



Crab RF System Status

HL-LHC WP4, CERN

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Big thanks to KEK colleagues
K. Hanagaki, T. Ogitsu



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RF system

HPRF

High Power RF station (including power transmission lines)

HPFL

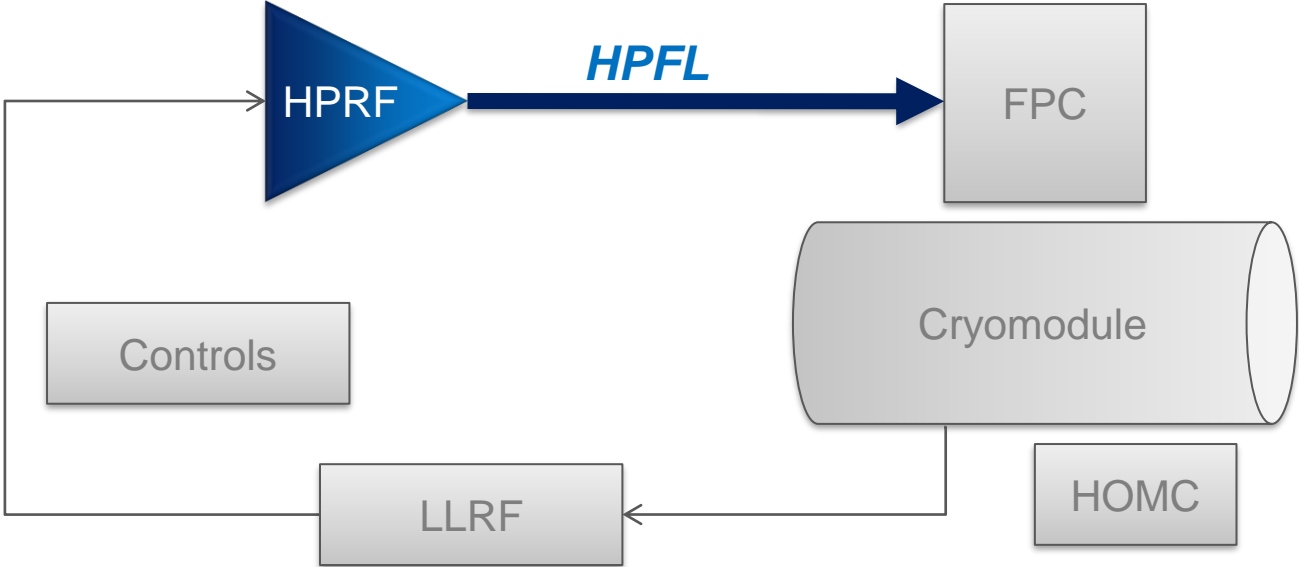
High Power RF Lines

HOMC

High Order Mode Coupler

LLRF

Low Level RF



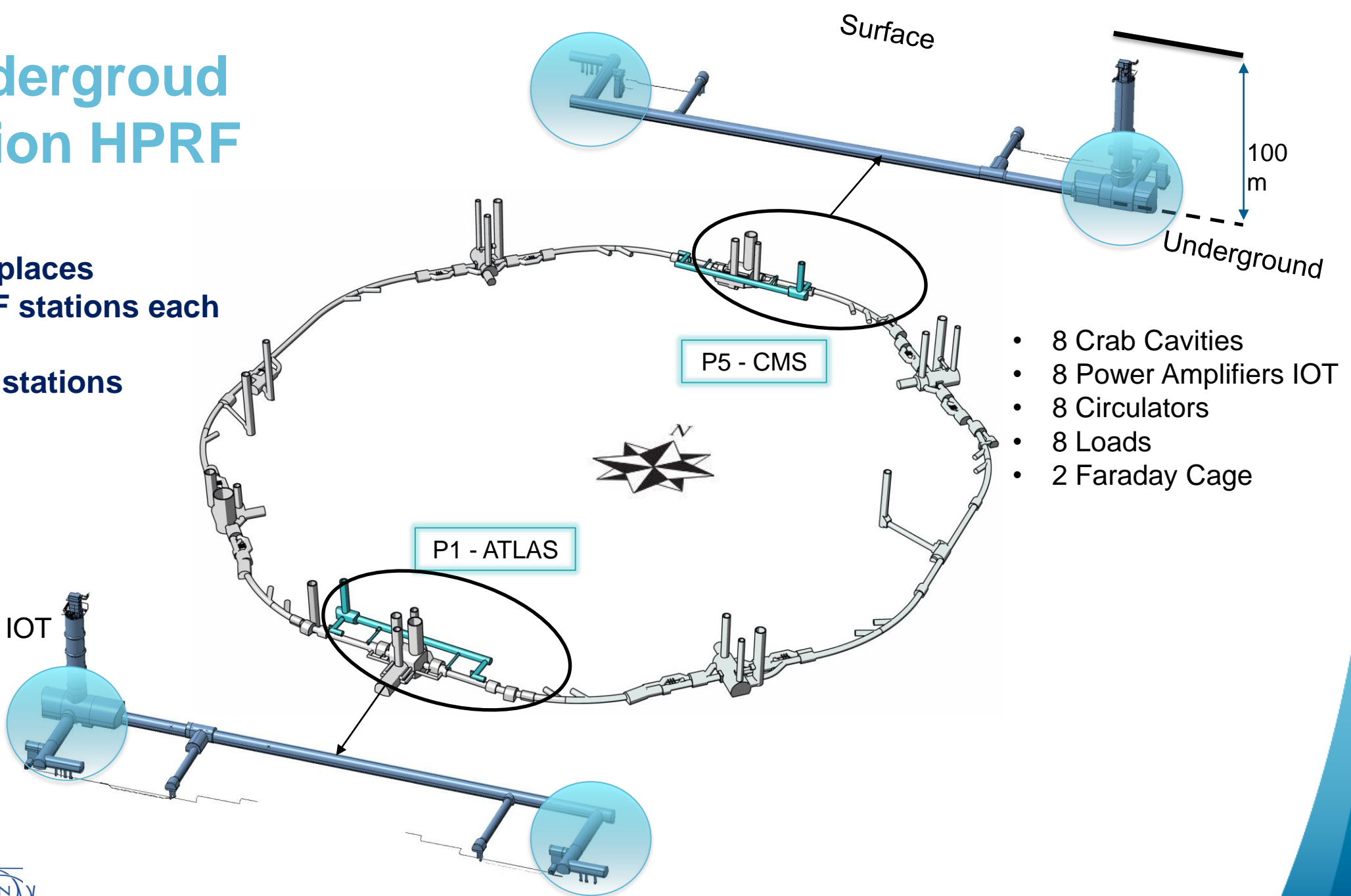
Courtesy Eric Montesinos

