FACET·II
Facility for Advanced Accelerator Experimental Tests

Commissioning Status & Beam Parameters for 2020

FACET-II Science Workshop, October 29-November 1, 2019

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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

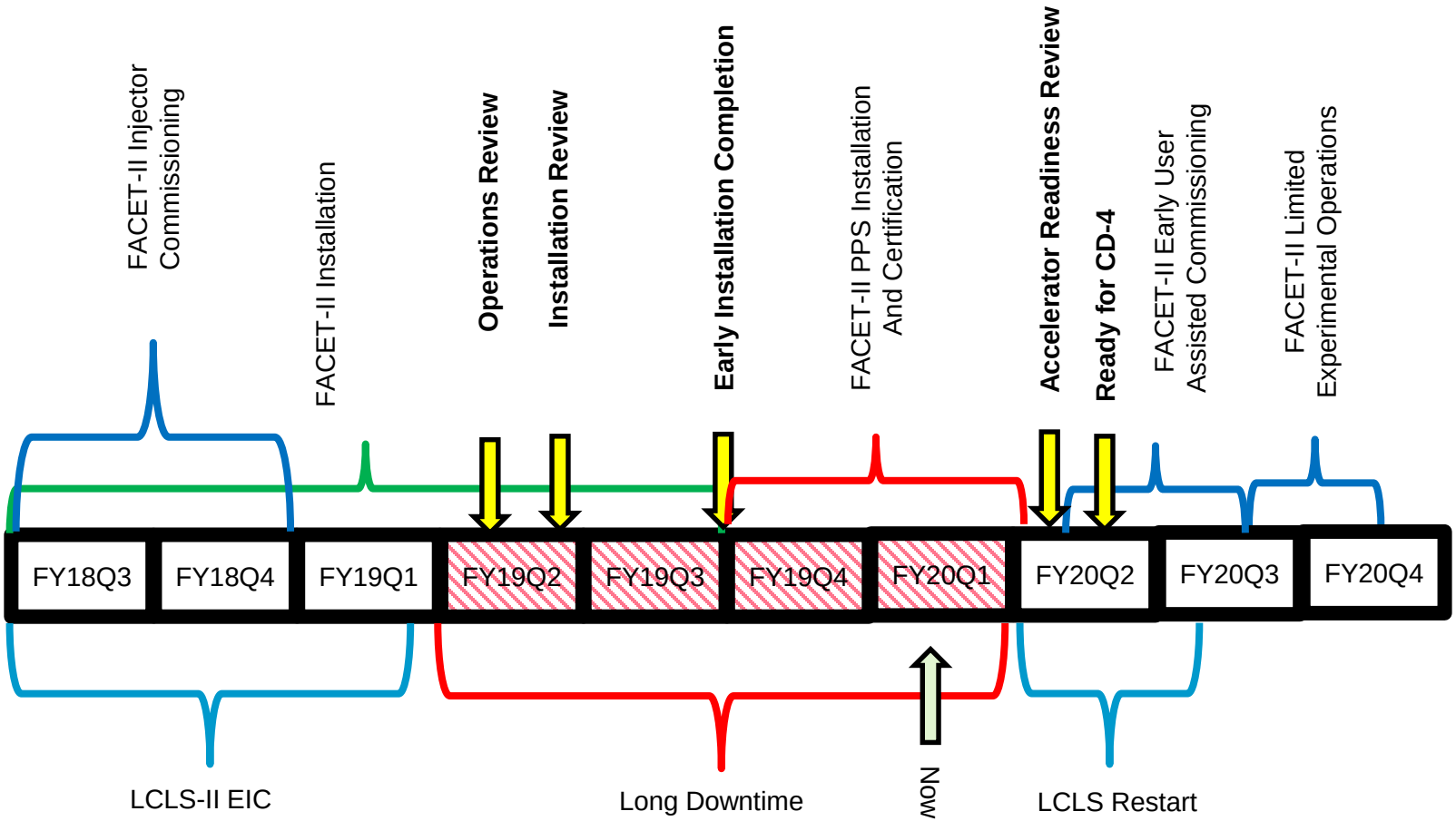
FACET-II Start of Commissioning

SLAC

- FACET-II ready for startup Feb/Mar 2020
  - Final PPS complete in December
  - ARR in January
  - LCLS Cu linac restart in February
- Will commence with laser cleaning as early as possible
  - Procedure adopted from established LCLS successes and tweaked by knowledgeable experts in group
  - Investigating feasibility of beginning prior to final beam authorization

