The 2011 Run: Availability Analysis

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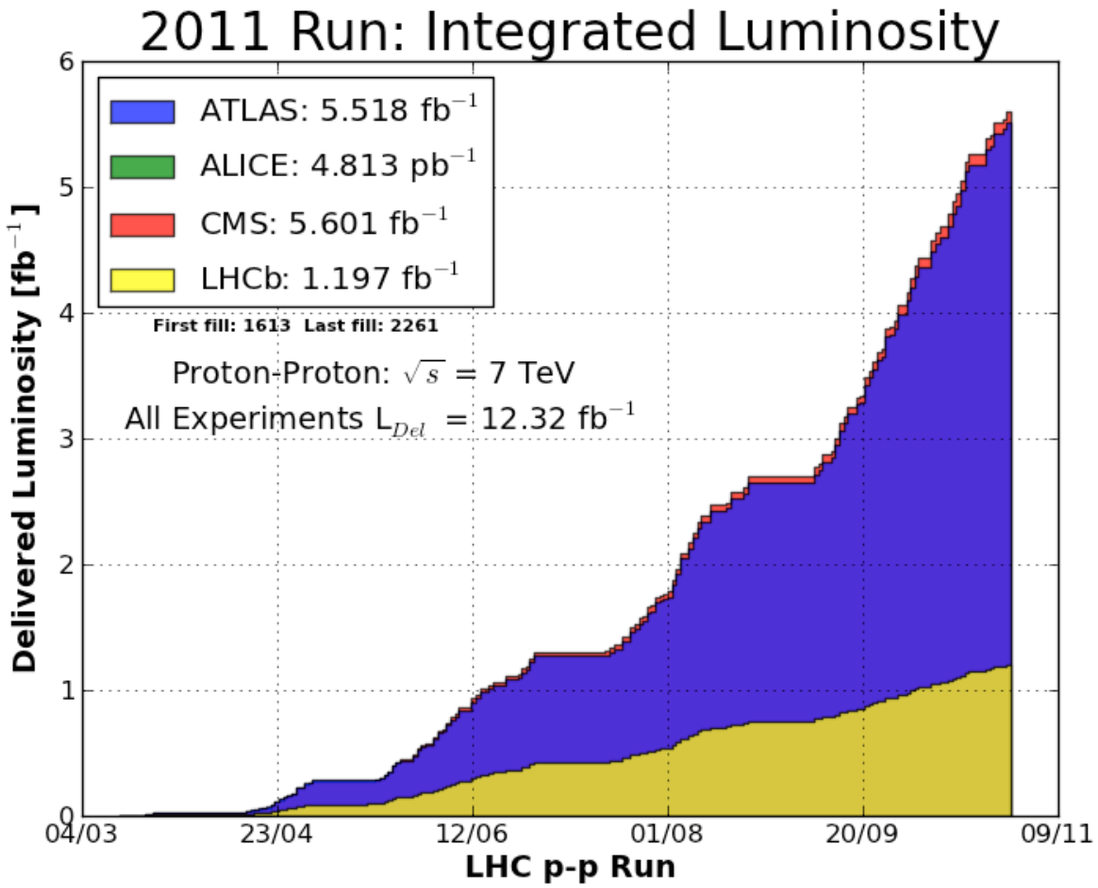
LHC Performance Workshop
Chamonix
6 January 2012

