CERN AWAKE Facility Readiness for First Beam

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CERN, Geneva, Switzerland.

Acknowledgments: full AWAKE collaboration
CERN groups: BE-OP, MCS,

Outline

- ✓ Introduction
- ✓ History and present status
- ✓ Hardware commissioning
- ✓ Next steps and future outlooks

AWAKE Collaboration

First Kickoff meeting of the Advanced WAKefield Experiment (AWAKE) collaboration was held in June 2012 in Lisbon

First world wide proton driven plasma wakefield acceleration experiment

Institutes Committed to AWAKE

Budker Institute of Nuclear Physics, Novosibirk, Russia

CERN, Geneva, Switzerland

Cockroft Institute, Daresbury, UK

Heinrich Heine University, Düsseldorf, Germany

Instituto de Plasmas e Fusao Nuclear, IST, Lisboa, Portugal

Imperial College, London, UK

Ludwig Maximilian University, Munich, Germany

Max Planck Institute for Physics, Munich, Germany

Max Planck Institute for Plasma Physics, Greifswald, Germany

Rutherford Appleton Laboratory, Chilton, UK

University College London, London, UK

University of Strathclyde, Glasgow, Scotland, UK

DESY, Hamburg, Germany

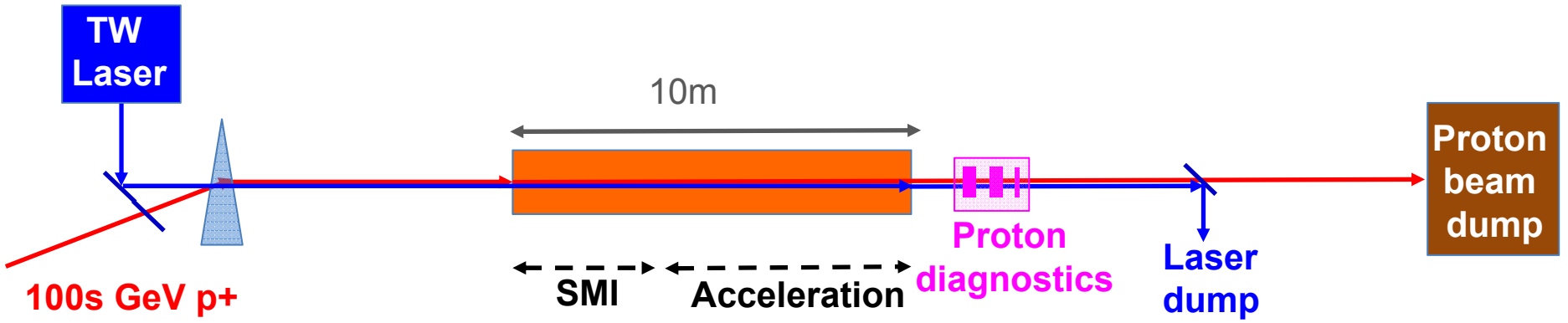
John Adams Institute for Accelerator Science, Oxford, UK

TRIUMF, Vancouver, Canada

Oslo, Norway

AWAKE Main Ingredients

Phase I



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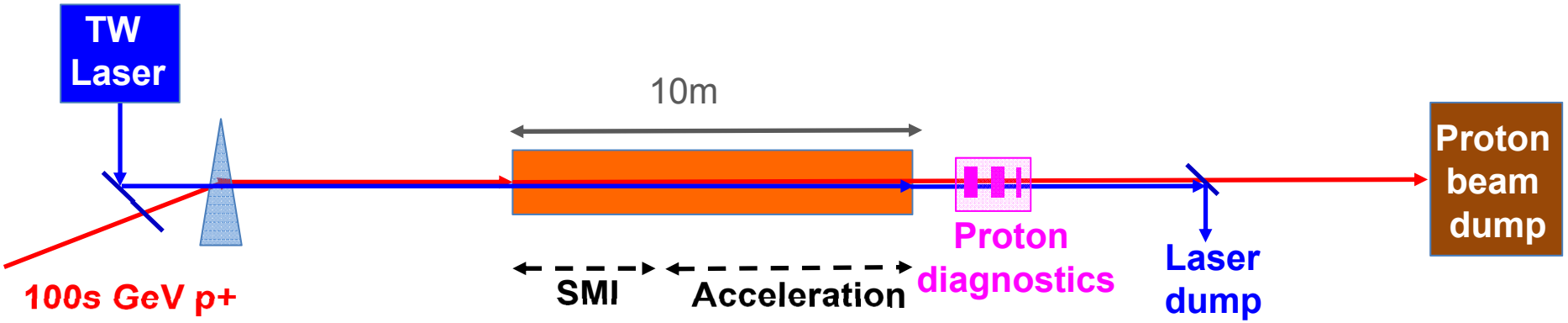
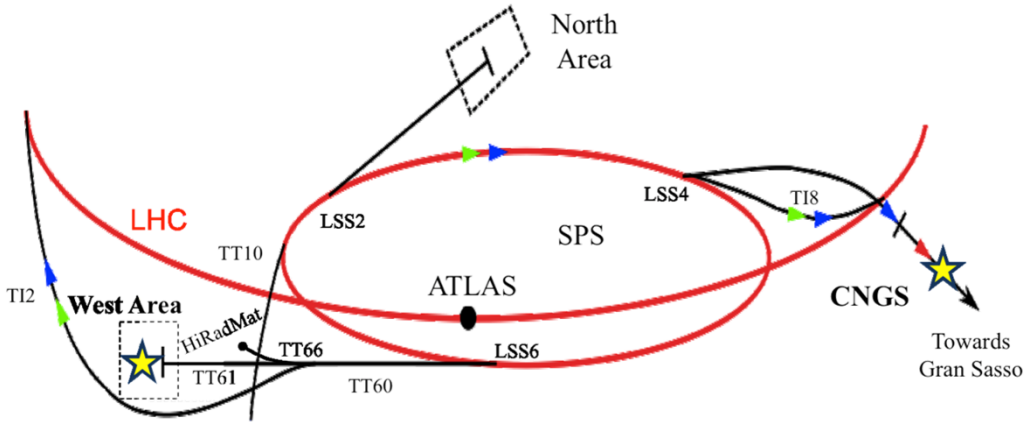




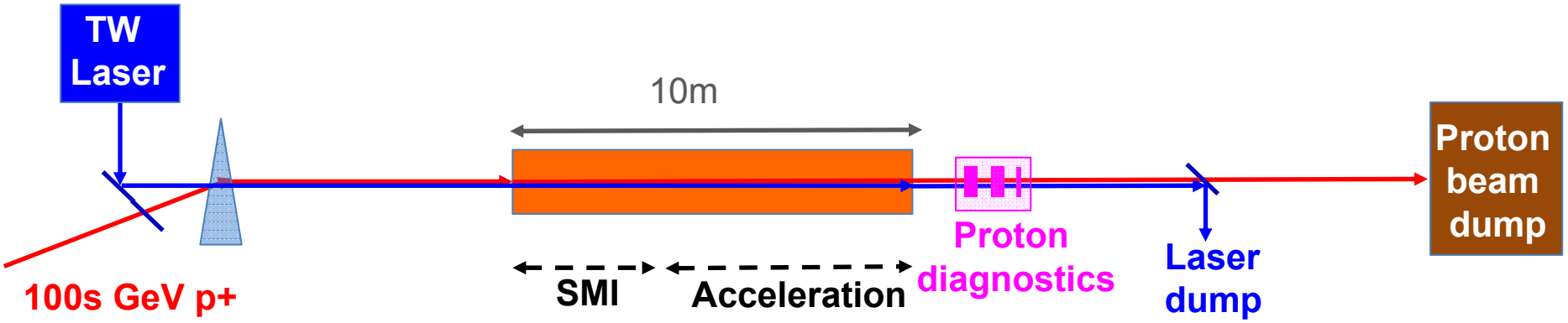
SPS p+ beam Characteristics	
# bunches	1
p+ per bunch	3e11
Repetition rate	0.03 Hz
r.m.s. norm. emittance	3.5 mm mrad
Bunch length	12 cm (0.4 ns)
Momentum	400 GeV/c
Momentum spread	0.035%