LHC underground Integration HPRF

Four different places
with four HPRF stations each

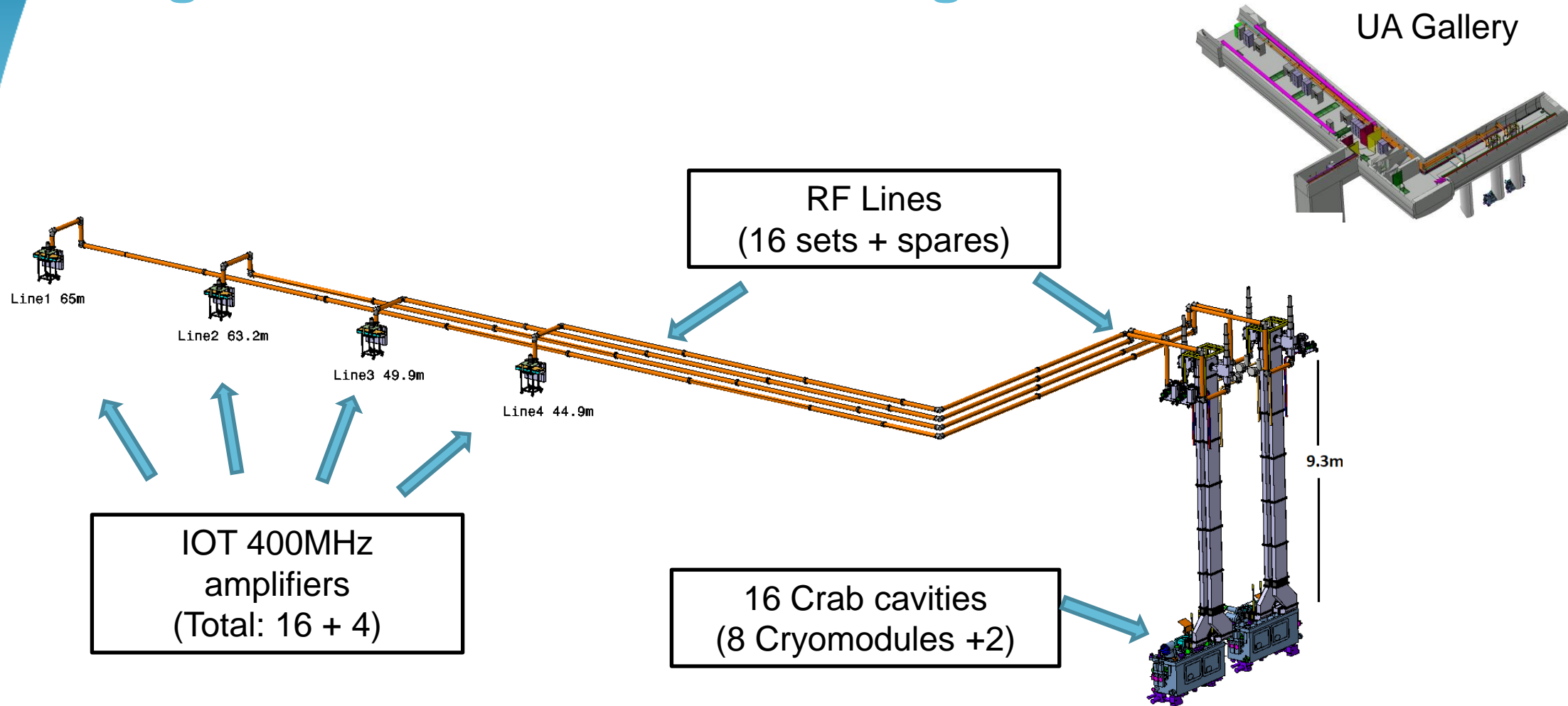
Total 16 HPRF stations

- 8 Crab Cavities
- 8 Power Amplifiers IOT
- 8 Circulators
- 8 Loads
- 2 Faraday Cage

