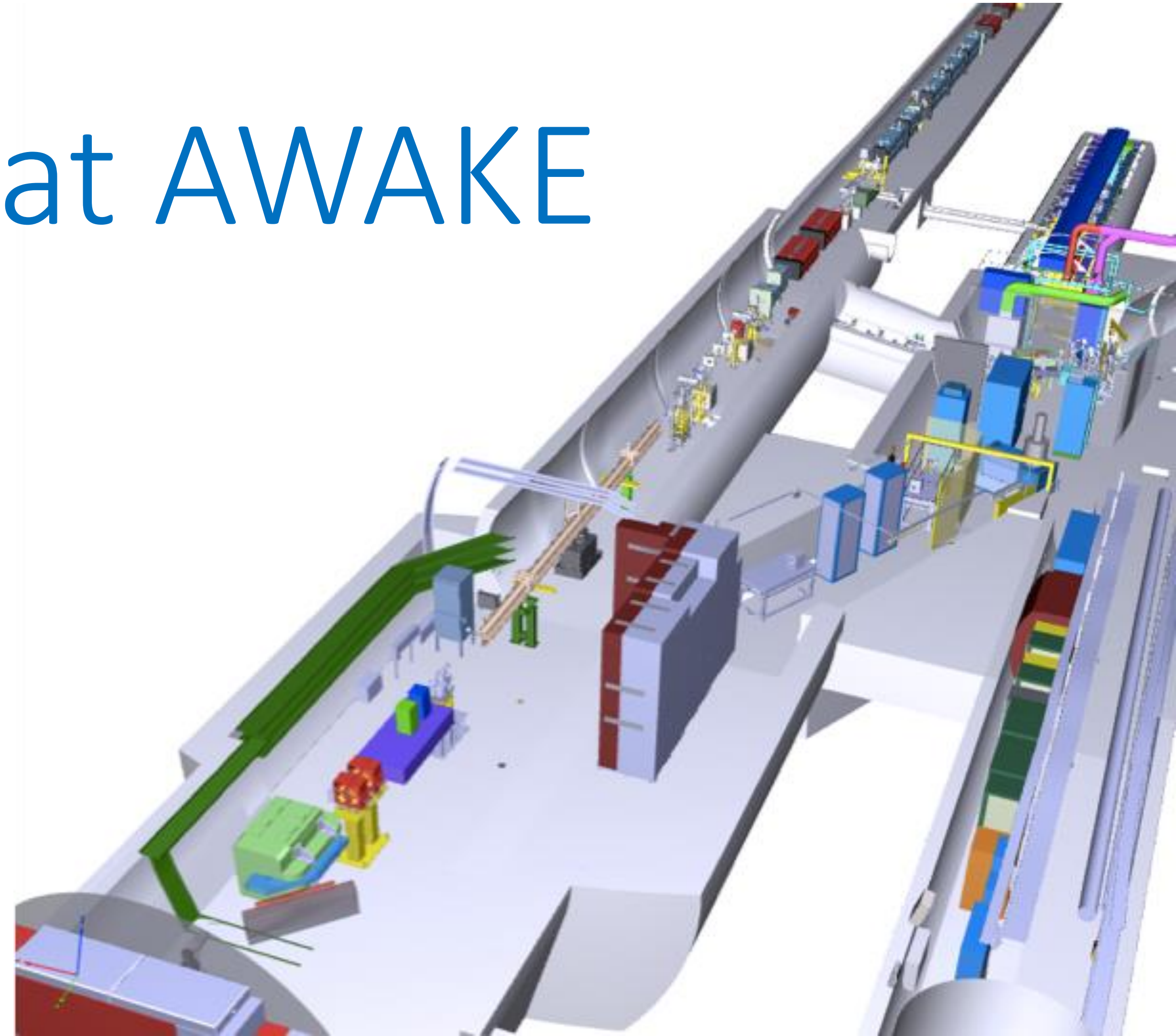
Beam Diagnostics at AWAKE

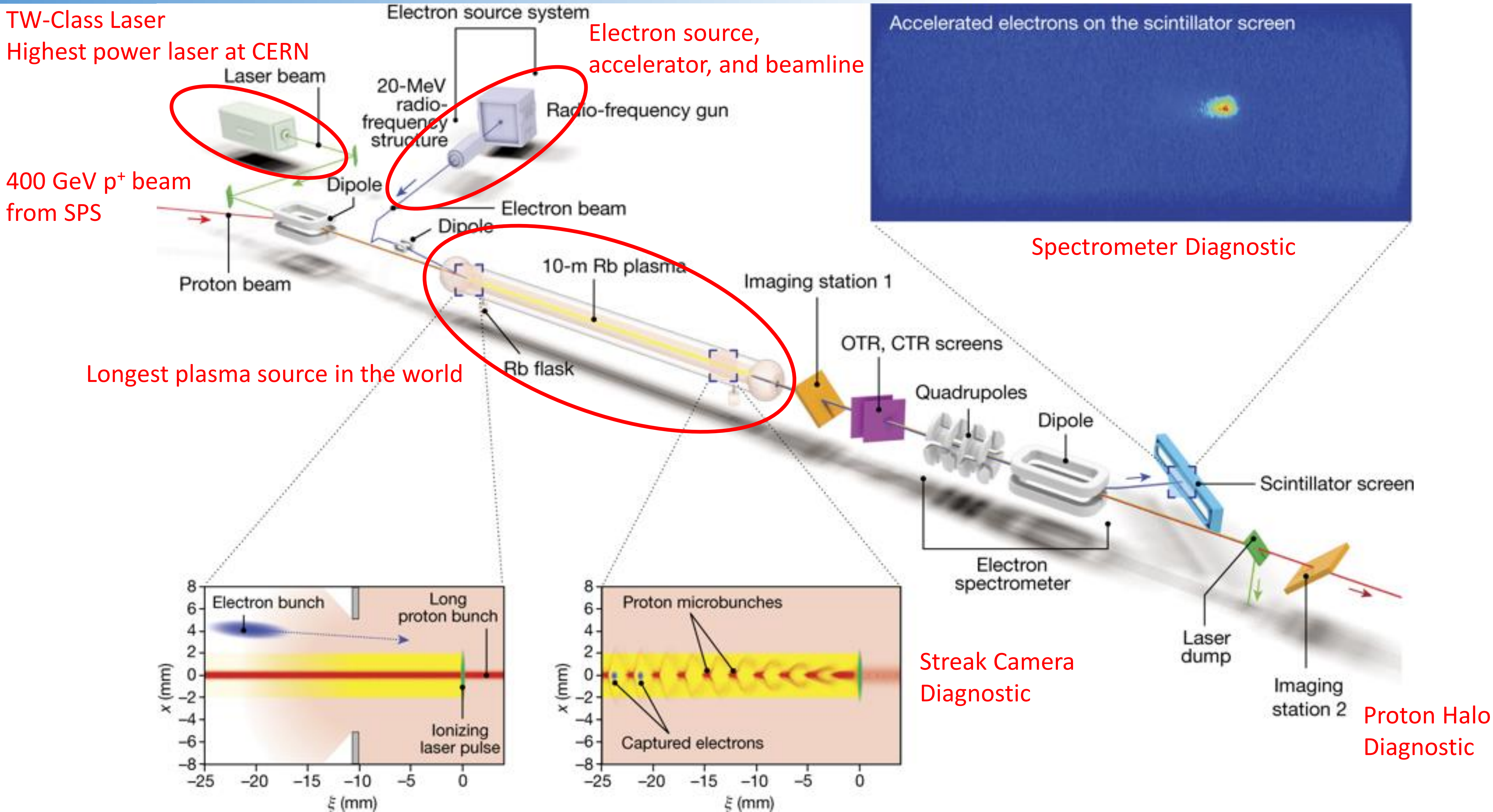


Spencer Gessner
AWAKE Instrumentation Meeting
27 September, 2018

Outline

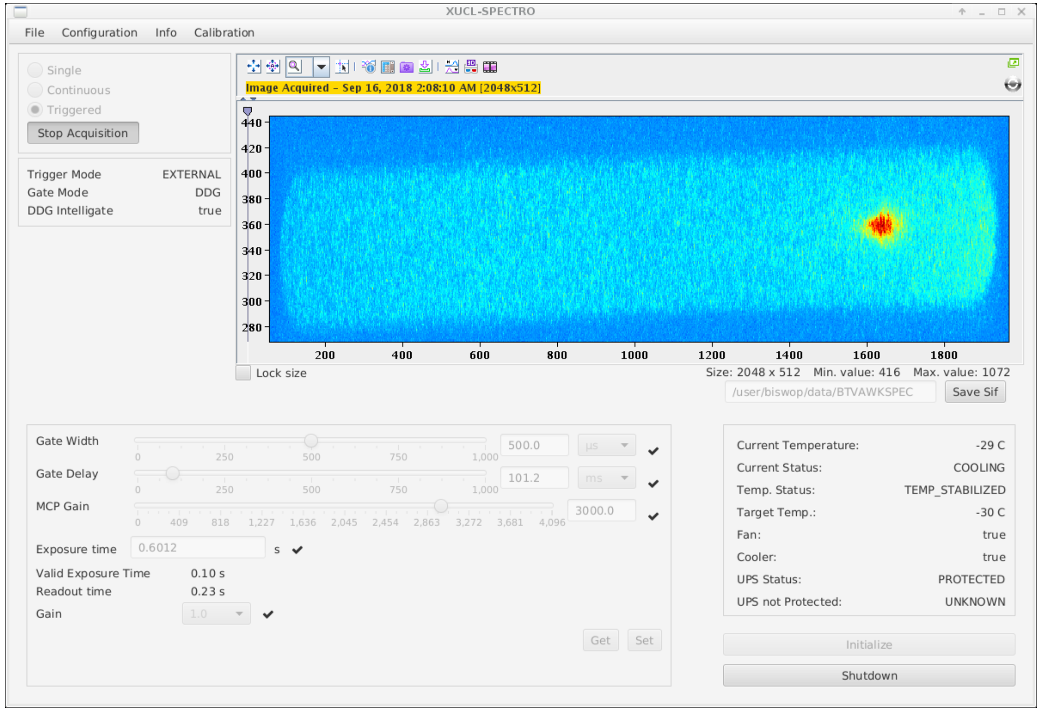
1. Overview and highlights from AWAKE
2. Summary of AWAKE Beam Instrumentation
3. Issues during AWAKE Run1

