation
- Cabling
- Supports
- Machine installation

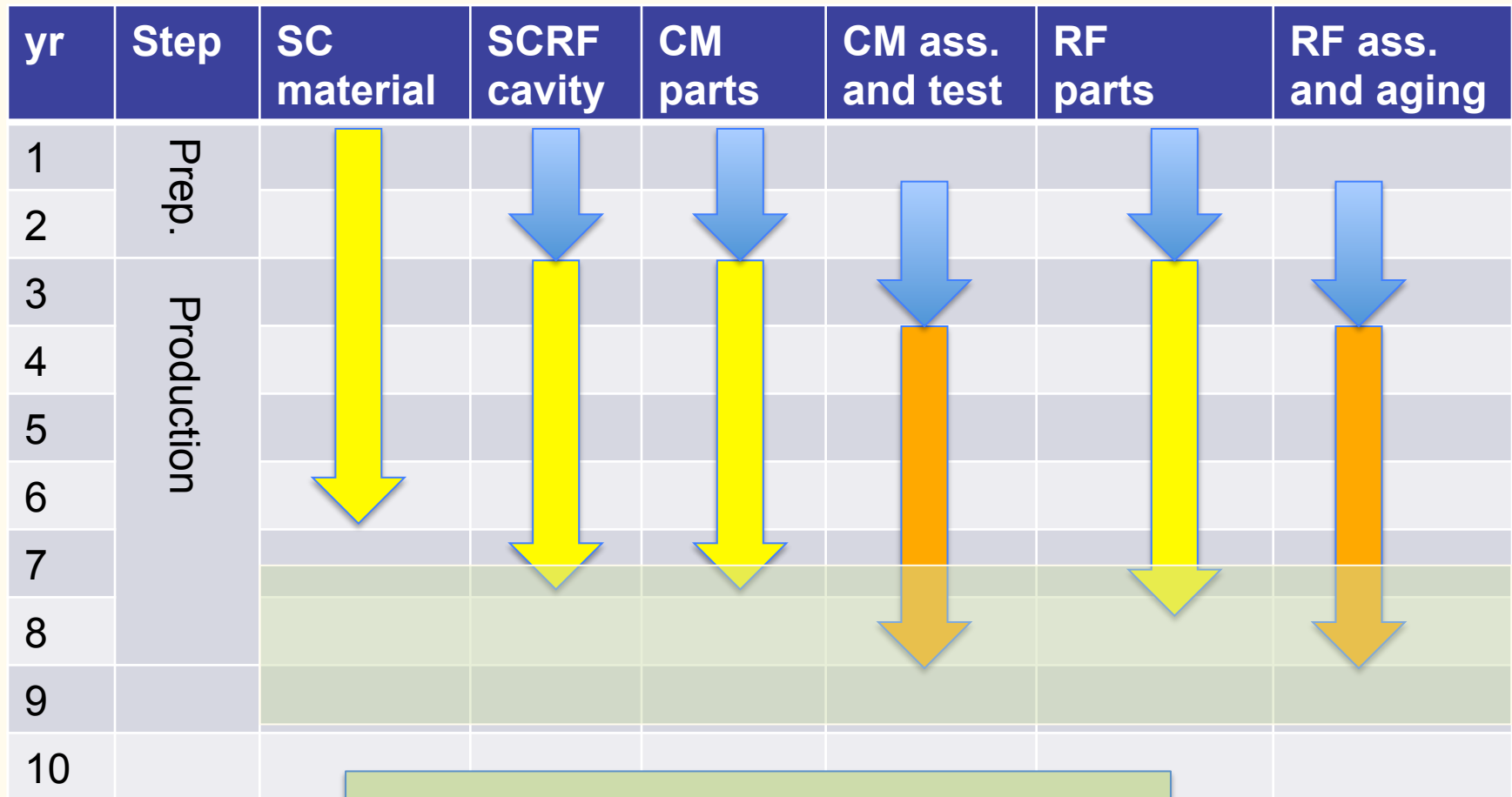


- The Asian site schedule is a lot more labor intensive
- The faster rate of TBMs allows for a faster completion of the civil engineering work in the FT schedule
 - Spoil management to be studied carefully
- Building the shielding wall takes an entire year in the MR schedule
- The installation of infrastructure is slightly faster in the MR region thanks to the deployment of more teams and greater tolerance to coactivity
- Allowing the installation of the machine components to be carried out by 4 teams allows the MR schedule to catch up with the FT schedule
- Milestone: Ready for early commissioning (BDS and ML up to PM7/AH1)
 - FT: Y7 Q2
 - MR: Y8 Q2
- Milestone: Ready for Full commissioning (whole accelerator available)
 - FT: Y10 Q1
 - MR: Y10 Q1
- Milestone: ILC ready for beam
 - FT: Y10 Q4
 - MR: Y10 Q4 (commissioning program to be fine tuned)