Condition to excite large amplitude wakefields: $\sigma_z \sim \lambda_p$ **(~1 mm)**

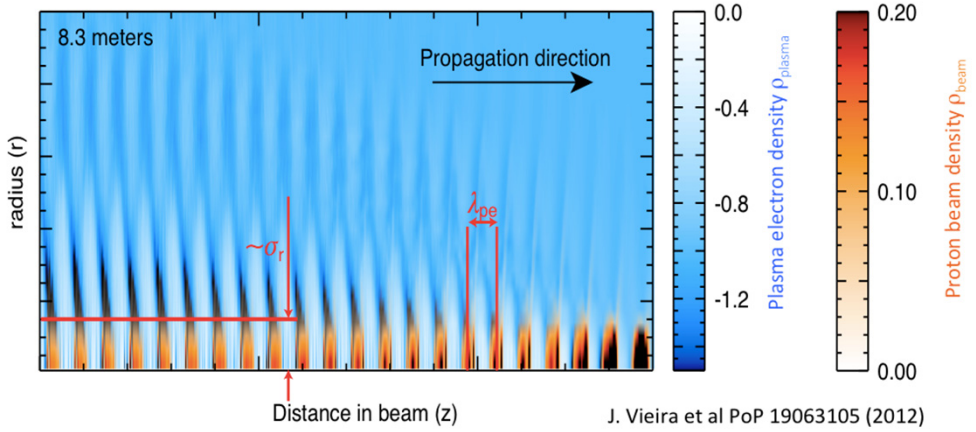
WEPMY019, P. Muggli

AWAKE Main Ingredients

Phase I



Self-Modulation Instability (SMI): When a long and narrow (transverse size ~200 μm) bunch of particles travels in a dense plasma is radially modulated in many ultra-short (~ λ) bunches



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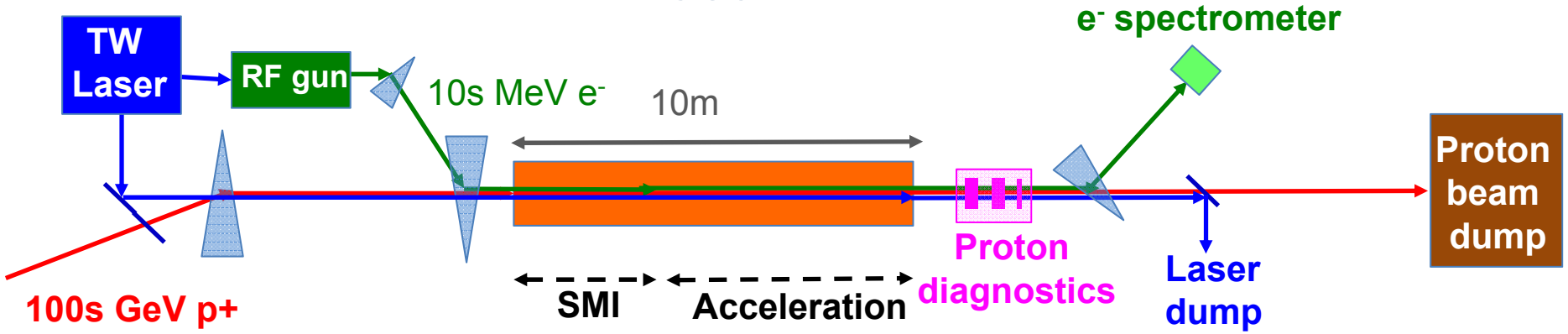
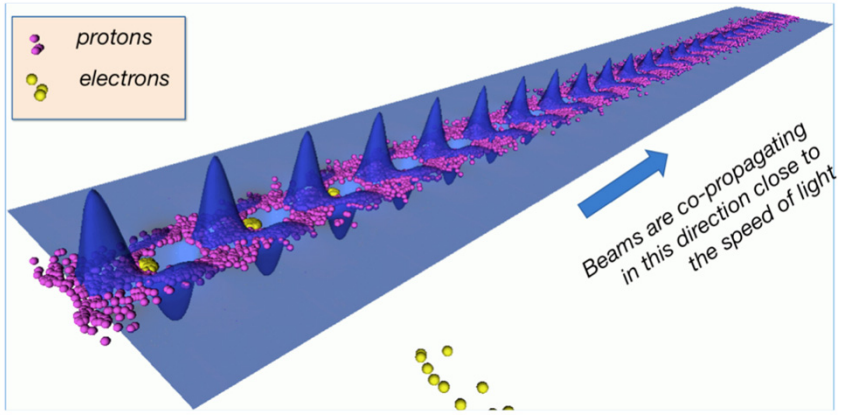
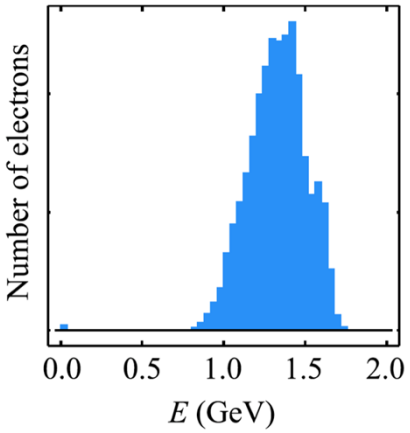
AWAKE Main Ingredients

Phase II







50% capture efficiency
Up to ~1 GeV e-
A few % energy spread

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AWAKE Approval

Feasibility and integration studies ➔ AWAKE in former CNGS facility

The AWAKE Facility at CERN
Technical Study, Design and Comparison between the AWAKE Facility at CNGS and at the West Area

Michele Battistin (EN-CV), Jeremie Bauche (TE-MSC), Marzia Bernardini (EN-MEF), Caterina Bertone (EN-HE), Luca Bottura (TE-MSC), Davide Bozzini (EN-EL), Chiara Bracco (TE-ABT), Andrew Butterworth (BE-RF), Reiner Denz (TE-MPE), Steffen Doebert (BE-RF), Valentin Fedosseev (EN-STI), Stephane Gabourin (TE-MPE), Brennan Goddard (TE-ABT), Silvia Grau (GS-ASE), Edda Gschwendtner (EN-MEF), Jean-Claude Guillaume (EN-EL), Jan Hansen (TE-VSC), Lars Jensen (BE-BI), Rhodri Jones (BE-BI), Andre Jorge Henriques (DGS-SEE), Verena Kain (BE-OP), Gilles Le Godec (TE-EPC), Thanasis Manousos (EN-STI), Christophe Martin (TE-MPE), Serge Mathot (EN-MME), Malika Meddahi (TE-ABT), Dominique Missiaen (BE-ABP), Richard Mompo (TE-MPE), Rui Nunes (GS-ASE), John Osborne (GS-SE), Ans Pardons (EN-MEF), Antonio Perillo Marcone (EN-STI), Alexey Petrenko (EN-MEF, Budker Institute), Bruno Puccio (TE-MPE), Ivan Romera Ramirez (TE-MPE), Frederic Savary (TE-MSC), Elena Shaposhnikova (BE-RF), Helga Timko (BE-RF), Francesco Maria Velotti (TE-ABT), Valentina Venturi (EN-STI), Helmut Vincke (DGS-RP), Vasilis Vlachoudis (EN-STI), Markus Zerlauth (TE-MPE); CERN Geneva Switzerland.