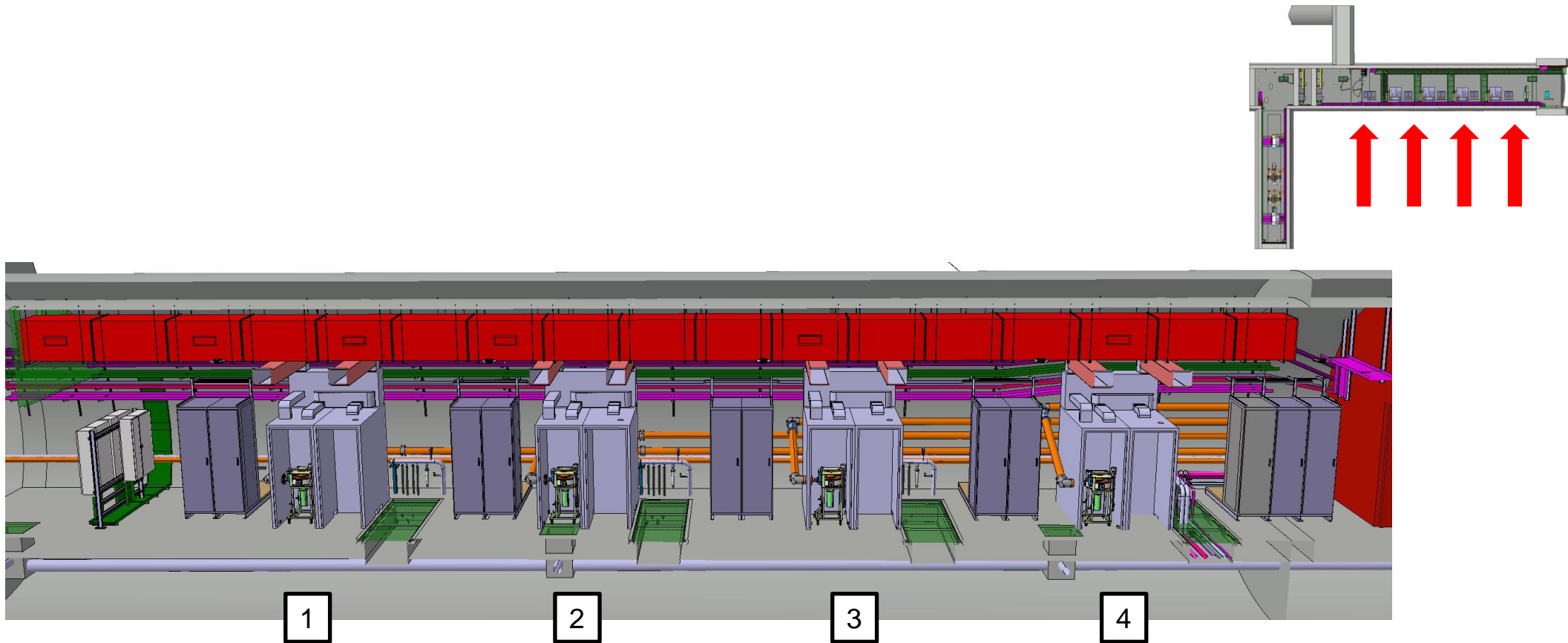


- 8 Crab Cavities
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Integration of the HPRF in the galleries



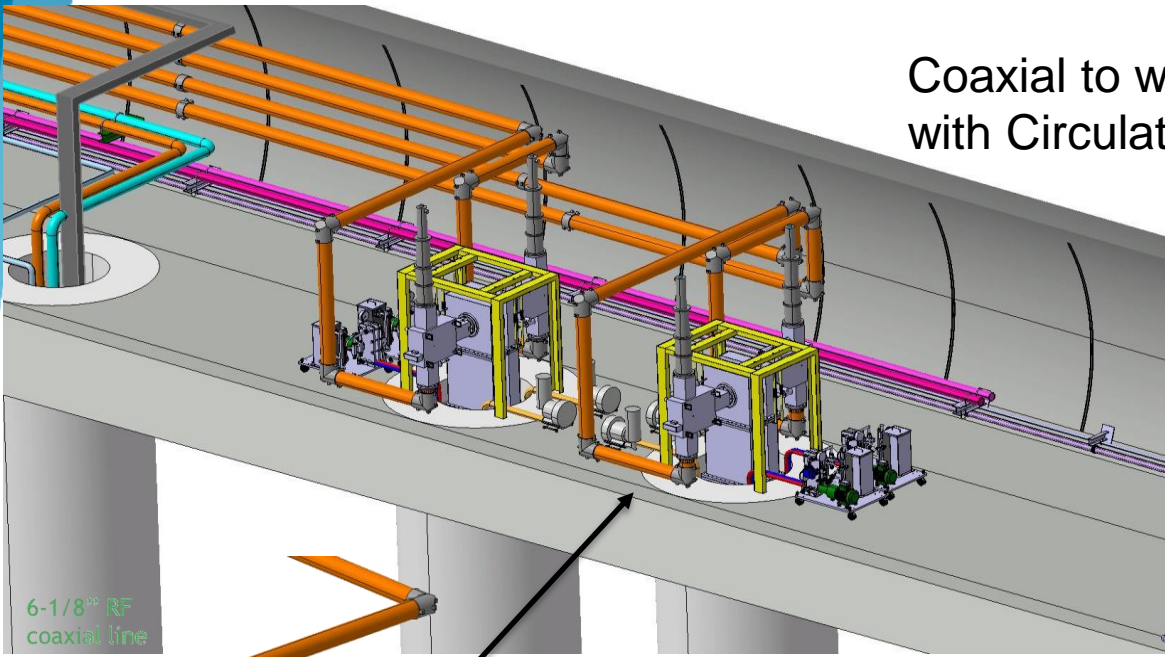
HPRF (RF Amplifiers & Coaxial Lines)