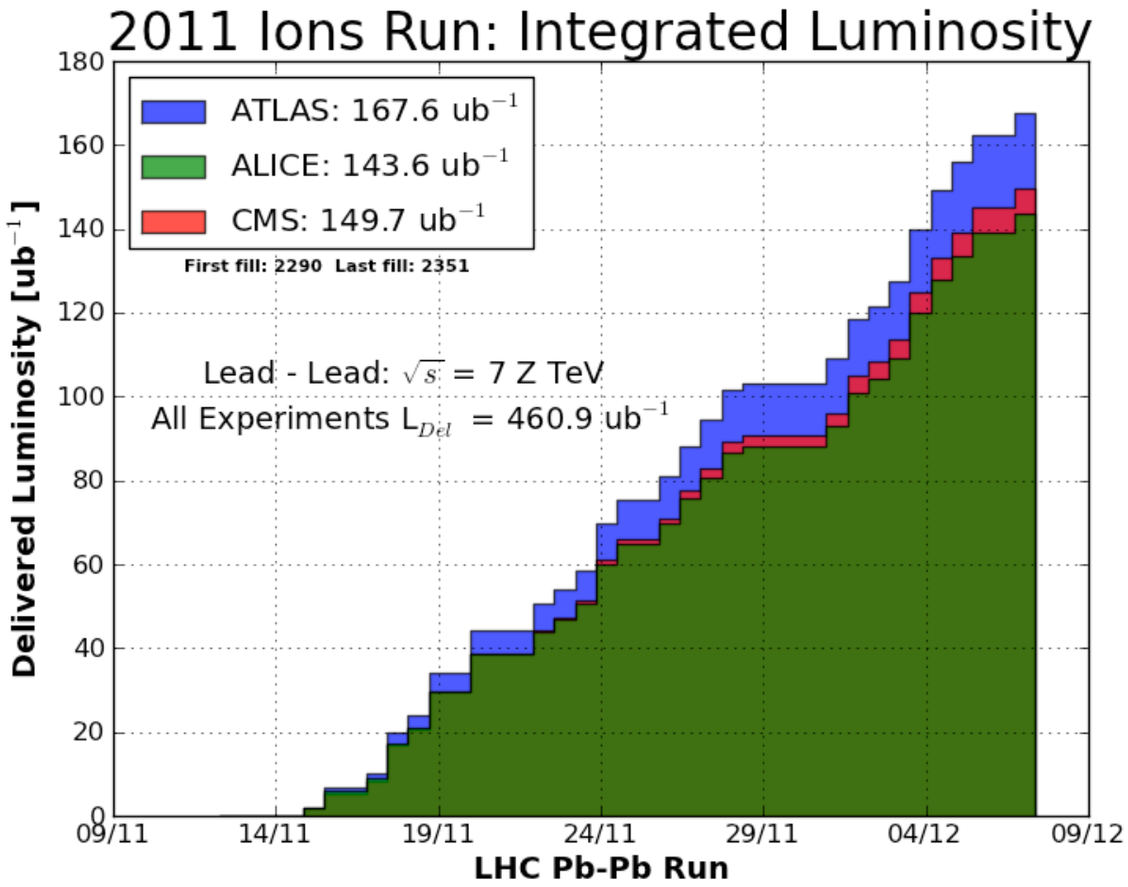
Topics:

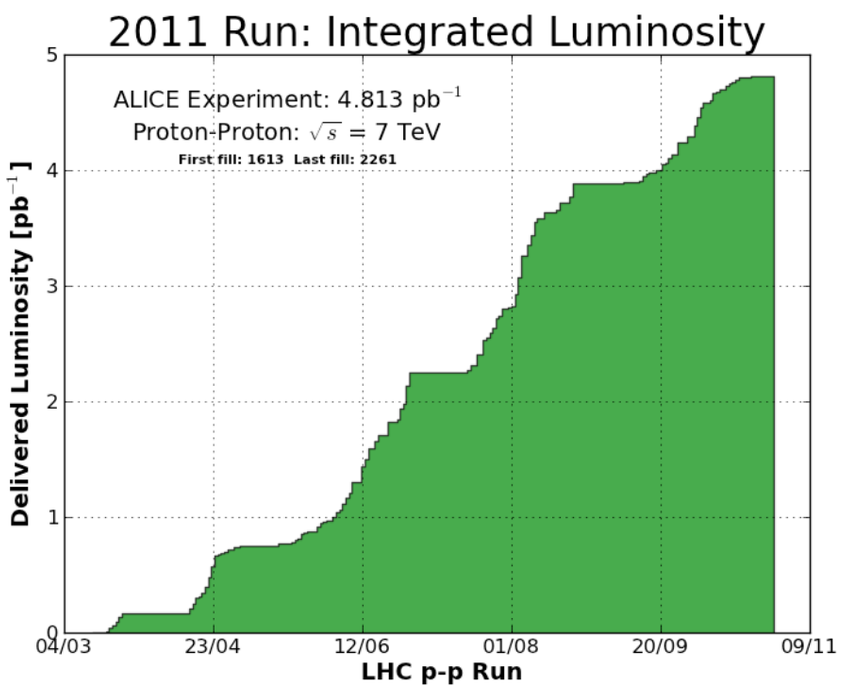
Machine Performance
Faults and Downtime
Beam Dumps