Submitted in March 2013

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APPROVED

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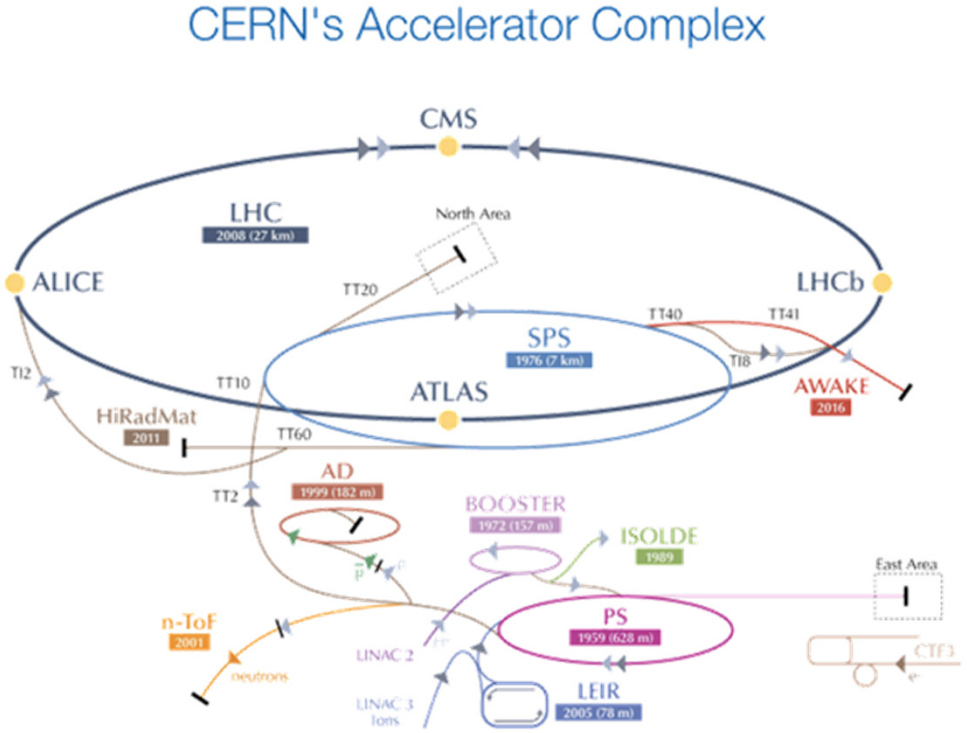
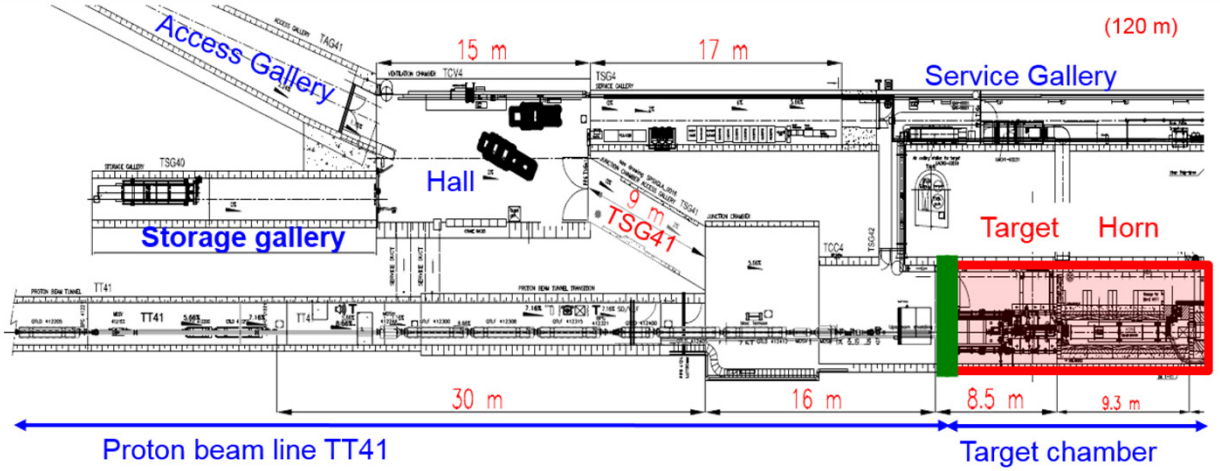
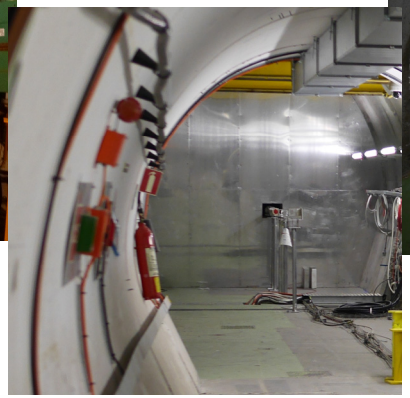


History and Present Status

CNGS layout



- ✓ Area cleaned from CNGS dismissed components (2014)
- ✓ Important decontamination works accomplished ➔ area was declassified from a limited stay (< 2 mSv/h) to a supervised radiation area (< 15 μSv/h) in Dec. 2015