- Light blue: Pre-production or pre-industrialization stage (or preparation for full production)
- Yellow : Full production of material and components/parts.
- Orange: Full assembly stage and test stage in parallel.

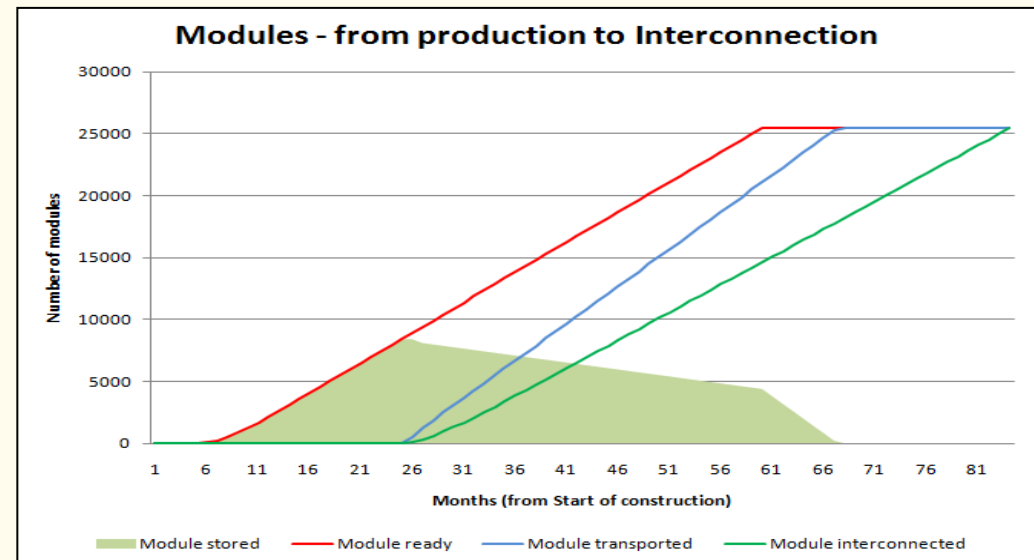
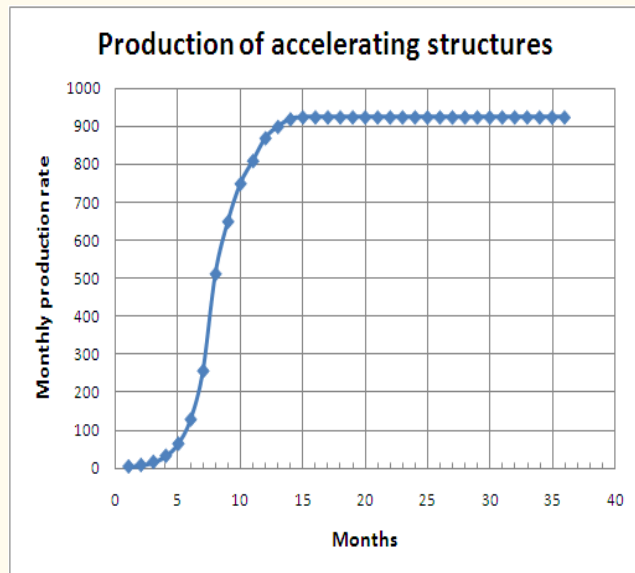