AWAKE Overview



Spectrometer Camera Diagnostic

F. Keeble, J. Chappell, D. Cooke, M. Wing, UCL
I. Gorgisyan, S. Mazzoni, D. Medina, BI

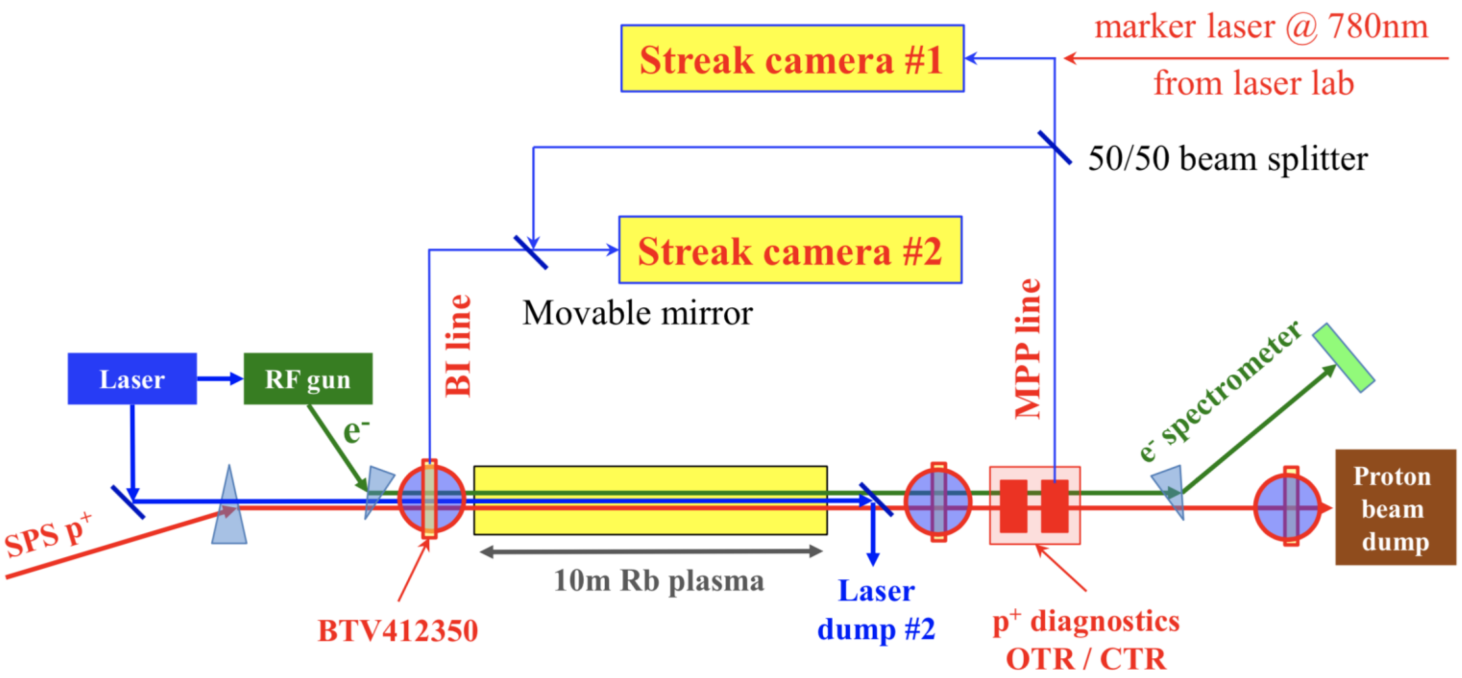


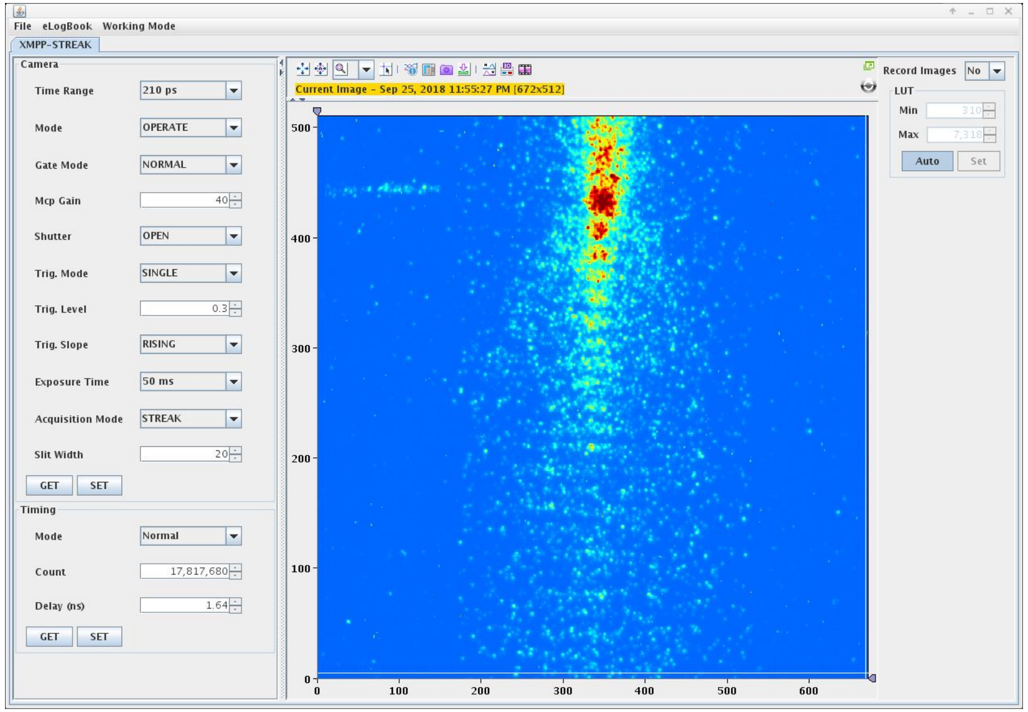
- This is an extremely important diagnostic for AWAKE.
- Also an extremely complicated diagnostic:
  - Scintillating screen
  - Massive optical system
  - Calibration system
  - Dark room
  - Spectrometer camera
  - FESA Class