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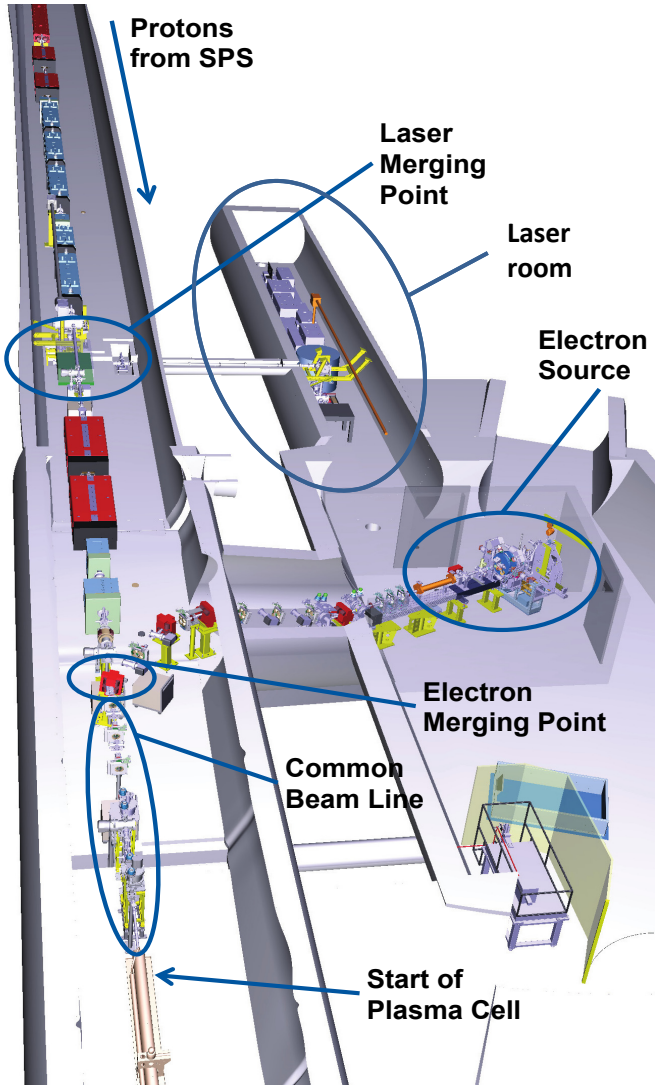
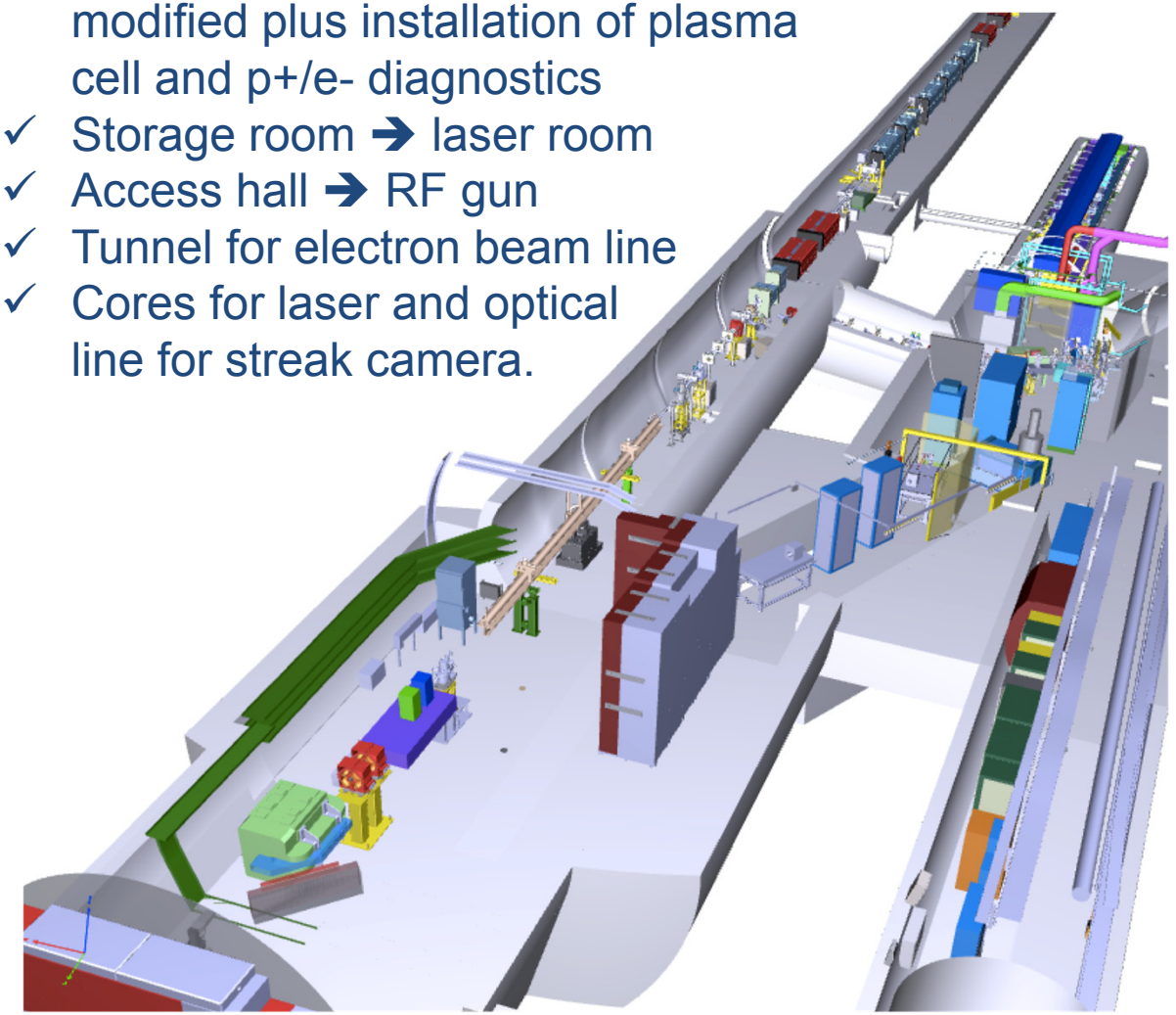


AWAKE layout

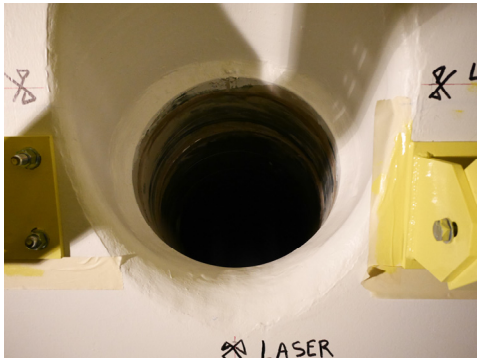
- ✓ Last 80 m proton beam line modified plus installation of plasma cell and p+/e- diagnostics
- ✓ Storage room ➔ laser room
- ✓ Access hall ➔ RF gun
- ✓ Tunnel for electron beam line
- ✓ Cores for laser and optical line for streak camera.



Civil Engineering Works

Main CE works were completed in summer 2014:

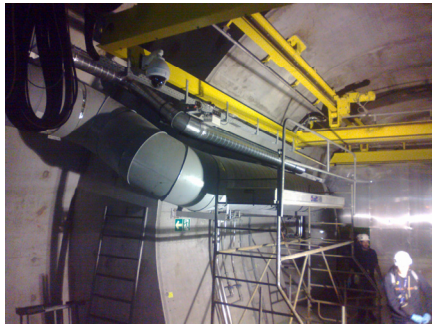
- ✓ Tunnel for e^- beam line
- ✓ Cores for laser beam and streak camera optical line



Services and Infrastructures

All services and infrastructures needed for 2016-2017 run ready in 2015:

- ✓ Cooling and ventilation
- ✓ Shielding
- ✓ Water and compressed air
- ✓ GSM
- ✓ Internets
- ✓ Cables (for powering and controls)
- ✓ Cable trays
- ✓ Racks



Access System and Fire Safety

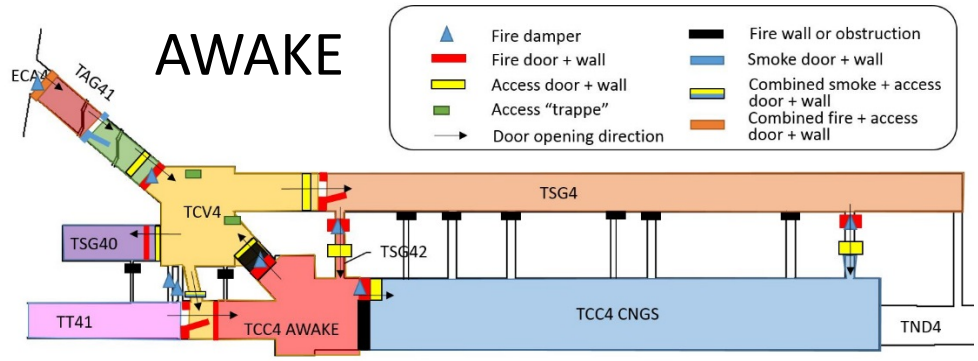
A complex access system is being put in place to insure safe access of personnel in the area:

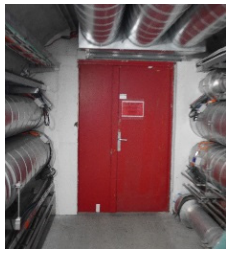
- ✓ Proton beam ON ➔ NO access
- ✓ Laser beam ON ➔ PARTIAL access
- ✓ Electron beam ON ➔ PARTIAL access

Fire safety aspects revised due to higher fuel dose wrt CNGS (racks, cables, klystron for RF gun), on-going installations works:

- ✓ 16 new fire doors and walls
- ✓ Modification of ventilation duct and new dumpers
- ✓ 20 additional dry-riser for fire water
- ✓ Additional coring for smoke extraction + trench for fire water tubes
- ✓ Additional smoke detection TAG41

Full system to be validated before first beam extraction in June 2016!

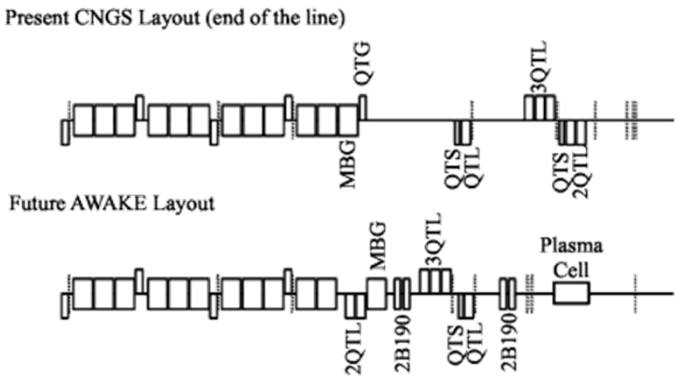


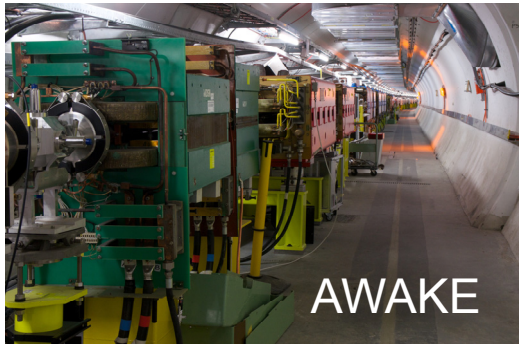


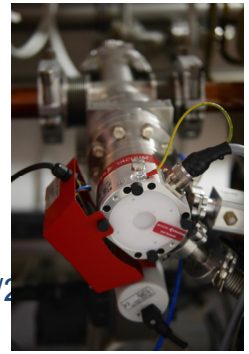
Proton Beam Line

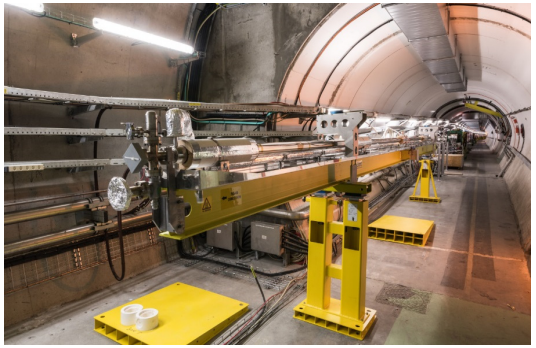
The last ~80 m of the proton beam line had to be modified to fulfill the new geometric and optics requirements.

- ✓ 16 magnets were refurbished and reinstalled.
- ✓ Beam diagnostics and all the related vacuum components installed
- ✓ Plasma cell installed (dummy ends in May)
- ✓ SMI diagnostics installation ongoing.