Installation of machine components - FT



Installation of machine components - MR

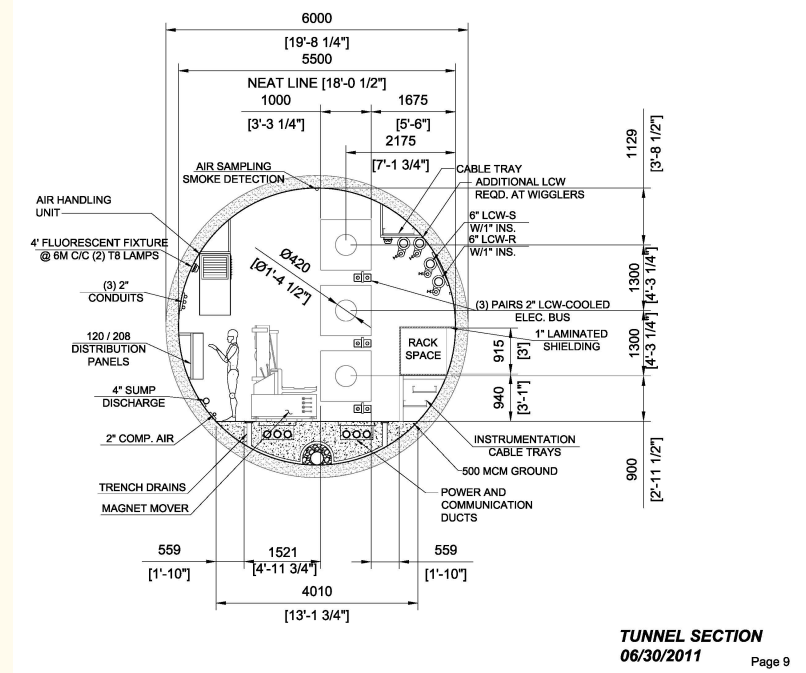
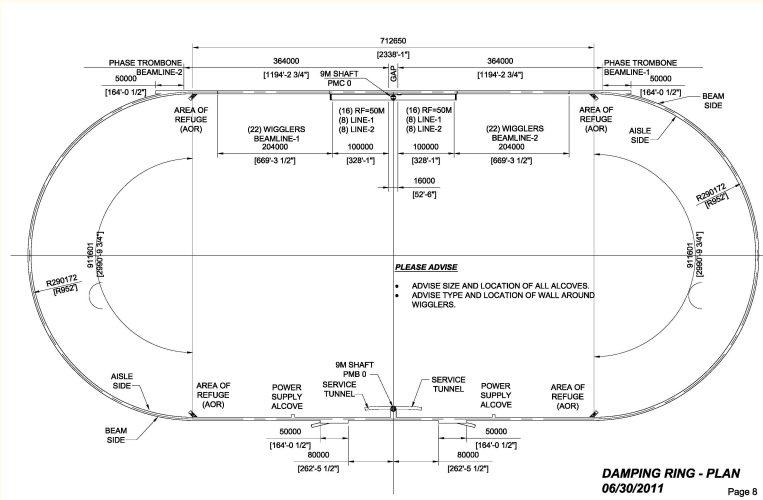
- The Asian region schedule allows for a longer production time of the accelerator parts
- Next step: come up with a production schedule compatible with an installation schedule, ex for CLIC shown below



- Early Commissioning : Draft program (Ewan):
 - The e- injector system to 5 GeV and dump : 3 Months
 - The e+ source and systems to 5 GeV and dump utilizing the auxiliary low current e- source to produce e+ : 3 Months
 - Hardware commissioning of injection lines and both Damping rings : 3 months
 - Commission both rings with beams from injectors with extraction only into first dump in the PLTR (beam still in injection/extraction tunnels): 9 months

- Requires the availability of:
 - BDS and ML up to PM7/AH1 (FT: Y7 Q2)
 - PLTR
 - Damping Rings

- Draft schedule for the construction and installation of the DR+PLTR – FT only
 - DR: One 6m diameter, 3240m long tunnel – excavation using TBM at a rate of 150m/w for 3 shifts
 - PLTR: Two 6-8m diameter, 270m long tunnels – excavation using road headers at a rate of 30m/w for 3 shifts
 - When possible, the RD and PLTR are treated as one 3780m tunnel



- CE phase
 - Invert and finishing: 250m/w
 - Ceiling ducts: 250m/w
 - Installation of infrastructure in DR and PLTR
 - Survey: 120m/w 120m/w
 - Electrics: 80m/w 120m/w
 - Piping & ventilation: 80m/w 120m/w
 - Cabling: 80m/w 120m/w
 - Installation of machine components
 - Supports: 250m/w
 - Machine elements: DR: 50m/w ; PLTR: 100m/w
- Many more components per meter to install in DR