We have achieved a level of reliability with this diagnostic thanks to the dedicated efforts of the UCL and CERN BI groups.

Streak Camera Diagnostic

M. Martyanov, K. Rieger, F. Batsch, P. Muggli, MPP
I. Gorgisyan, S. Mazzoni, D. Medina, BI



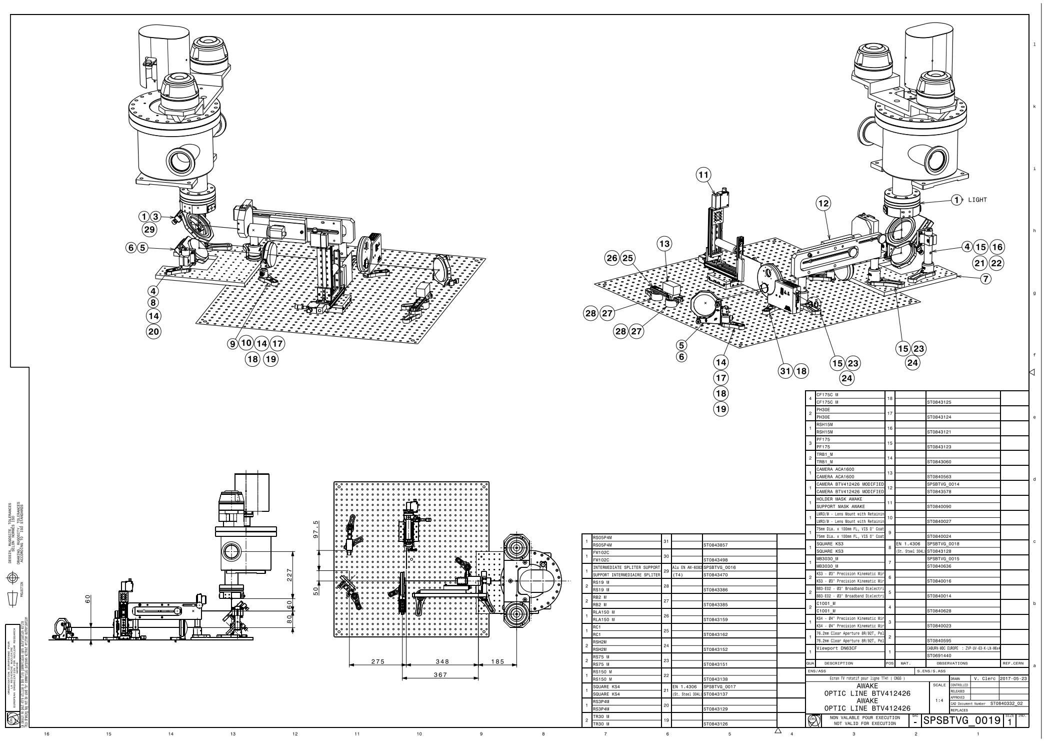


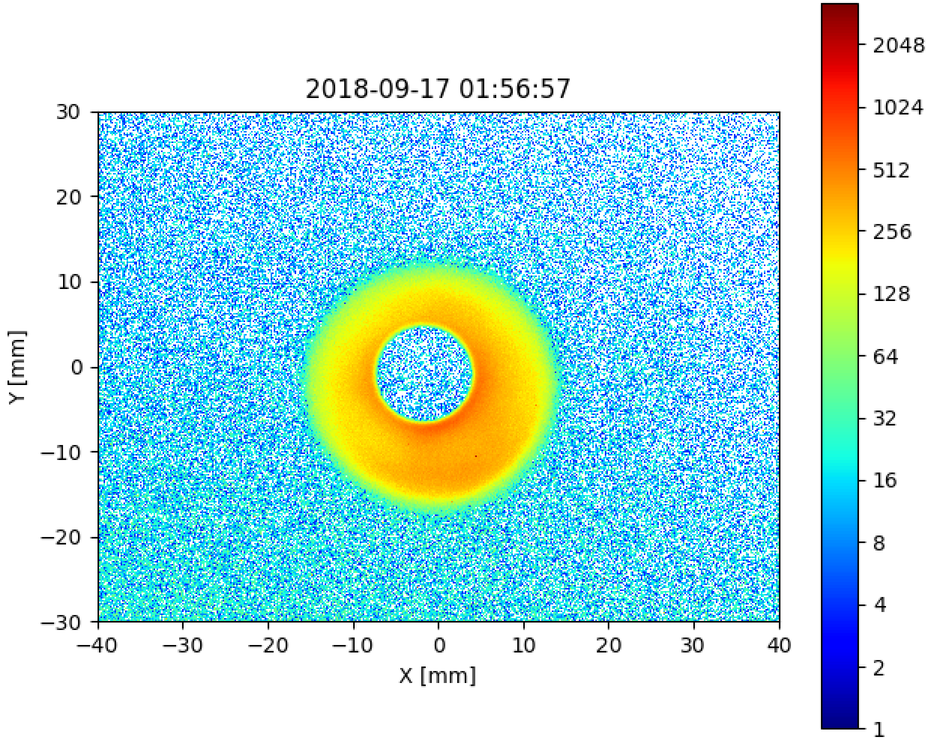
- This an extremely important diagnostic for AWAKE.
- Also an extremely complicated diagnostic:
  - OTR screens
  - Transport optics
  - Marker laser
  - Dark room
  - Streak Camera
  - RemoteEx connection
  - FESA Class