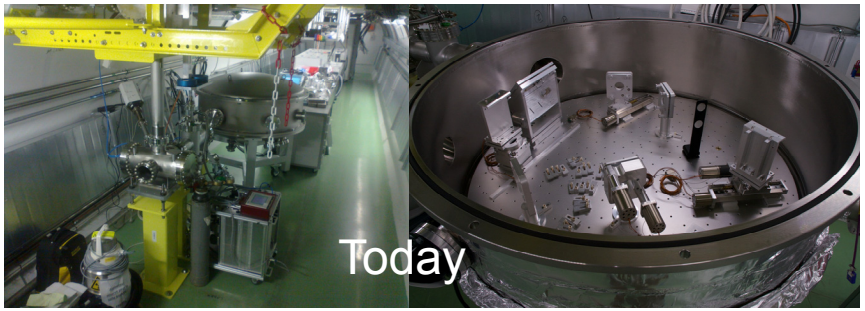


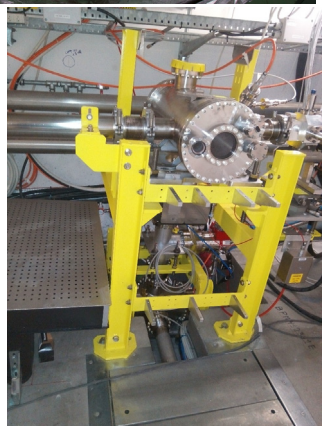


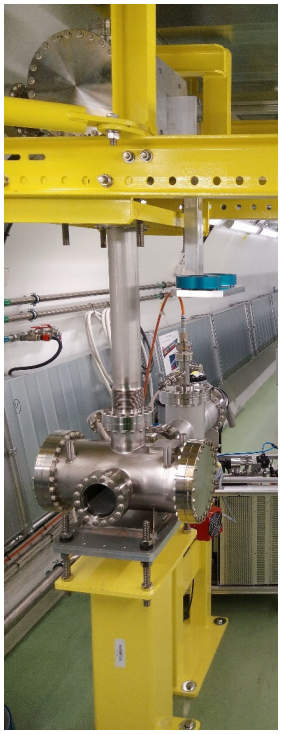


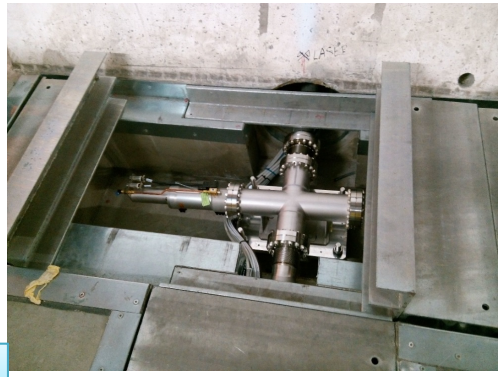


Laser Room and Laser Transport







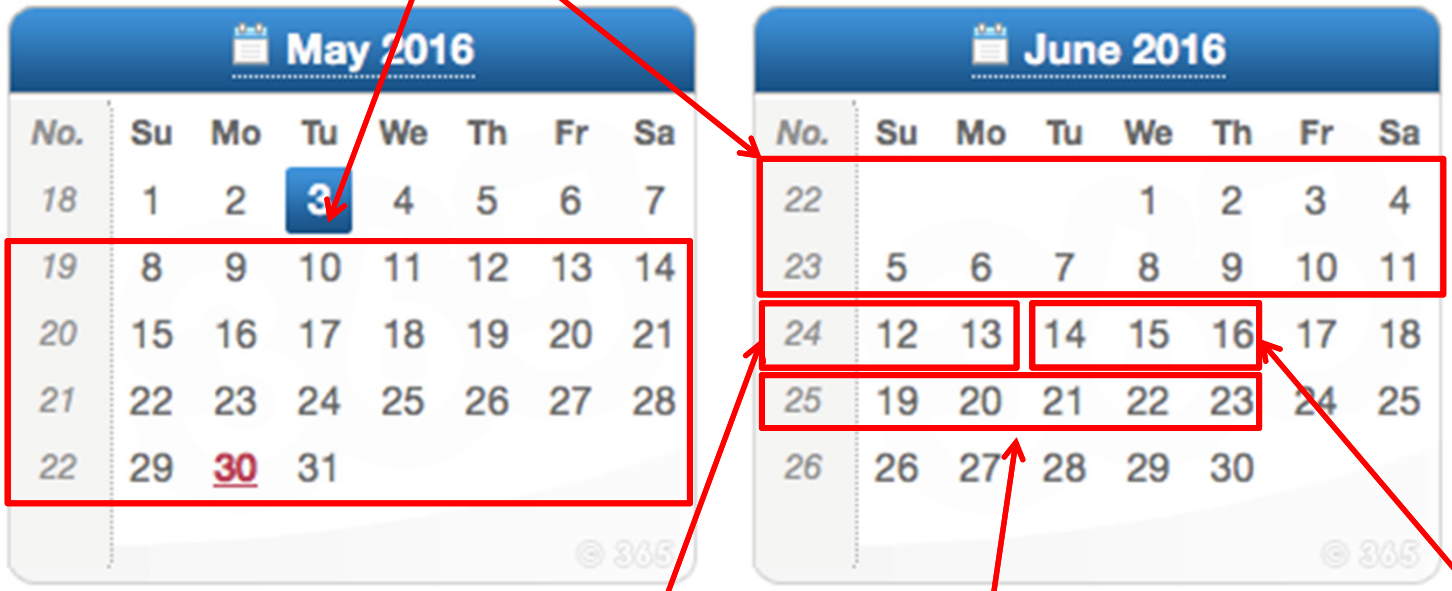


- ✓ Laser room ready
- ✓ Vacuum system for laser beam transport from laser room to laser-proton merging point completed (three laser mirror tanks, a vacuum laser beam shutter and a merging vessel)
- ✓ The installation of laser, compressor, beam transport optics, dumps and the diagnostics on-going

WEPMY020 V.N. Fedosseev

Schedule and Earliest Milestones

Five weeks for Hardware Commissioning (HWC) of the proton beam line



Formal test of full access system

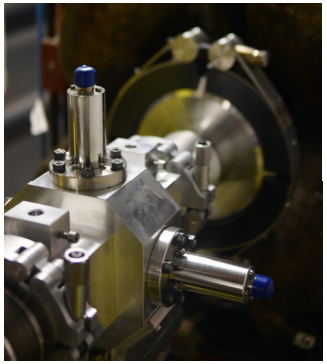
First proton beam to plasma cell

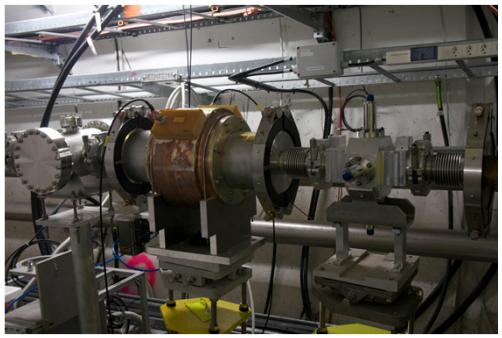
Dry run proton beam line

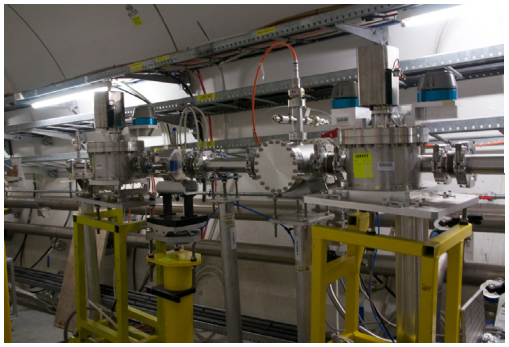
Hardware Commissioning 1/3

Beam diagnostics checks:

- ✓ BLM: connection checks
- ✓ BPM: new electronics compatible with single bunch operation installed in May/June 2016. Need to preform polarity checks and calibration (quantify and scale possible offsets)
- ✓ BCT: calibration (ADC signal -> number of charges)
- ✓ BTV:
  - Movement of actuators for screens, filters and mirrors.
  - Screen calibration: pixels-to-mm conversion.
  - Alignment of filters, final focusing mirrors and the time profile of the streak camera (timing signal to check the ps resolution of the streak camera).







Hardware Commissioning 2/3

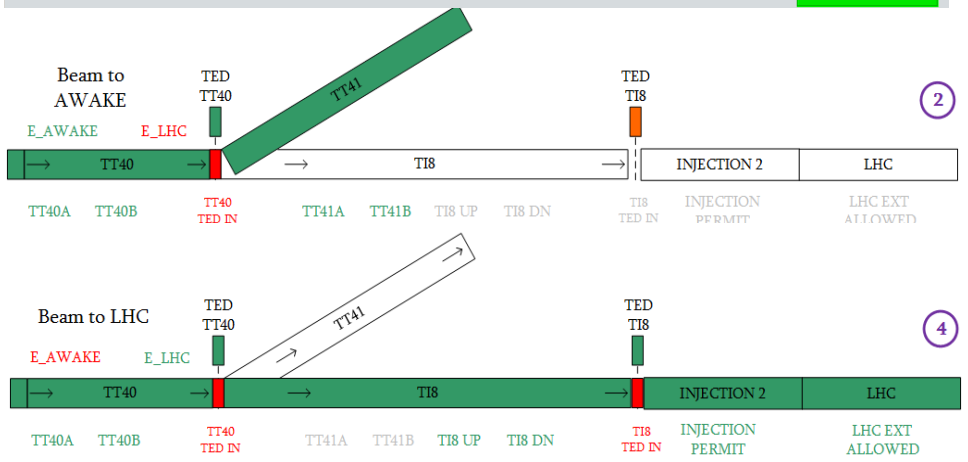
Beam Interlock System:

Unmaskable channels: position of vacuum valves, laser dump and proton beam stoppers plus Warm Interlock Magnets (WIC, survey magnet overheating)

Maskable channels: current surveillance of the TT41 magnets and Fast Magnet Current Change Monitor (FMCM)

Diagnostics (BLM and BPM) connected to Software Interlock System (SIS)

AWAKE and LHC beams share the same SPS extraction point and the initial part of the transfer line. The extraction towards the right destination (either LHC or AWAKE) has to be verified.