FACET-II Commissioning Plans Developed

FACET-II Installation and Commissioning Timeline



A look back at and into the near-future of FACET-II

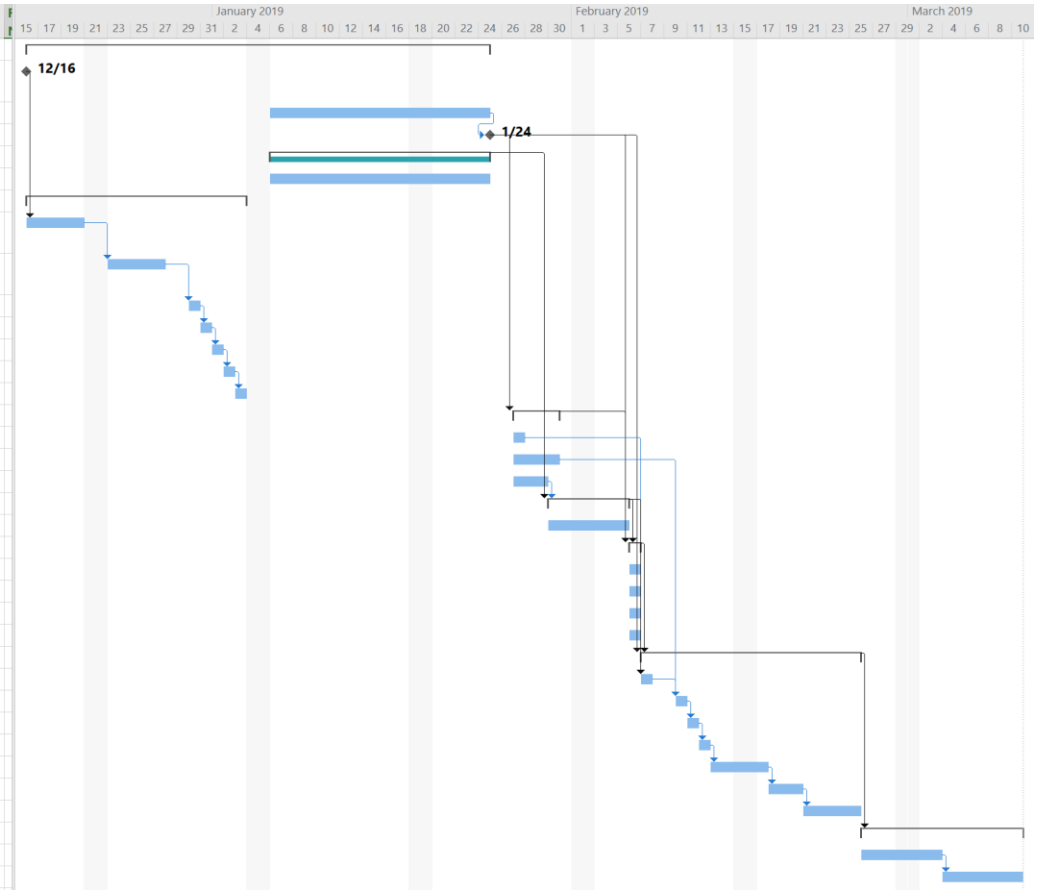
Checkout Activities

	Ops	ADSO	RP	PHYS	CTRL	CBL	FAC	PEM	AMRF	MFD	Eng	AM
Cold checkout												
Shielding in place	x	x	x									x
PPS system certified	x	x	x		x							
BCS system certified	x	x	x		x							
Water flow							x				x	
Air flow							x					
Electrical (EEIP)					x			x				
Cable checkout					x	x		x				
Leak check										x		
Alignment				x-data						x		
Movement checks				x	x							
Component software checks					x							
Control system checks	x				x							
Magnet polarity				x				x				
Correct beamline components				x							x	
Overall tunnel site check				x							x	x
Hot checkout												
Magnet checkout	x				x			x				
RF checkout	x			x	x			x	x			
Timing checkout	x			x	x				x			