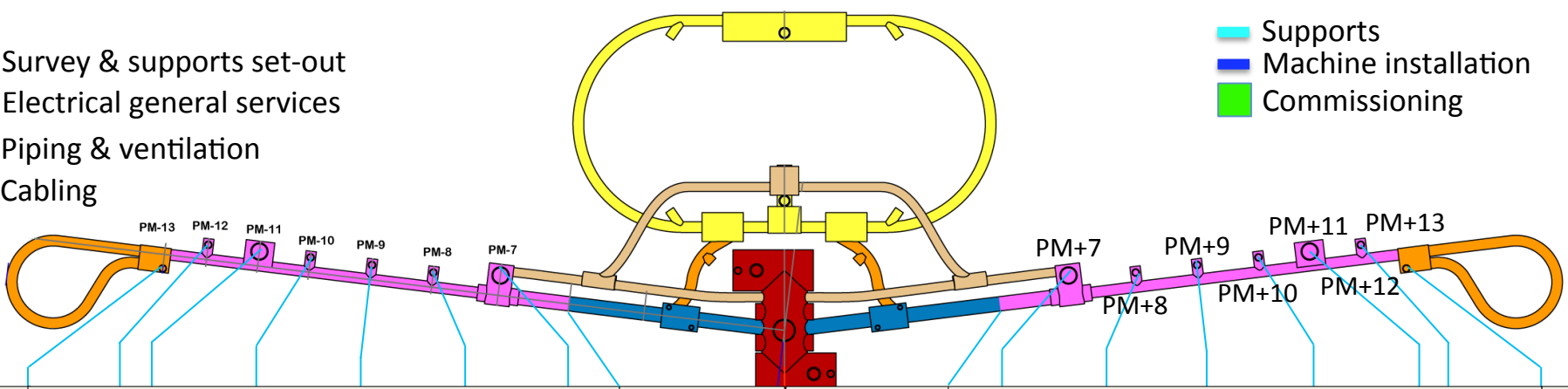
ID	Task Name	Duration	2020		2022		2024		2026		2028		2030		2032		
			Qtr 1	Qtr 1	Qtr 1	Qtr 1	Qtr 1	Qtr 1	Qtr 1	Qtr 1	Qtr 1	Qtr 1	Qtr 1	Qtr 1	Qtr 1		
1	DR and PLTR construction	1850.5 days															
2	Excavate PMA0 and PMBo	52 wks	01/01														
3	Excavate DR caverns	40 wks	30/12														
4	Setup TBM	15 wks	30/12														
5	Excavate DR	21.6 wks	14/04														
6	Excavate PLTR	18 wks	10/05														
7	Invert and finishing for DR and PLTR	15 wks	13/09														
8	Install ceiling partitions (DR PLTR)	15 wks	27/12														
9	Survey + supports setout	31.5 wks	11/04														
10	Electrics	45 wks	16/11														
11	Piping and ventilation	45 wks	27/09														
12	Cabling	45 wks	07/08														
13	Supports installation	15 wks	18/06														
14	Machine installation	70 wks	01/10														
15	DR and PLTR ready for commissioning	0 days															
16	BDS ready for commissioning	0 days															
17	e- injector system to 5GeV and dump	13 wks	01/04														
18	e+ source and systems to 5GeV and dump	13 wks	01/04														
19	Hardware commissioning of injection lines and DR	13 wks	01/04														
20	Commissioning with beam of DR	39 wks	01/07														
21	Early commissioning complete	0 days															

- Under our set of assumptions, the DR and PLTR would be made available to commissioning before the BDS becomes available (Y7Q1 vs Y7Q2)
- Early commissioning complete- FT:Y8 Q2
- It has been assumed that the same approach could be used for the MR sites