This diagnostic works well because of a strong initial effort from CERN BI and a continuous effort to improve the device by the MPP group.

Halo Camera Diagnostic

M. Turner, EN-EA
I. Gorgisyan, S. Mazzoni, BI

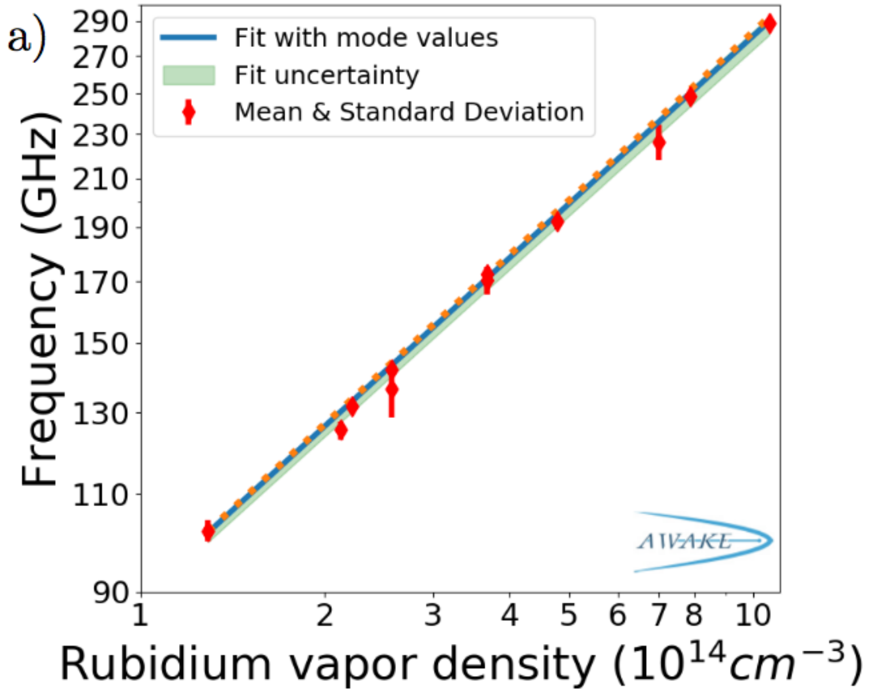




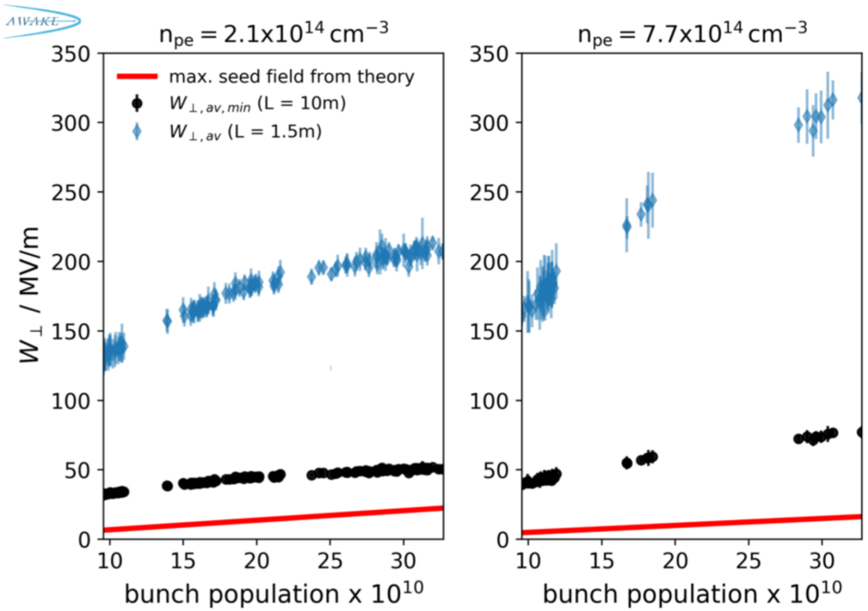
- This an extremely important diagnostic for AWAKE.
- Also an extremely complicated diagnostic:
  - OTR screens
  - Transport optics
  - Movable mask
  - Core camera
  - Halo camera

We have achieved a level of reliability with this diagnostic thanks to the dedicated effort of the M. Turner and the CERN BI group.

AWAKE Research Highlights



Experimental observation of proton bunch modulation in a plasma, at varying plasma densities
Submitted to Phys. Rev. Lett.



Experimental observation of plasma wakefield growth driven by the seeded self-modulation of a proton bunch
Submitted to Phys. Rev. Lett.