Hardware Commissioning 3/3

	Magnet name	Magnet Interlock cable id.	Power Converter name	PC interlock cable id.	PC IST	DC cable connection (magnet side)	Water check (leaks??)	Nominal R (Ω)	Measured R (Ω)	Checked R to ground at 1 kV (Ω)	ELQA OK/Not OK	WIC-magnet interlock test	WIC-PC interlock test	PC-circuit connection	PS setup 10% Inom	Polarity Test >50% Inom	Heat Run Inom of the magnet	Performance test (for each circuit difference wrt reference, peak-to-peak noise)	I min op	I nominal op	Released for OP
Responsibles		G. Gros, R. Mompo	G. Le Godec, C. Mutin	C. Mutin	C. Mutin	J. Bauche	J. Bauche	J. Bauche	J. Bauche	J. Bauche	J. Bauche	R. Mompo	R. Mompo, C. Mutin	C. Mutin, G. Le Godec	C. Mutin, G. Le Godec	J. Bauche, CCC	J. Bauche, CCC	C. Mutin, G. Le Godec	CCC	CCC	
			RBI.410010	3404612																	
			RQD.410100	3404614																	
			RQF.410200	3404615																	
			RQD.410300	3404616																	
			RQF.410400	3404617																	
			RQD.411700	3404618																	
			RQF.411800	3404619																	
			RQD.411900	3404620																	
	QTGF.412000	3404741	RQF.412000	3404621																	
	MBG.412008	3404742	RBI.410147	3404613																	
	MBG.412022	3404743																			
	MBG.412115	3406607																			
	QTLD.412100	3404745	RQD.412100	3404623																	
	QTLD.412108	3406606																			
	MBHFD.412133	3406608	RBH.412133	3404622																	
	MBHFD.412141	3404746																			
	MDSH.412147	3404747	RBH.412147	3404627																	
	QTLF.412200	3404748	RQF.412200	3404624																	
	QTLF.412208	3404749																			
	QTLF.412215	3404750																			
	MDSV.412223	3404751	RBV.412223	3404626																	
	QTSD.412300	3404752	RQD.412300	3404625																	
	QTLD.412305	3404753																			
	MBHFD.412324	3404754	RBH.412324	3406612																	
	MBHFD.412330	3404755																			
	MDSV.412335	3404756	RBV.412335	3404628																	
	MDSH.412338	3404757	RBH.412338	3404629																	
	MQWBR.412432	3406609	RQM.412432	3406613																	
	MQWBR.412433	3406610																			
	MBXFB.412435	3406611	RBN.412435	3406614																	

A well established sequence of tests and acceptance criteria defined for HWC of p+ beam magnets. Required conditions before and during checks, correct sequence, detailed procedures and list of circuit to be tested ready.

What is this power converter "B4-R34XS INTERL. POWER CONV." found in Gesmar ?

Magnets which were displaced	Changed connections
New magnets	New PC
Secondary beam line magnets (installed in 2017)	PC for secondary beam line

Commissioning 3/3

MBG.412115	3406607		
QTLD.412100	3404745	RQID.412100	3404623
QTLD.412108	3406606		
MBHFD.412133	3406608	RBIH.412133	3404622
MBHFD.412141	3404746		
MDSH.412147	3404747	RBIH.412147	3404627
QTLF.412200	3404748	RQIF.412200	3404624
QTLF.412208	3404749		
QTLF.412215	3404750		
MDSV.412223	3404751	RBIV.412223	3404626
QTSD.412300	3404752	RQID.412300	3404625
QTLD.412305	3404753		
MBHFD.412324	3404754	RBIH.412324	3406612
MBHFD.412330	3404755		
MDSV.412335	3404756	RBIV.412335	3404628
MDSH.412338	3404757	RBIH.412338	3404629
MQNBR.412432	*3406609*	*RQNI.412432*	*3406613*
MQNBR.412433	*3406610*		
MBXFB.412435	*3406611*	*BBIH.412435*	*3406614*

Nominal R (Ω)	Measured R (Ω)	Checked R to ground at 1 kV (Ω)	ELQA OK/Not OK	WIC-magnet interlock test	WIC-PC interlock test	PC-circuit connection	PS setup 10% Inom	Polarity Test >50% Inom	Heat Run Inom of the magnet	Performance test (for each circuit difference wrt reference, peak-to-peak noise)	I min op	I nominal op	Released for OP
. Bauche	J. Bauche	J. Bauche	J. Bauche	R. Mompo	R. Mompo, C. Mutin	C. Mutin, G. Le Godec	C. Mutin, G. Le Godec	J. Bauche, CCC	J. Bauche, CCC	C. Mutin, G. Le Godec	CCC	CCC	

A well established sequence of tests and acceptance criteria defined for HWC of p+ beam magnets. Required conditions before and during checks, correct sequence, detailed procedures and list of circuit to be tested ready.

Magnets which were displaced

New magnets

Secondary beam line magnets (installed in 2017)

Changed connections

New PC

PC for secondary beam line

Hardware Commissioning 3/3

Magnets all PC disconnected

During Yets upstream part

Magnet name	Magnet Interlock cable id.	Power Converter name	PC interlock cable id.	PC IST	DC cable connection (magnet side)	Water check (leaks??)	Nominal R (Ω)	Measured R (Ω)	Checked R to ground at 1 kV (Ω)	ELQA OK/Not OK	WIC-magnet interlock test

Connect DC cales

value

value

value

WIC-PC interlock test	PC-circuit connection	PS setup 10% Inom	Polarity Test >50% Inom	Heat Run Inom of the magnet	Performance test (for each circuit difference wrt reference, peak-to-peak noise)	I min op	I nominal op	Released for OP

QTGF.412000	3404741	RQF.412000	3404621
MBG.412008	3404742	RBI.410147	3404613
MBG.412022	3404743		
MBG.412115	3406607		
QTLD.412100	3404745	RQD.412100	3404623
QTLD.412108	3406606		
MBHFD.412133	3406608	RBH.412133	3404622
MBHFD.412141	3404746		
MDSH.412147	3404747	RBH.412147	3404627
QTLF.412200	3404748	RQF.412200	3404624
QTLF.412208	3404749		
QTLF.412215	3404750		
MDSV.412223	3404751	RBV.412223	3404626
QTSD.412300	3404752	RQD.412300	3404625
QTLD.412305	3404753		
MBHFD.412324	3404754	RBH.412324	3406612
MBHFD.412330	3404755		
MDSV.412335	3404756	RBV.412335	3404628
MDSH.412338	3404757	RBH.412338	3404629
MQNBR.412432	3406609	RQM.412432	3406613
MQNBR.412433	3406610		
MBXFB.412435	3406611	RBH.412435	3406614

A well established sequence of tests and acceptance criteria defined for HWC of p+ beam magnets. Required conditions before and during checks, correct sequence, detailed procedures and list of circuit to be tested ready.

What is this power converter "B4-R34XS INTERL. POWER CONV." found in Gesmar ?