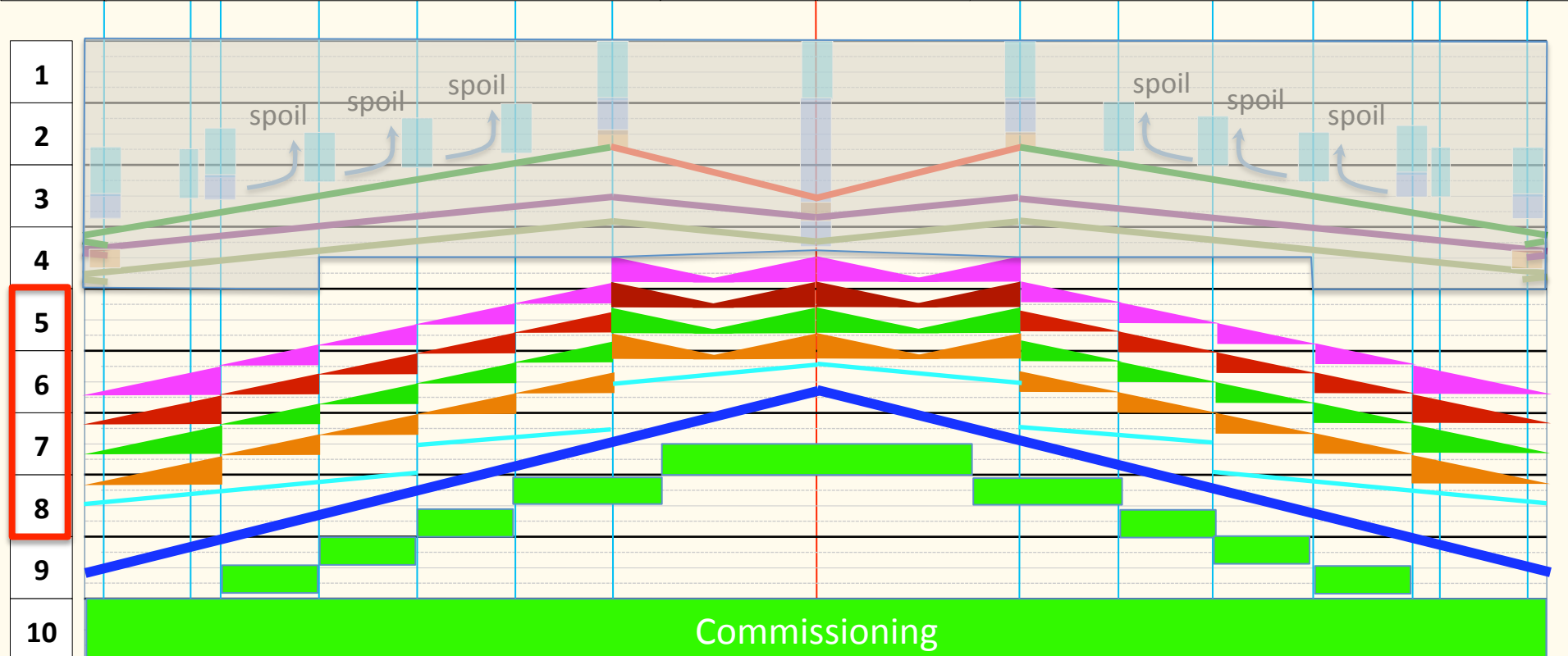
- Still quite early to come up with precise estimates
- Based on LHC:
 - 6 month of pre-commissioning per sector
 - 12 months of global commissioning
- Key dates
 - Ready for Early Commissioning- FT: Y7Q2 ; MR: Y8Q2
 - Ready for Global Commissioning- FT:Y9Q4 ; MR:Y9Q4
- Pre-requisite to launch commissioning with beam IF detectors not available
 - Temporary vacuum pipe through IR area
 - Temporary QD0
 - Temporary shielding

- Survey & supports set-out
- Electrical general services
- Piping & ventilation
- Cabling