AWAKE Research Highlights

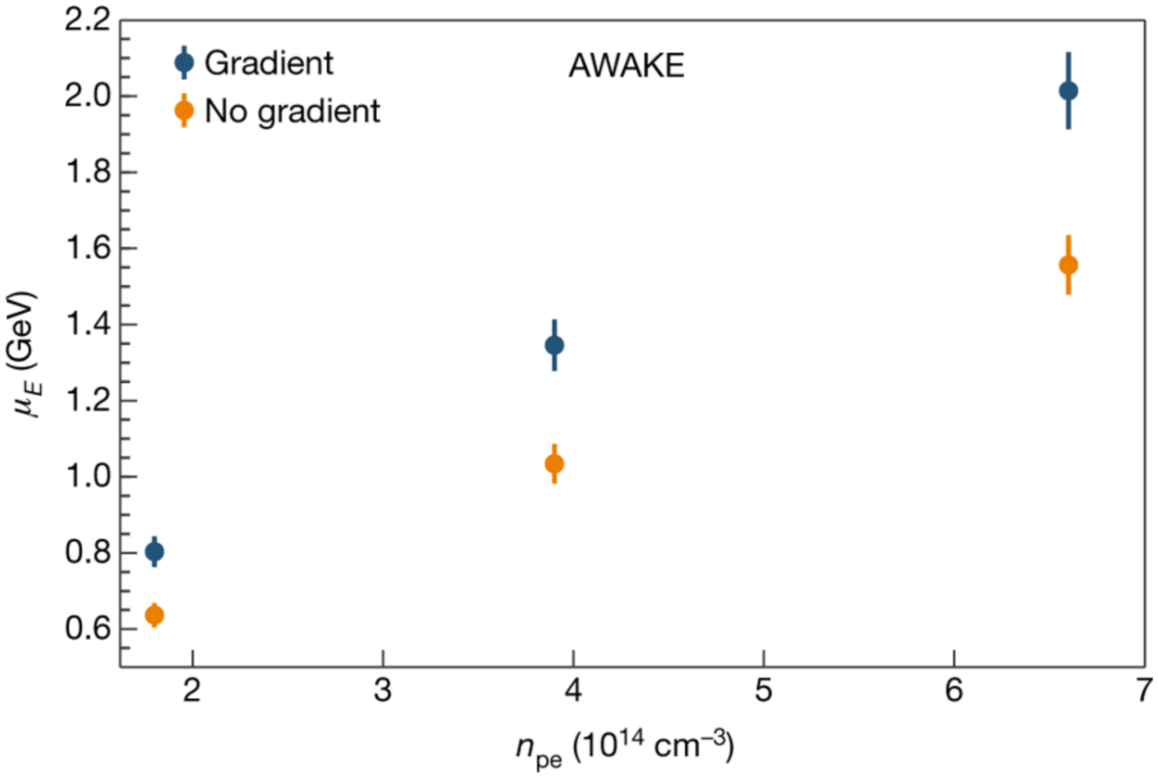
LETTER

OPEN

https://doi.org/10.1038/s41586-018-0485-4

Acceleration of electrons in the plasma wakefield of a proton bunch

E. Adli[1], A. Ahuja[2], O. Apsimon[3,4], R. Apsimon[4,5], A.-M. Bachmann[2,6,7], D. Barrientos[2], F. Batsch[2,6,7], J. Bauche[2], V. K. Berglyd Olsen[1], M. Bernardini[2], T. Bohl[2], C. Bracco[2], F. Braunmüller[6], G. Burt[4,5], B. Buttenschön[8], A. Caldwell[6], M. Cascella[9], J. Chappell[9], E. Chevallay[2], M. Chung[10], D. Cooke[9], H. Damerau[2], L. Deacon[9], L. H. Deubner[11], A. Dexter[4,5], S. Doebert[2], J. Farmer[12], V. N. Fedosseev[2], R. Fiorito[4,13], R. A. Fonseca[14], F. Friebel[2], L. Garolfi[2], S. Gessner[2], I. Gorgisyan[2], A. A. Gorn[15,16], E. Granados[2], O. Grulke[8,17], E. Gschwendtner[2], J. Hansen[2], A. Helm[18], J. R. Henderson[4,5], M. Hüther[6], M. Ibison[4,13], L. Jensen[2], S. Jolly[9], F. Keeble[9], S.-Y. Kim[10], F. Kraus[11], Y. Li[3,4], S. Liu[19], N. Lopes[18], K. V. Lotov[15,16], L. Maricalva Brun[2], M. Martyanov[6], S. Mazzoni[2], D. Medina Godoy[2], V. A. Minakov[15,16], J. Mitchell[4,5], J. C. Molendijk[2], J. T. Moody[6], M. Moreira[2,18], P. Muggli[2,6], E. Öz[6], C. Pasquino[2], A. Pardons[2], F. Peña Asmus[6,7], K. Pepitone[2], A. Perera[4,13], A. Petrenko[2,15], S. Pitman[4,5], A. Pukhov[12], S. Rey[2], K. Rieger[6], H. Ruhl[20], J. S. Schmidt[2], I. A. Shalimova[16,21], P. Sherwood[9], L. O. Silva[18], L. Soby[2], A. P. Sosedkin[15,16], R. Speroni[2], R. I. Spitsyn[15,16], P. V. Tuev[15,16], M. Turner[2], F. Velotti[2], L. Verra[2,22], V. A. Verzilov[19], J. Vieira[18], C. P. Welsch[4,13], B. Williamson[3,4], M. Wing[9]*, B. Woolley[2] & G. Xia[3,4]



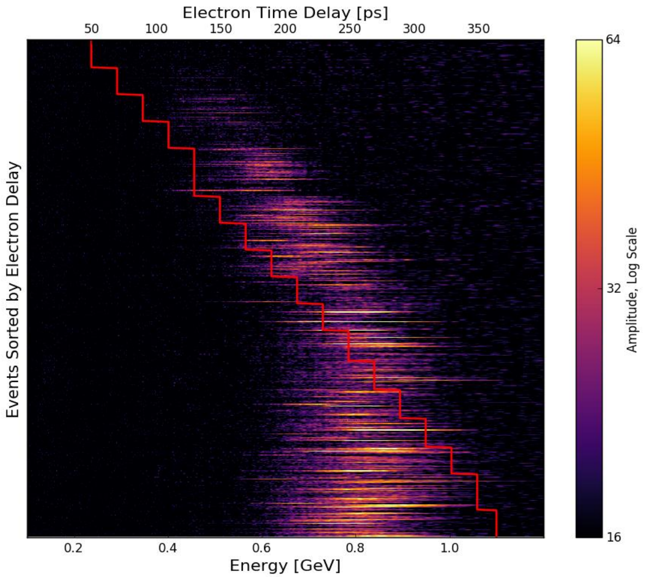
First demonstration of acceleration of an electron witness beam by a self-modulated proton drive beam. Published 29 August!

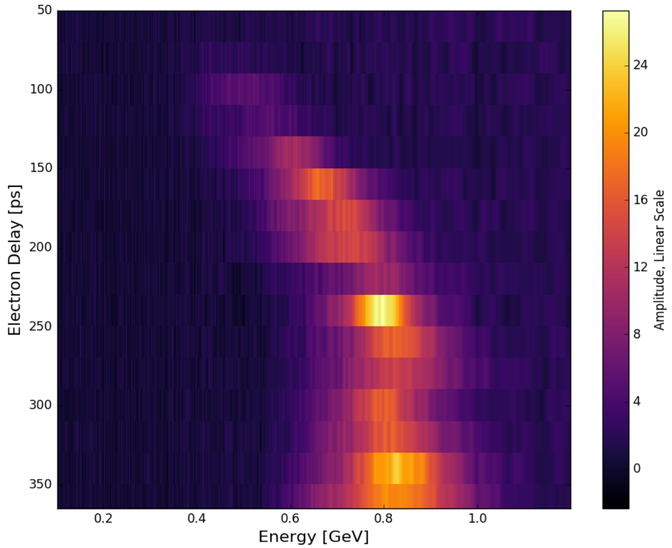
We demonstrated a dependence of acceleration on plasma density and gradient.