Groups Identified for Cold and Hot Checkout Activities

FACET-II Commissioning Plan

	Task Mode	Task Name	Duration	Start	Finish	Predecessc	Successors
1		**Milestones**	**30 days**	**12/16/2019**	**1/24/2020**		
2		FACET-II Stage 1 installation complete	0 days	12/16/2019	12/16/2019		8
3		PPS Certification	15 days	1/6/2020	1/24/2020		4
4		BAS issued	0 days	1/24/2020	1/24/2020	3	21,26,15
5		**Drive Laser Re-Commisioning**	**15 days**	**1/6/2020**	**1/24/2020**		**19**
6		Laser stuff	15 days	1/6/2020	1/24/2020		
7		**pre-beam checkout**	**15 days?**	**12/16/2019**	**1/3/2020**		
8		Verify s-location all components	5 days	12/16/2019	12/20/2019	2	9
9		Verify polarity of devices	5 days	12/23/2019	12/27/2019	8	10
10		Verify interlocks	1 day?	12/30/2019	12/30/2019	9	11
11		Verify water flow	1 day?	12/31/2019	12/31/2019	10	12
12		Verify turn-on	1 day?	1/1/2020	1/1/2020	11	13
13		Verify calibration	1 day?	1/2/2020	1/2/2020	12	14
14		Verify STDZ	1 day?	1/3/2020	1/3/2020	13	
15		**RF Processing**	**4 days?**	**1/27/2020**	**1/30/2020**	**4**	**21**
16		L0A/B Processing	1 day?	1/27/2020	1/27/2020		27
17		Linac RF Processing	4 days	1/27/2020	1/30/2020		28
18		Gun processing	3 days?	1/27/2020	1/29/2020		19
19		**Laser cleaning**	**5 days**	**1/30/2020**	**2/5/2020**	**18,5**	**27,21**
20		Cleaning tasks	5 days	1/30/2020	2/5/2020		
21		**Injector Commisioning**	**1 day?**	**2/6/2020**	**2/6/2020**	**4,15,19**	**26**
22		Set temporal profile	1 day?	2/6/2020	2/6/2020		
23		Set transverse profile	1 day?	2/6/2020	2/6/2020		
24		Optimize L0A	1 day?	2/6/2020	2/6/2020		
25		Optimize L0B	1 day?	2/6/2020	2/6/2020		
26		**Linac commissioning**	**13 days?**	**2/7/2020**	**2/25/2020**	**4,21**	**34**
27		Beam to DL1	1 day?	2/7/2020	2/7/2020	16,19	28
28		Beam to BC11	1 day	2/10/2020	2/10/2020	27,17	29
29		Beam to BC14	1 day?	2/11/2020	2/11/2020	28	30
30		Beam to S20	1 day?	2/12/2020	2/12/2020	29	31
31		BBA L2	3 days	2/13/2020	2/17/2020	30	32
32		BBA L3	3 days	2/18/2020	2/20/2020	31	33
33		Align linac	3 days	2/21/2020	2/25/2020	32	
34		**S20 Recommission**	**10 days**	**2/26/2020**	**3/10/2020**	**26**	
35		Beam to dump	5 days	2/26/2020	3/3/2020		36
36		BBA S20	5 days	3/4/2020	3/10/2020	35	



High level commissioning plan developed;
Detailed plan in progress and complete before ARR

Commissioning Goals and Schedule

- Subsystem goals and daily shift plans developed

Day #	Goal	Goal	Goal	Goal	Goal	
-n	Laser Cleaning					
0	BAS signed					
1	Process gun	Process L0A	Process L0B		Diagnostics checkout	
2	Process gun	Process L0A	Process L0B		Diagnostics checkout	
3	Process gun	Process L0A	Process L0B		Diagnostics checkout	
4	Process gun	Process L0A	Process L0B	Process linac RF		Diagnostics checkout
5	Process gun	Process L0A	Process L0B	Process linac RF		Diagnostics checkout
6	Accelerate to 135MeV		TCAV 0		Process linac RF	
7	Accelerate to 135MeV		TCAV 0		Process linac RF	
8	Accelerate to 335Mev				Process linac RF	
9	Beam through BC11				Process linac RF	
10	Beam through L2				Process linac RF	
11	Beam through BC14					TCAV 3 checkout
12	TCAV 3					
13	TCAV 3					
14	Beam through L3					
15	Beam to S20					
16	Beam to S20 dump					
17	linac BBA	XTCAV recommission				
18	linac BBA					
19	linac BBA					
20	S20 BBA					
21	S20 BBA					
22	Optimize compression					
23	Optimize compression					
24	Optimize compression					