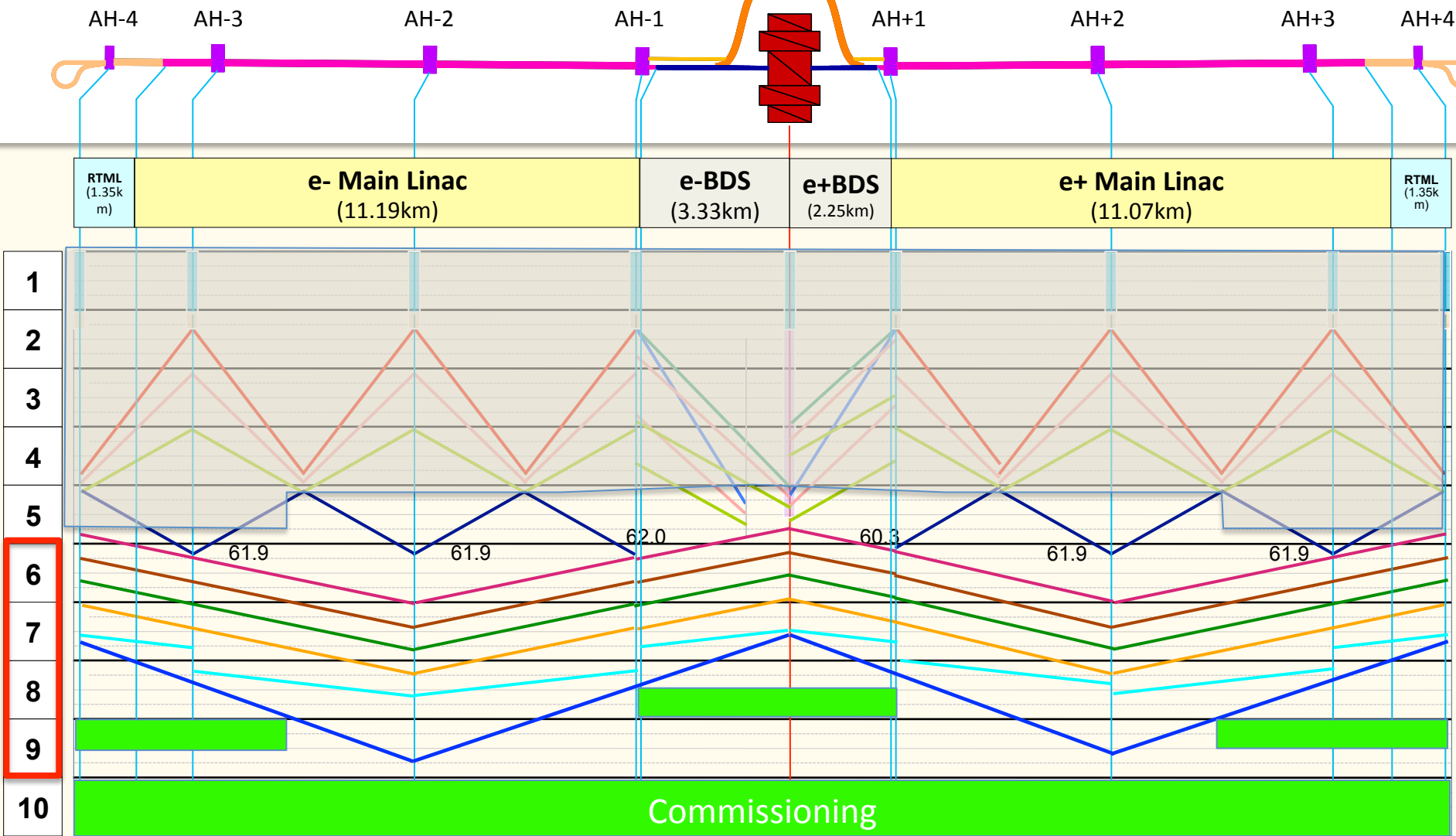
- Supports
- Machine installation
- Commissioning



RTML (0.6km)	e- Main Linac (11.9km)	e-BDS (3.2km)	e+BDS (3.2km)	e+ Main Linac (11.9km)
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- Access Tunnel ex.
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- BDS Service Tunnel excavation
- Survey & supports set-out
- Electrical general services
- Piping & ventilation
- Cabling
- Supports
- Machine installation



- This draft schedules shows how the ILC could be built and commissioned in less than 10 years
- Many additional studies will be necessary to finalise the work plans
- New iteration would be necessary if layouts are modified
- Consolidated scheduling studies for the construction and installation of the detectors in both FT and RM regions can be found in the TDR chapter

Milestone	Flat topography	Mountainous region
Civil Engineering work complete	Y4, Q4	Y5, Q1
Common Facilities installed	Y7, Q3	Y8, Q2
Accelerator ready for early commissioning (BDS and ML up to PM7/AH1)	Y7, Q2	Y8, Q2
ILC ready for full commissioning (whole accelerator available)	Y9, Q4	Y9, Q4
ILC ready for beam	Y10, Q4	Y10, Q4
Caverns ready for beneficial occupancy	Y7, Q1	
Detector ready to be lowered	Y7, Q1	
Detector ready for commissioning with beam	Y8, Q3	