AWAKE Recent Results

Our new measurements are focused on:

- Optimization of injection parameters
- Understanding the physics of electron beam injection
- Longitudinal mapping of the plasma wakefield

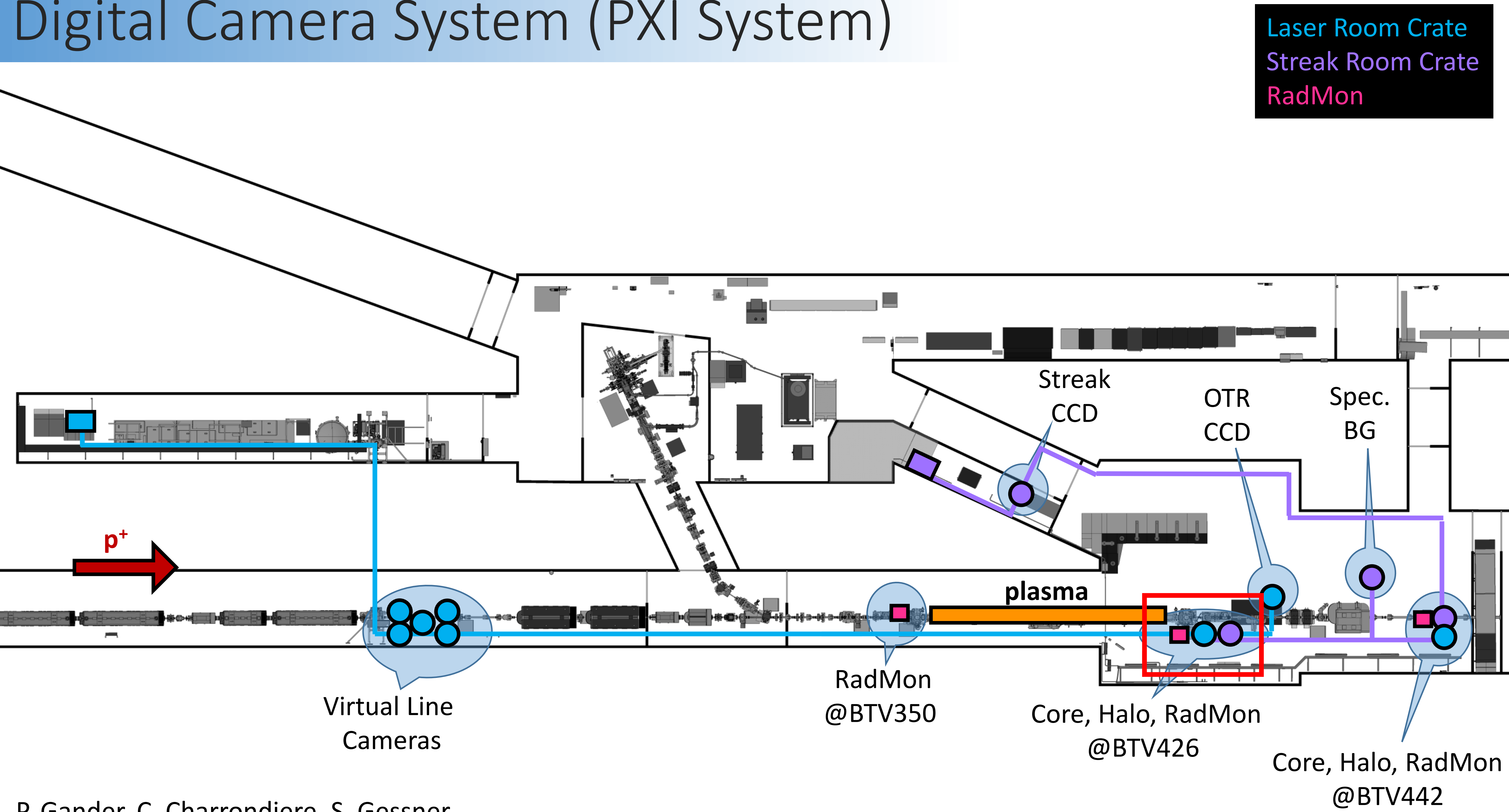




Summary of AWAKE Diagnostics

Device	Protons	Electrons	Laser	Number	Rep Rate	Issues?
Proton BPMs	Yes			20	Cycle	Yes, when plasma present
Electron BPMs	Yes	Yes		12	10 Hz	Synchronicity, No readings when protons present
BTVs	Yes	Yes	Yes	3	Cycle/1 Hz	Synchronicity
Digital (PXI) Cameras	Yes	Yes	Yes	20	Cycle/10 Hz	Radiation hardness
Streak Camera	Yes	Yes	Yes	2	Cycle/1 Hz	VTU system and PPM-ness
Spectrometer Camera	Yes	Yes		1	Cycle/1 Hz	
Laser energy meter			Yes	5	Cycle/1 Hz	Synchronicity, Robustness
Faraday Cup		Yes		1	10 Hz	
Electron BLMs	Yes	Yes		8	Async	FileReader
CTR Heterodyne	Yes			1	Async	FileReader
Rb spectrograph				2	Async	FileReader
Autocorrelator			Yes	1	Async	FileReader

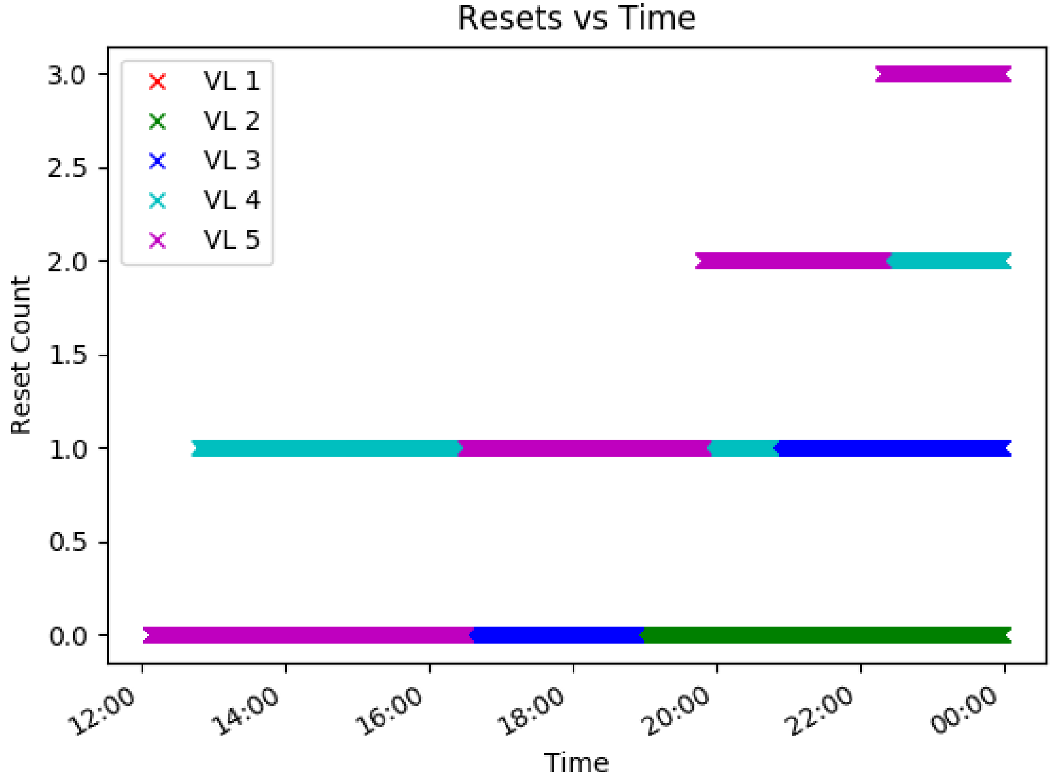
Digital Camera System (PXI System)