- Magnets which were displaced
- New magnets
- Secondary beam line magnets (installed in 2017)
- Changed connections
- New PC
- PC for secondary beam line

End of HWC ➔ Dry Run

- ✓ Magnet heat run test to be performed during SPS Technical Stop (TS, week 23) ➔ last step of HWC
- ✓ Dry run: final and global check of all systems, functionalities and the related controls. To be checked:
  - ✓ GUI functionalities for measurements and beam/equipment controls
  - ✓ Correct data acquisition and logging in DB
  - ✓ Interlock logic with realistic thresholds
  - ✓ Correct triggering of diagnostics with SPS timing
  - ✓ Correct triggering of magnet pulsing at operational current with SPS timing
- ✓ First beam extraction to the end of the AWAKE transfer line at the end of June 2016.*
- ✓ Proton beam commissioning and operation interleaved with installation work.

*TUPMR052 J.S. Schmidt

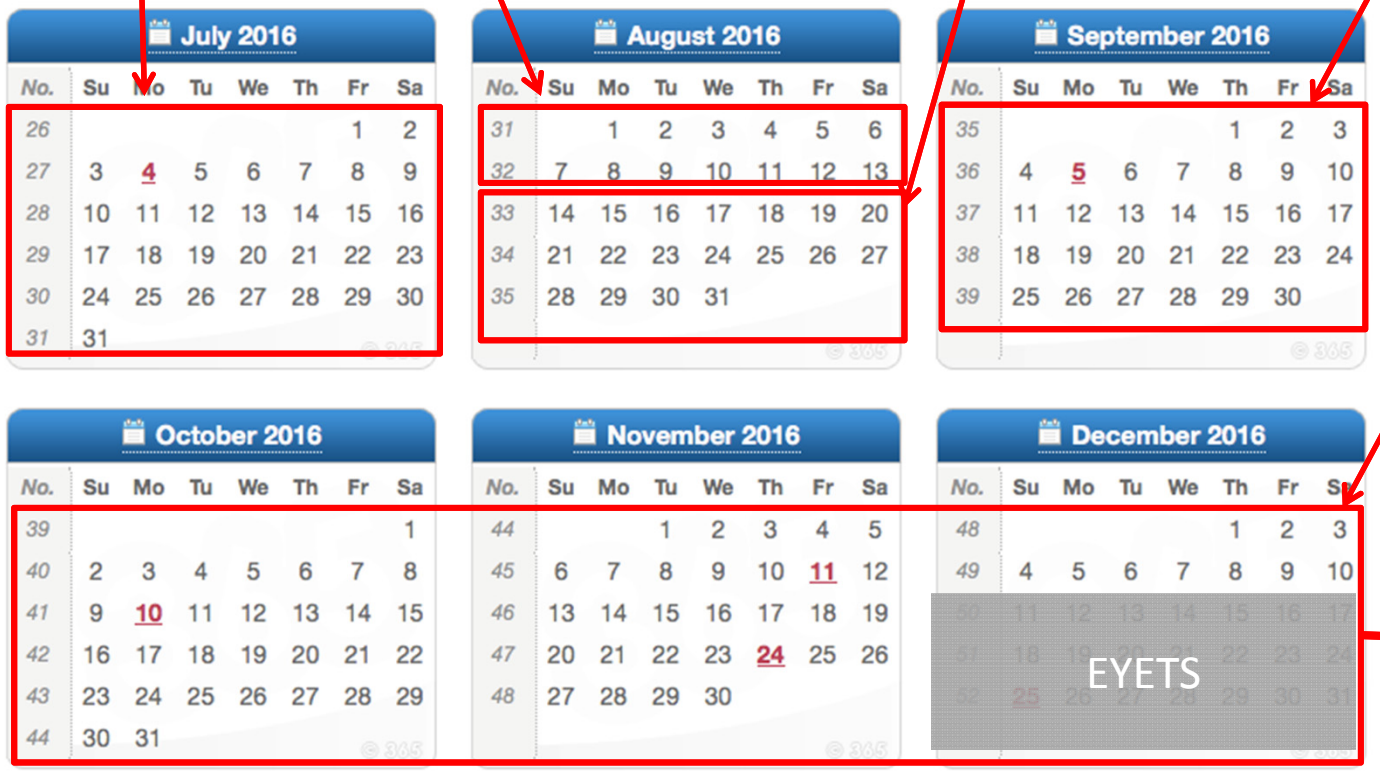
Next Steps & Future Outlooks

Complete laser and SMI diagnostics installation

HW for laser-SPS RF synchronization installed and operational*

Laser commissioning

Complete plasma cell installation



Plasma cell commissioning and Phase I proton Physics**

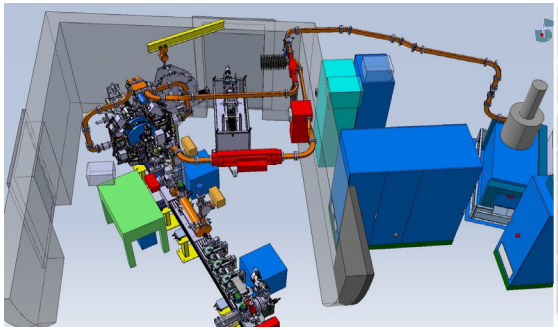
2017

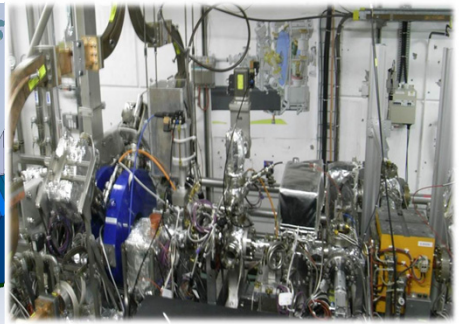
*THPMY039 H. Damerau

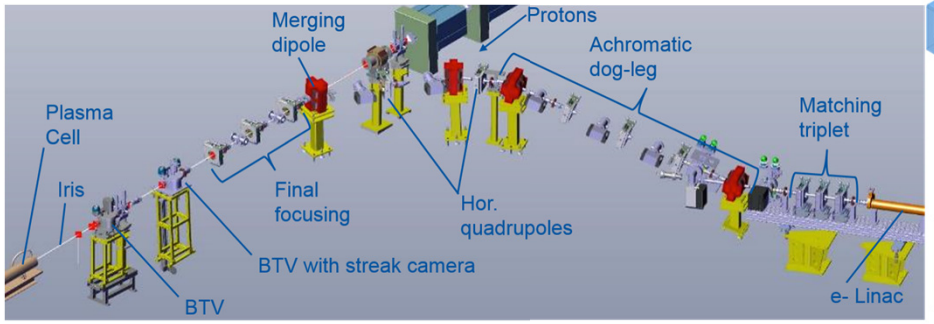
Next Steps & Future Outlooks

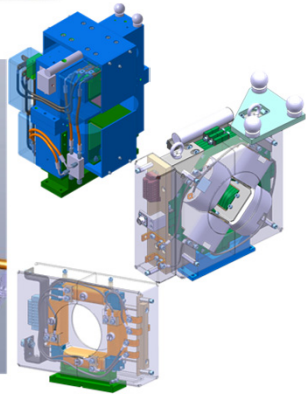
2017 installation works:

- ✓ RF gun and klystron (CTF3) + accelerating booster*
- ✓ Electron beam line
- ✓ Electron spectrometer**, quadrupoles and optical line









*THPMB056 O. Mete Apsimon
MOPMR039 O. Mete Apsimon
**WEPMY024 L. Deacon

2018: Phase II physics

WEPMY021 A. Petrenko

2021: Phase III

WEPMY008 E. Adli

THANK YOU FOR YOUR ATTENTION