Daily schedule built with flexibility in mind

Key Performance Parameters

SLAC

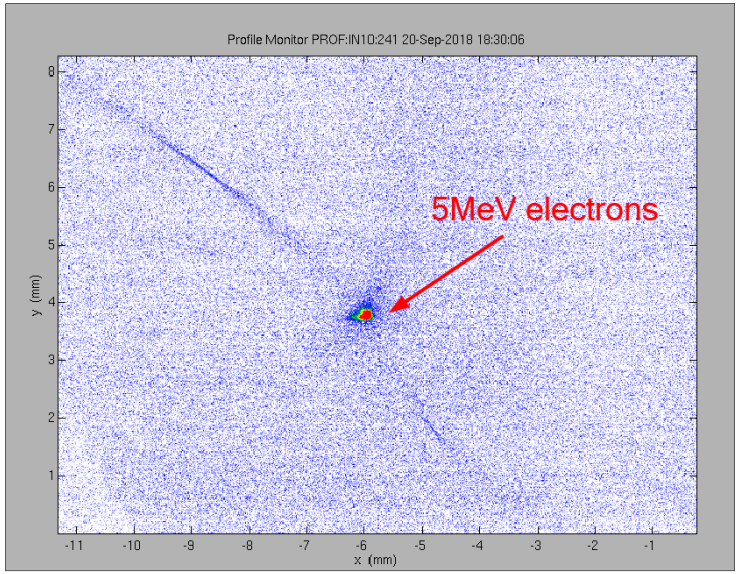
- The threshold KPPs are the minimum parameters against which the project's performance is measured
- The objective KPPs are the desired operating parameters that the project will design to

Description of Scope	Units	Threshold KPP	Objective KPP
Beam Energy	[GeV]	9	10
Bunch Charge (e-)	[nC]	0.1	2
Normalized Emittance in S19 (e-)	[μm]	50	20
Bunch Length (e-)	[μm]	100	20

Objective KPP will support the majority of the proposed science program
FACET-II flexibility allows other optimizations to meet User needs

FACET-II Subsystem Goals

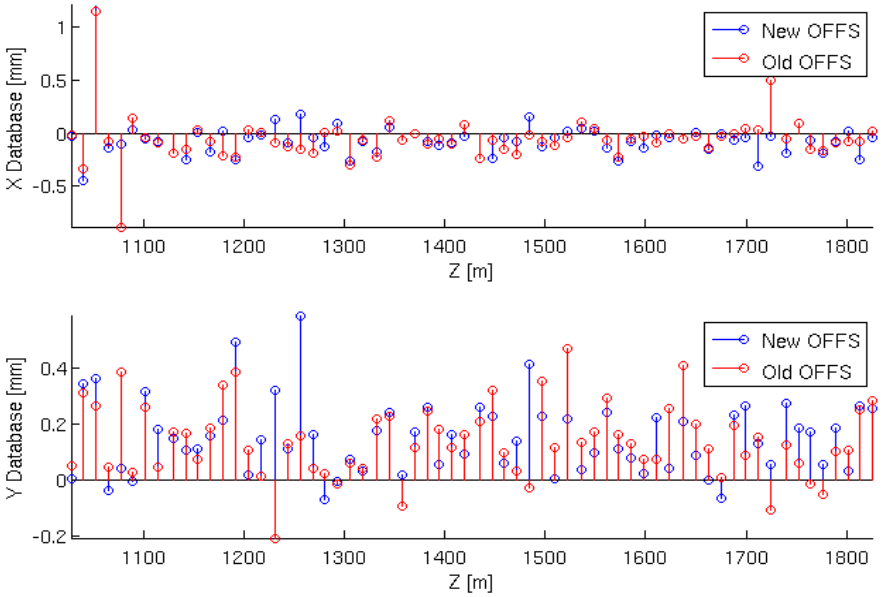
- Laser
  - 50uJ, 2mm laser spot to cathode
    - *Delivered 15-Sep-2018*
- Gun
  - 5MeV electrons to fixed Faraday cup
    - *Delivered 21-Sep-2018*
- Injector
  - 100pC 135MeV electrons to DL1
  - Diagnostics checkout (detectable beam)
- BC11
  - 100pC 335MeV electrons to BC 11 screen
  - Diagnostics checkout (detectable beam)
- BC14
  - 100pC 4.5GeV electrons to S15 wires
  - Diagnostics checkout (detectable beam)
  - TCAV calibration
- L3
  - 100pC 8GeV electrons to S18 wire
  - Size measurements
- BC20
  - 100pC 9GeV electrons to experimental area
  - Diagnostics checkout (detectable beam)