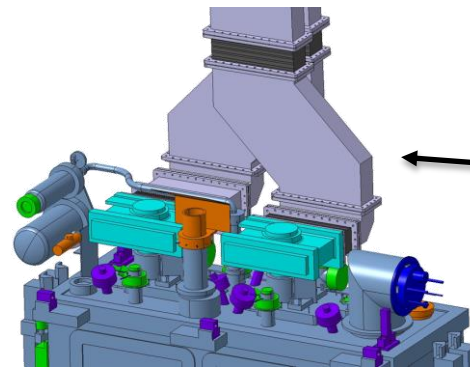
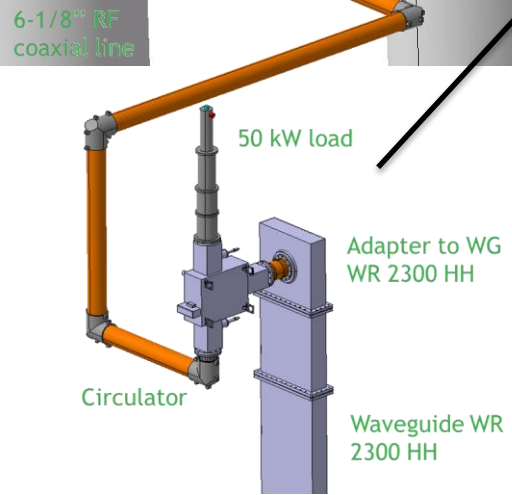
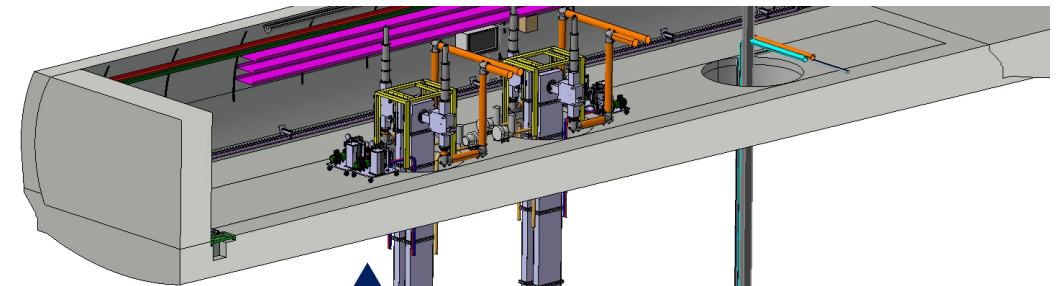
The cavities are powered by 4 amplifiers IOT 400MHz. One for each cavity.

HPRF & RF Lines Distribution

Coaxial to waveguide transitions
with Circulators & RF Loads



Waveguide connections to cavity in special cores



10.4m

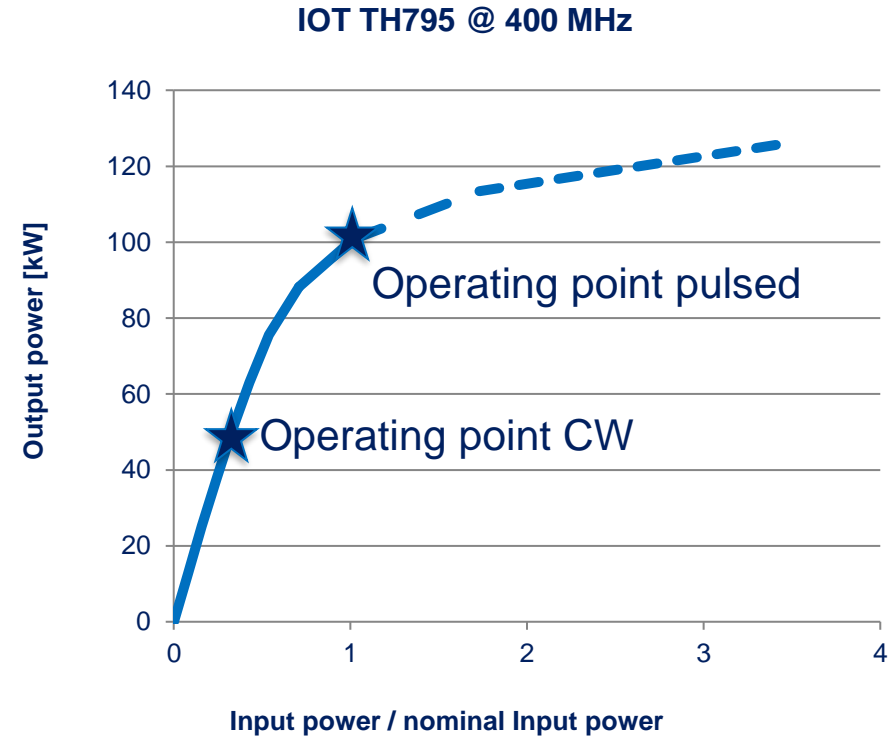
Why IOTs

A great advantage of gridded tubes is that they allow overdrive without damage

Tetrodes & Diacrodes are limited in frequency (max ~ 400 MHz)