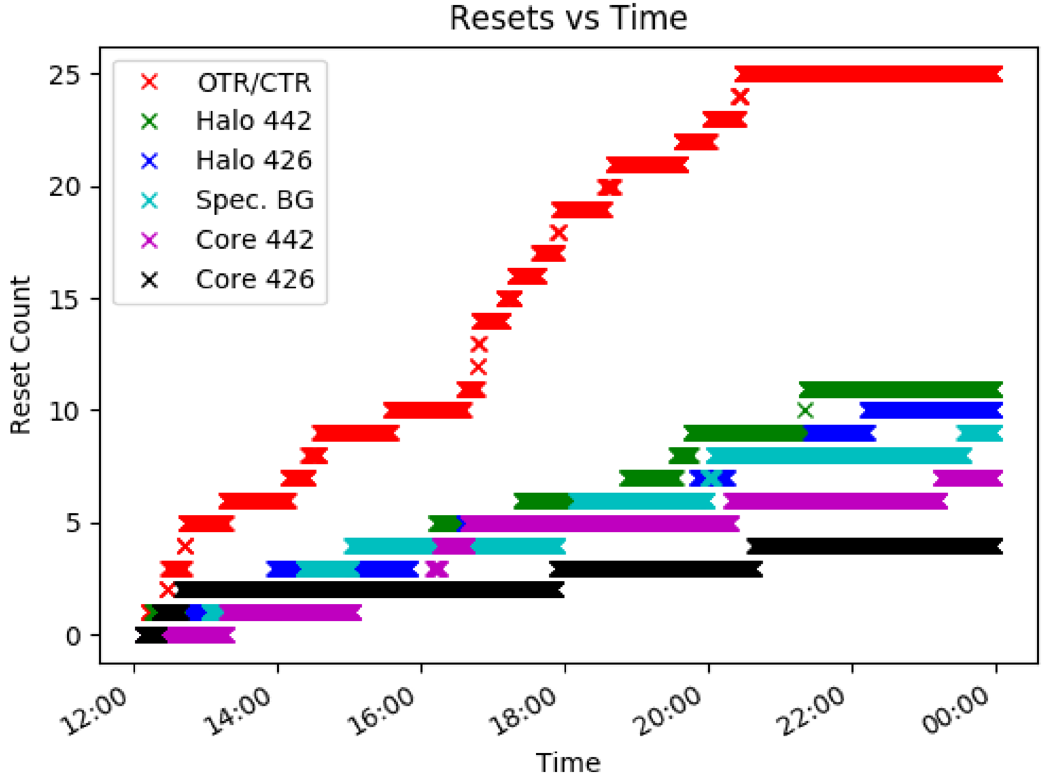
P. Gander, C. Charrondiere, S. Gessner

PXI Radiation Hardness

Upstream Cameras



Downstream Cameras



For the cameras upstream of the plasma cell, the per-shot-SEU probability is extremely low, about 0.05%.

Excluding the OTR/CTR camera, the per-shot SEU probability for the downstream cameras averages about 0.5%.

We have achieved a level of robustness and reliability with this diagnostic.

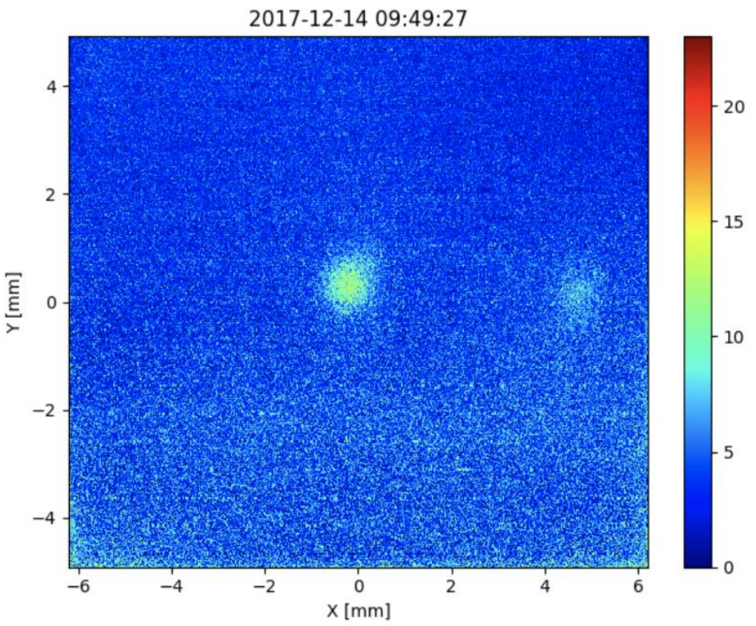
Data Rate Issue

Data from a single image is between 1-10 Megabytes.

The data rate is measured in Gbps (Gigabits per second).

One Megabyte is approximately 10 Megabits.