5MeV electrons to profile monitor

FACET-II Initial Tuning Focus

- Laser Stability
- Linac:
  - Beam Based Alignment (BBA)
  - Klystron phase stability
  - Compression management (feedback development, ML, etc.)
- S20 configuration development
  - Three main configurations (GW talk)



Laser Cleaning Experience in LCLS

- Extensive studies of laser cleaning at LCLS & ASTA

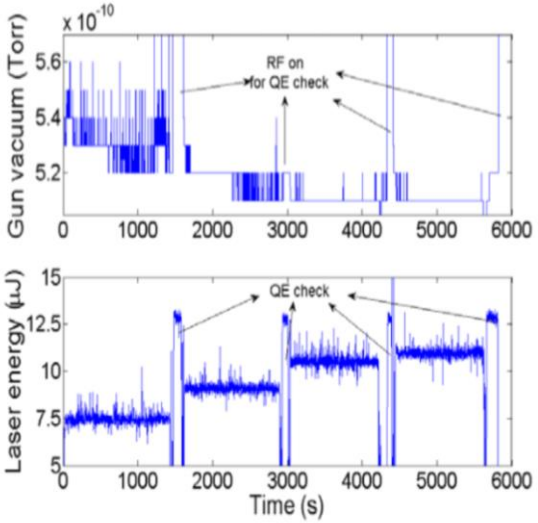


Fig.6. Laser energy and gun vacuum activity during the laser cleanings at ASTA. The QE is checked between each round of laser cleaning.

Table 2. Laser cleaning parameters for ASTA compared to previous cle
parenthesis were used at the LCLS.

Laser cleaning parameters	ASTA (LCLS)
Laser pulse length in ps FWHM	1.6 (~3)
Laser size for cleaning in x/y in μm, rms	~40 (~30)
Laser shots per spot	60 (120)
Laser wavelength in nm	253 (253)
Laser raster step size in x/y in μm	30 (30)
Base gun vacuum range with RF power off	4×10^{-10} to 1.2×10^{-9} Torr (4×10^{-10} to 7×10^{-10} Torr)
RF power is off during laser cleaning	
Multi-round laser cleaning: - start with 7 μJ (17 μJ) - laser energy for subsequent rounds is increased in 0.5-1μJ (1-2 μJ) - take 3-8 rounds (2-3 rounds) until QE up to $3\text{-}5\times10^{-5}$	

High Level Application Deployment

- Many Matlab GUIs adapted from LCLS-I
  - Reuse profile monitor, correlation plot, laser cathode alignment, QE imaging, RF sync, and beam synchronous acquisition
  - Some new algorithms required based on beamline instrumentation – phase, amplitude, and Schottky scans
- FACETHome EDM launch panel has started update for FACET-II use
- New link node MPS system
- New summary and status displays for operations, using PyDM

Further application deployment will be interleaved with commissioning activities

Run Hours

- Plan for User Assisted Commissioning (UAC)
  - Commission diagnostics at machine-experiment interfaces
  - 4-5 days/week of delivery or machine development (MD)
    - Other days are either machine access for repairs and experimental setup, software development, or operator training
- Plan for operation of 26 weeks, 5-6 days/week
  - ~3000 total hours
  - ~2250 hours experimental time
  - ~750 hours MD
    - MD initially heavy on commissioning activities
    - Transition into experimental configuration development
    - Development of future extensions to experimental delivery capabilities
  - 80% availability

FACET-II Operation Modes

Simplified injector system and LCLS operations experience allows us to consider different patterns for 6 months/year operations:

1 week on - 1 week off

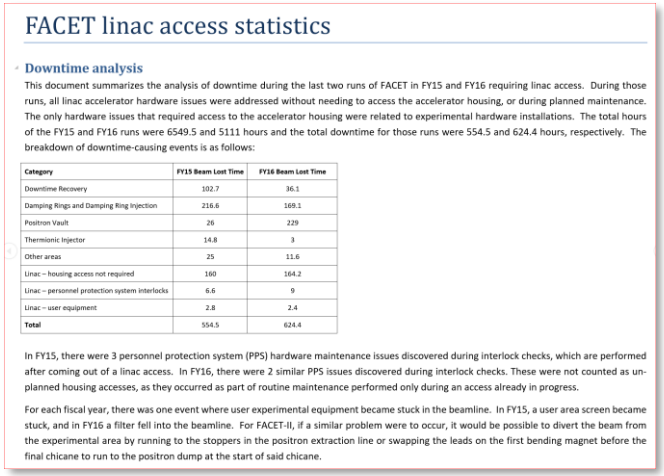
2 weeks on - 2 weeks off

…

6 months on - 6 months off

Week on
Week off

6 months on
6 months off



FACET linac access statistics

Downtime analysis

This document summarizes the analysis of downtime during the last two runs of FACET in FY15 and FY16 requiring linac access. During those runs, all linac accelerator hardware issues were addressed without needing to access the accelerator housing, or during planned maintenance. The only hardware issues that required access to the accelerator housing were related to experimental hardware installations. The total hours of the FY15 and FY16 runs were 6549.5 and 5111 hours and the total downtime for those runs were 554.5 and 624.4 hours, respectively. The breakdown of downtime-causing events is as follows:

Category	FY15 Beam Lost Time	FY16 Beam Lost Time
Downtime Recovery	102.7	36.1
Damping Rings and Damping Ring Injection	216.6	169.1
Positron Vault	26	229
Thermionic Injector	14.8	3
Other areas	25	11.6
Linac – housing access not required	160	164.2
Linac – personnel protection system interlocks	6.6	9
Linac – user equipment	2.8	2.4
Total	554.5	624.4

In FY15, there were 3 personnel protection system (PPS) hardware maintenance issues discovered during interlock checks, which are performed after coming out of a linac access. In FY16, there were 2 similar PPS issues discovered during interlock checks. These were not counted as un-planned housing accesses, as they occurred as part of routine maintenance performed only during an access already in progress.

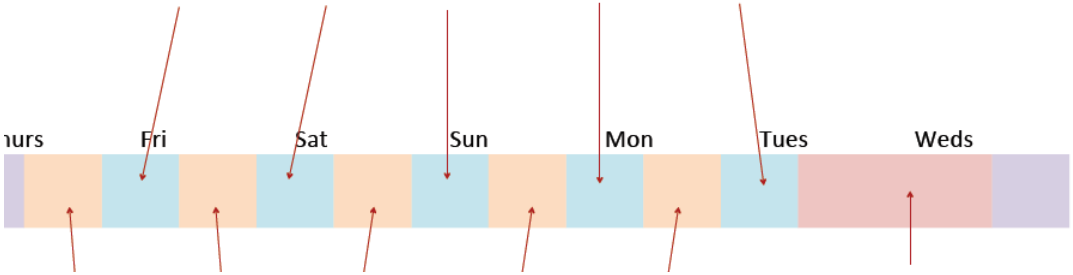
For each fiscal year, there was one event where user experimental equipment became stuck in the beamline. In FY15, a user area screen became stuck, and in FY16 a filter fell into the beamline. For FACET-II, if a similar problem were to occur, it would be possible to divert the beam from the experimental area by running to the stoppers in the positron extraction line or swapping the leads on the first bending magnet before the final chicane to run to the positron dump at the start of said chicane.

FACET linac access statistics support FACET-II operational mode assumptions

Experience will guide optimal operational mode

Daily Planning: A typical week at FACET

Delivery to experiments ~ typically 12 hours/day



Machine maintenance, development of new beam configurations and set-up for experiments during day shift

Scheduled access to FACET to switch experiments, install upgrades and troubleshoot issues

- Users provided procedures for their beam time + previous shift analysis
  - Advanced Accelerator Research department reviewed to ensure beam time is used effectively
  - Beam needs were relayed by AAR department to Operations department
  - Operations department developed beam configuration and procedures
  - Hardware/support needs were assessed and provided by TF department
- During shift: Regular contact between users and AAR department staff
- After shift: Users post shift report to e-log giving immediate feedback

Feedback between all stakeholders to produce efficient, excellent science

Summary

- Commissioning to begin when PPS certified and within constraints of LCLS Cu linac restart
- Daily commissioning activity plans and goals developed
- Startup schedule flexible to accommodate LCLS recommissioning and other unknowns

FACET-II Accelerator Physics and Beam Operations Department is ready for the start of commissioning