IOT can operate from low (100 MHz) to high frequencies (1.3 GHz), including 400 MHz

The gain of an IOT is around 23 dB, so to reach 100 kW, an only 500 W driver is needed



Courtesy Eric Montesinos

IOT Experience at CERN

More than 10 years of operations in the SPS



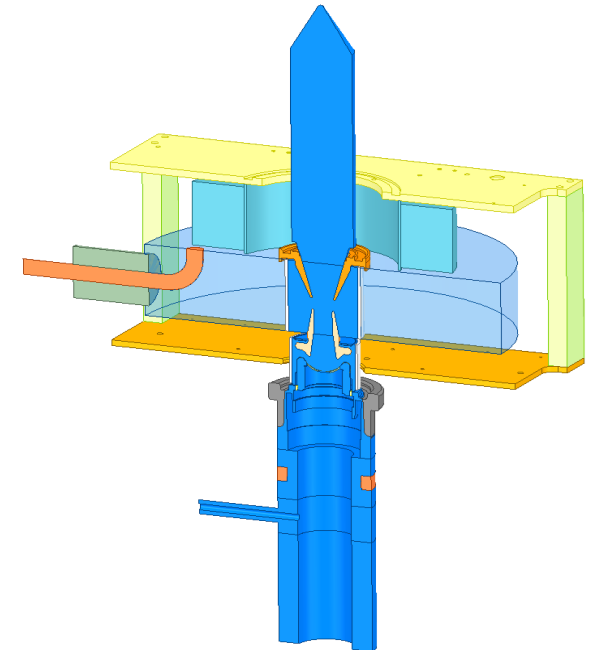
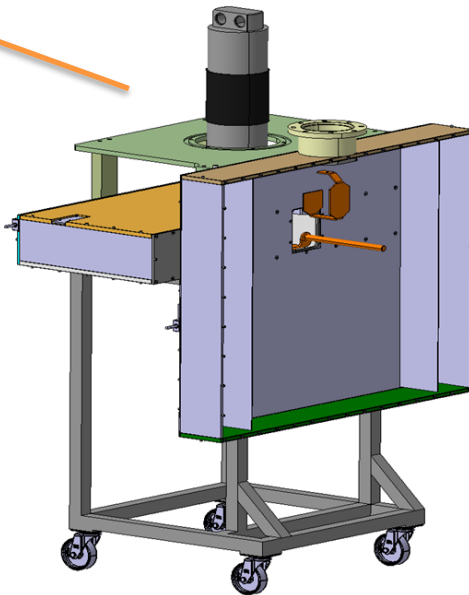
CERN SPS, TH 793 IOT, Trolley (single amplifier), and transmitter (combination of amplifiers)
Two transmitters of four tubes delivering 2 x 160 kW @ 801 MHz, into operation since 2014

Update from SPS-Crab tests



SPS IOTs modified to 400 MHz for crab cavity tests in the SPS in 2018

For the series, a simplified trolley is under feasibility study with THALES to change the 2-cavity output to a single cavity



Courtesy Thales

Estimated Budget (2024)

HPRF Amplifiers

Item	Type	Company	Total quantity	Unit price CHF	Total cost CHF
Transmitter		Thales	20	300,000	6,000,000
IOT - Tubes	TH795C	Thales	20	85,000	1,700,000
Trolley	TH18795	Thales	20	75,000	1,500,000
Total					9,200,000

Project scope: [EDMS 2874821](#)