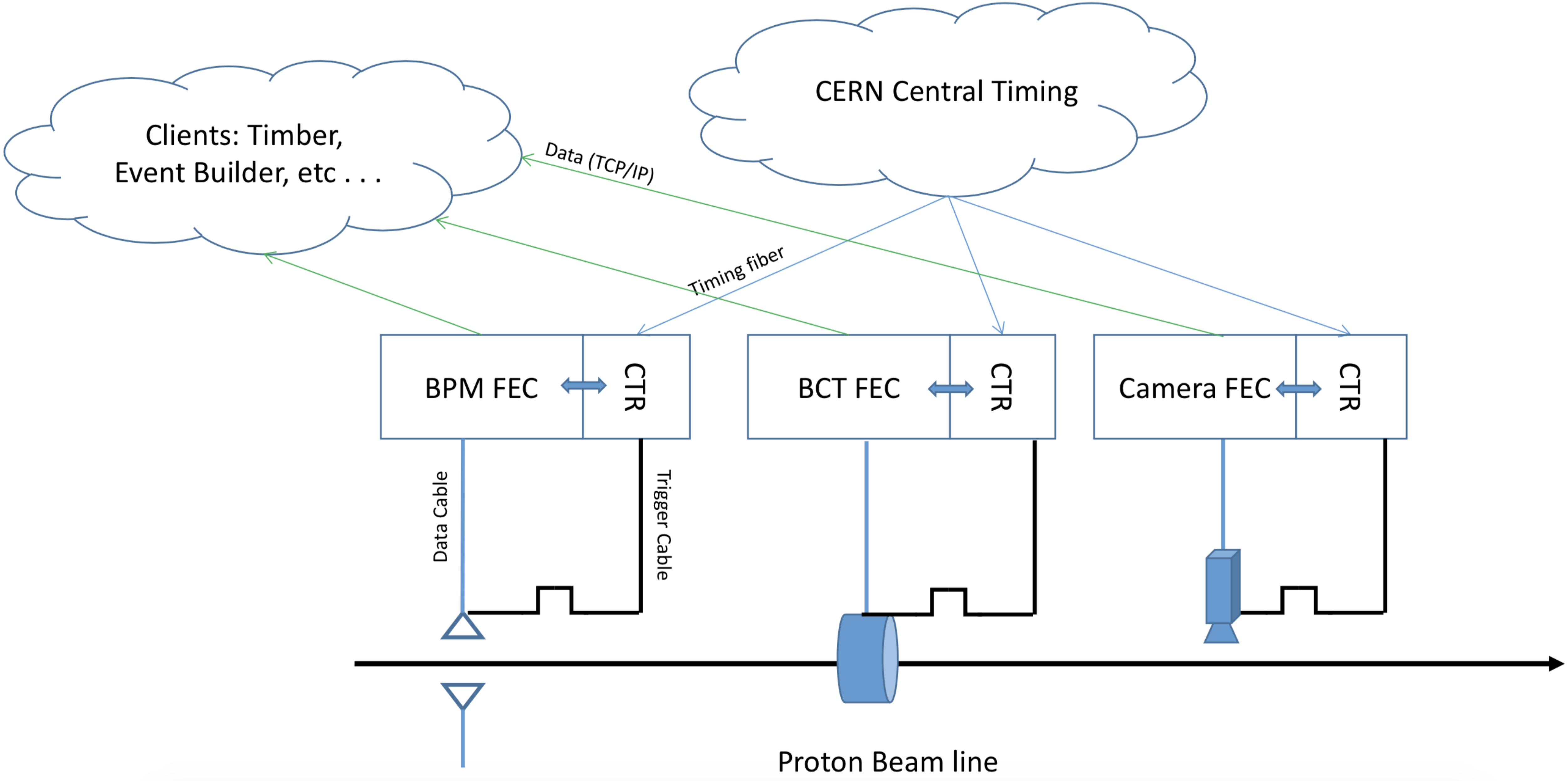
Therefore, a 10 Megabyte image (MB) streamed at 10 Hz works out to roughly 1 Gbps.



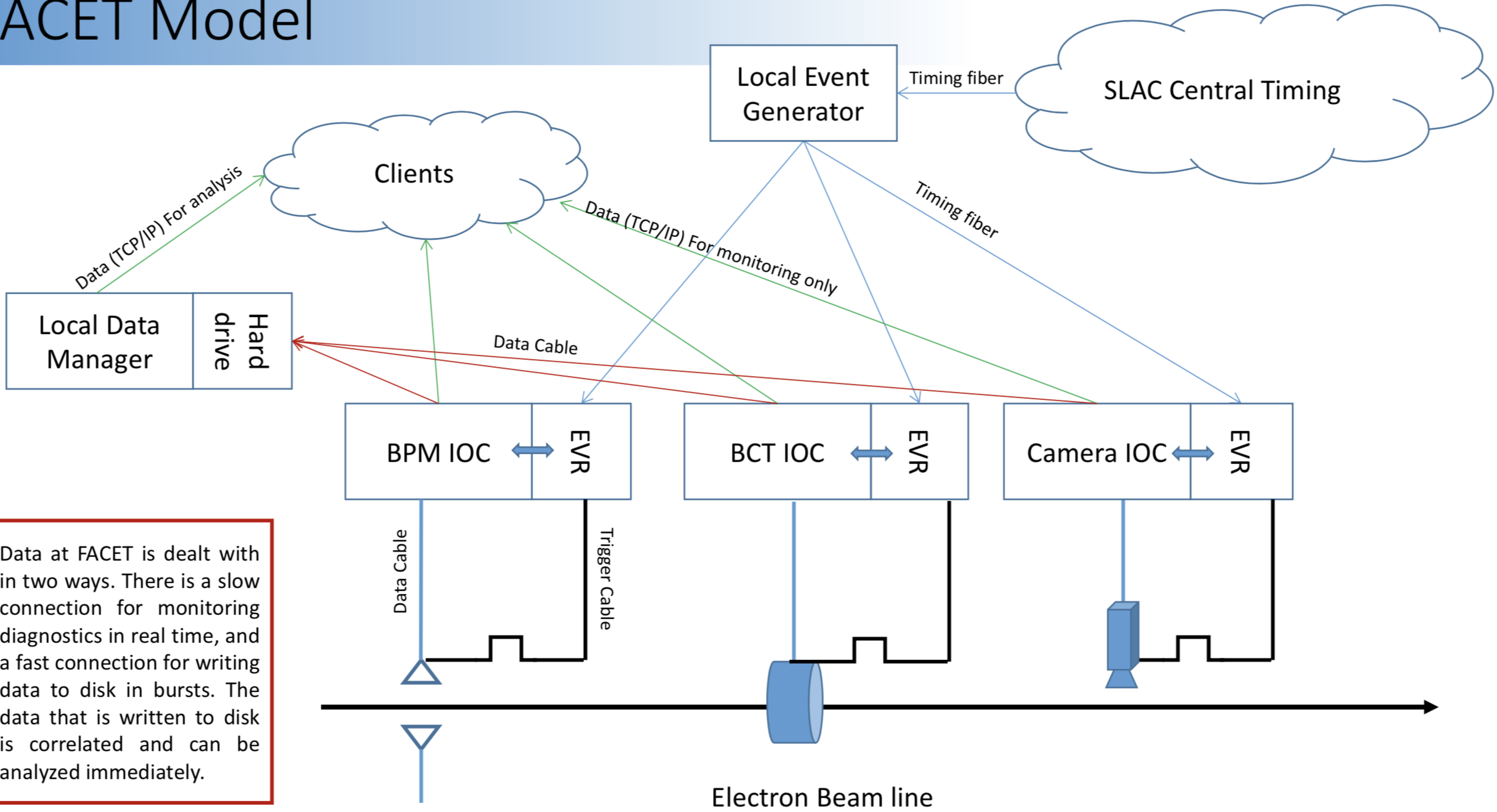
Data from a *single camera* at 10 Hz is enough to overwhelm the network.

We have approximately 30 cameras in operation at AWAKE.

Data Rate Issue



FACET Model



Data at FACET is dealt with in two ways. There is a slow connection for monitoring diagnostics in real time, and a fast connection for writing data to disk in bursts. The data that is written to disk is correlated and can be analyzed immediately.

Conclusions

- Overall, AWAKE Run 1 has been extremely successful!
  - No results possible without excellent beam diagnostics like the streak camera, spectrometer camera, and halo monitors.
- We use 20+ digital cameras at AWAKE.
  - The PXI system is robust and reliable.
- Much of the AWAKE beam instrumentation is “bricolage”
  - Especially “FileReader” devices.
- Synchronization and 10 Hz operation is a major issue.
- AWAKE requires a DAQ system that meets it’s needs.