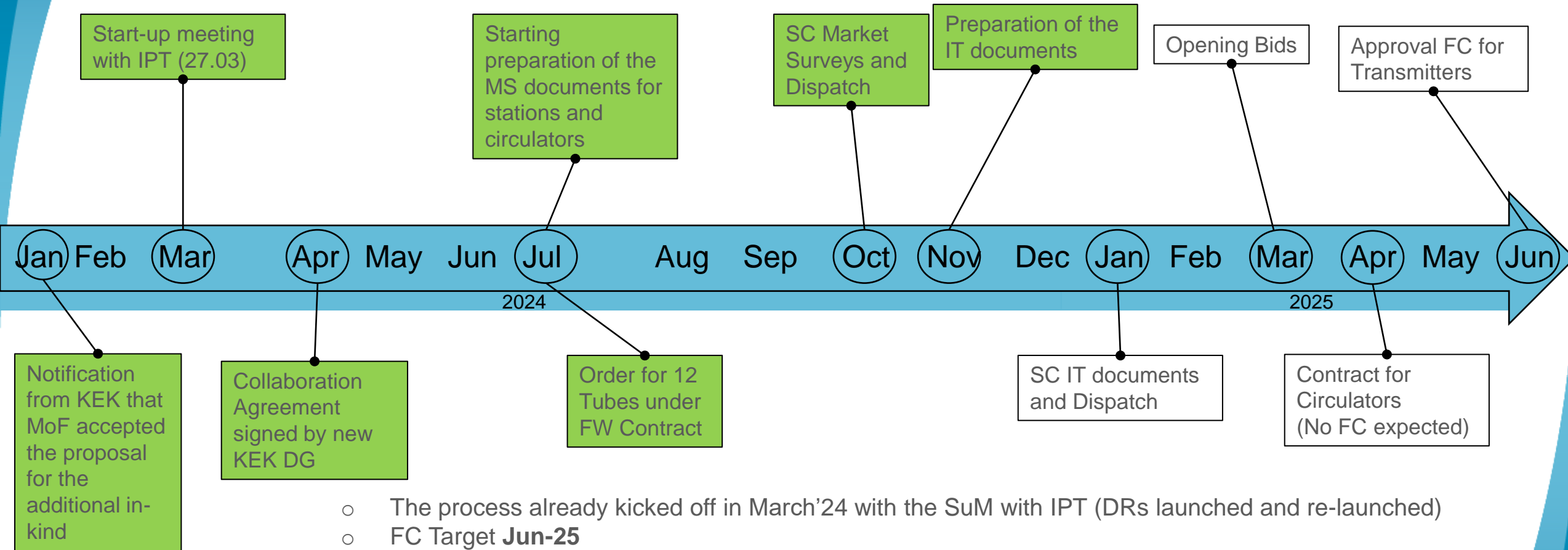
Collaboration agreement:
[KR5904 SYADD5 RFCC](#) signed
 2024

HPRF Lines

	Item	Company	Total quantity	Unit price CHF	Total cost CHF
6-1/8" Coaxial Line	Straight 5 meters	Rymosa	200	560	112,000
6-1/8" Coaxial Line	Elbow	Sira	100	700	70,000
6-1/8" Coaxial Line	Directional Coupler (FWD,REV)	CERN	18	1,000	18,000
6-1/8" + WR2300HH	Circulator	AFT	18	56,111	1,010,000
6-1/8"	Dummy load	AFT	18	21,667	390,000
WR2300HH	Flexible WG	CERN	54	5,650	305,100
WR2300HH	E-corner	CERN	36	5,000	180,000
WR2300HH	Straight 2 meters	CERN	72	4,500	324,000
WR2300HH	DC(FWD,REF)	CERN	18	1,950	35,100
WR2300HH	H&E corners	CERN	18	3,100	55,800
Total					2,500,000

**Total estimated Budget :
 11,700,000 CHF**

CERN Procurement Timeline



- The process already kicked off in March'24 with the SuM with IPT (DRs launched and re-launched)
- FC Target **Jun-25**
- No need for FC approval for circulators due to the new procurement thresholds

Procurement already started for other systems:

- [DAI-10275566](#) – 12 Tubes under existing FW Contract already purchased for the HL-LHC HPRF
- Extension of contract B1641 sent for approval to FC in September 24 – It includes HL needs
- Jobs under preparation for in-house production

Status today (Nov 24)

HPRF Station, IOT Based		
Transmitter	MS Dispatched	IT under preparation
Trolley	Extension of existing blanket Contract B1641	Approved FC Sep 24
IOT - Tubes	Extension of existing blanket Contract B1641	Approved FC Sep 24 Order already placed for 12 units

RF Lines	
6-1/8" Coaxial	Price enquiries under preparation
Circulators	Market Survey dispatched soon, Dec 24
Dummy load	Price enquiry under preparation
Wave guides WR2300HH	Done

Expenditure profile

As agreed, will be invoiced this year



Document	Description	FY2024	FY2025	FY2026	FY2027	Total
DR 10450082	WG WR2300	468	432			900
DR 10449709	Coaxial lines		200			200
DR 10433507	Circulators		250	525	235	1010
DR 10432515	Loads		28	260	102	390
DR 10432432	HPRF cubicles		1000	4300	700	6000
DR 10432536	IOTs & Trolleys	730	950	880	640	3200
Total		1198	2860	5965	1677	11700

Agreed with KEK colleagues

Budget Structuring & Procurement

Budget code	BC Name	Project	BAC [kCHF]	BAC per scope [kCHF]
69099	HL-LHC WP4-KEK RF power for CC – EXTREV	HL	7,360	9,200
69057	HL-LHC WP4-KEK RF power for CC – CONS – EXTREV	HL-C	1,840	
69058	HL-LHC WP04-LHC RF power distribution – EXTREV KEK	HL	2,000	2,500
69059	HL-LHC WP04-LHC RF power distribution – CONS – EXTREV KEK	HL-C	500	

Two dedicated sets of budget codes for procurement

Each main component structured with associated work units for EVM tracking and departmental requests for procurement

Table 1: HPRF station, IOT based - breakdown of costs

Item	Type	Company	Total quantity	Unit price CHF	Total cost CHF	DRs in EDH
Transmitter		Thales	20 (16 for installation + 4 spares)	300,000	6,000,000	DR1 https://edh.cern.ch/Document/SupplyChain/DepartmentRequest/10275584 DR value OK Budget Codes to be modified: 80% 69099; 20% 69057
IOT - Tubes	TH795C	Thales	20	85,000	1,700,000	DR2 https://edh.cern.ch/Document/SupplyChain/DepartmentRequest/10275586 The DR covers both tubes and trolleys – Single Source foreseen and actually procurement of IOTs already started (12 already purchased via https://edh.cern.ch/Document/SupplyChain/DAI/10275566) DR value to be modified to 3.2 MCHF Budget Codes to be modified: 80% 69099; 20% 69057
Trolley	TH18795	Thales	20 (16 for installation + 4 spares)	75,000	1,500,000	
Total					9,200,000	

Table 2: RF distribution lines - breakdown of costs (see Annex for detailed breakdown of parts)

	Item	Company	Total quantity	Unit price CHF	Total cost CHF	DRs in EDH
6-1/8" Coaxial Line	Straight 5 meters	Rymsa	200	560	112,000	DR3 https://edh.cern.ch/Document/SupplyChain/DepartmentRequest/10275589 DR value OK Budget Codes to be modified: 88% 69058; 12% 69059
6-1/8" Coaxial Line	Elbow	Sira	100	700	70,000	
6-1/8" Coaxial Line	Directional Coupler (FWD,REV)	CERN	18 (16 for installation + 2 spares)	1,000	18,000	DR4 https://edh.cern.ch/Document/SupplyChain/DepartmentRequest/10275588 DR value to be modified to 1,010,000 Budget Codes to be modified: 88% 69058; 12% 69059
6-1/8" + WR2300HH	Circulator	AFT	18 (16 for installation + 2 spares)	56,111	1,010,000	
6-1/8"	Dummy load	AFT	18 (16 for installation + 2 spares)	21,667	390,000	DR5 https://edh.cern.ch/Document/SupplyChain/DepartmentRequest/10275588 DR value to be modified to 390,000 Budget Codes to be modified: 88% 69058; 12% 69059
WR2300HH	Flexible WG	CERN	54	5,650	305,100	DR6 https://edh.cern.ch/Document/SupplyChain/DepartmentRequest/10275590 DR value to be modified to 900,000 Budget Codes to be modified: 88% 69058; 12% 69059
WR2300HH	E-corner	CERN	36	5,000	180,000	
WR2300HH	Straight 2 meters	CERN	72	4,500	324,000	
WR2300HH	DC (FWD,REF)	CERN	18	1,950	35,100	
WR2300HH	H&E corners	CERN	18	3,100	55,800	
Total					2,500,000	

Conclusion

- Very fruitful discussions and collaboration with KEK colleagues during 2023-24 to prepare project scope, exchange of technical details and effort to get project approval
- Significant progress accomplished in 2024 to rapidly launch the procurement process with 10% of the budget to be invoiced in 2024 as planned
- On track with HL-LHC deliverables for 2025-27



Thank you