Machine Performance

2011 Run: Luminosity Production







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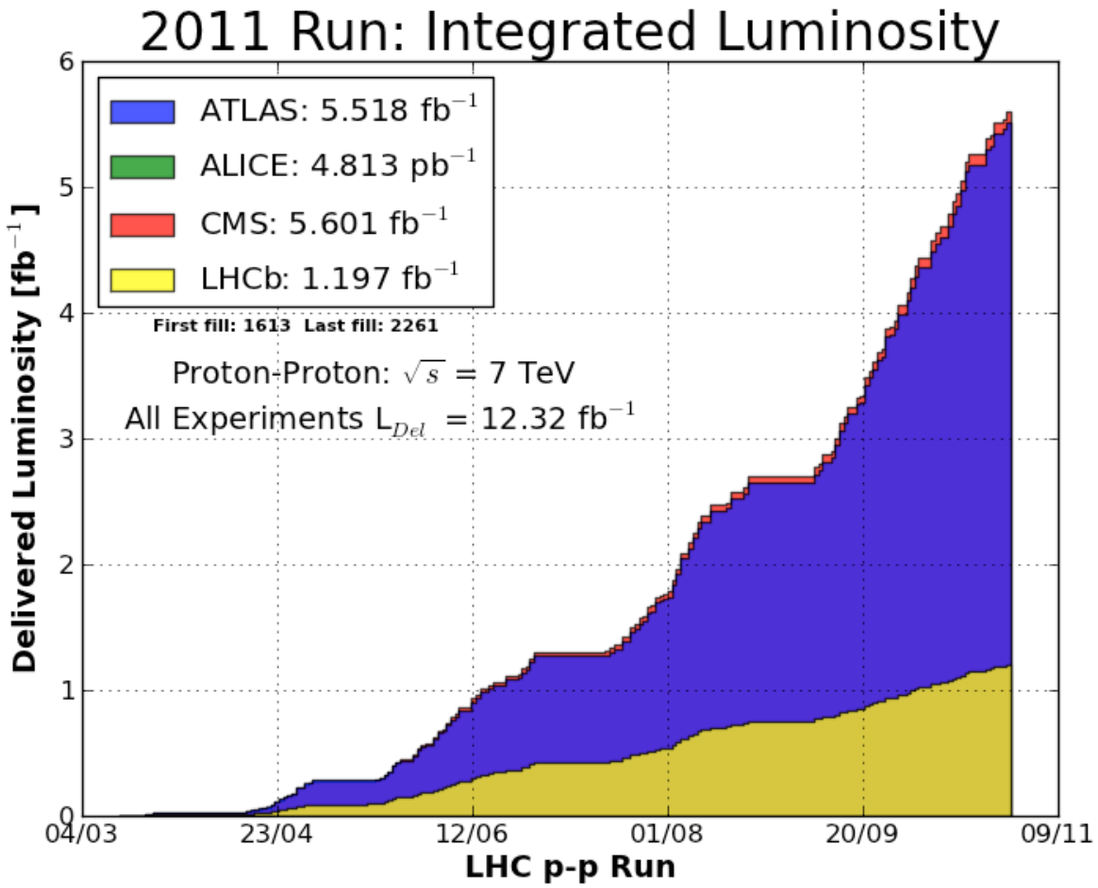
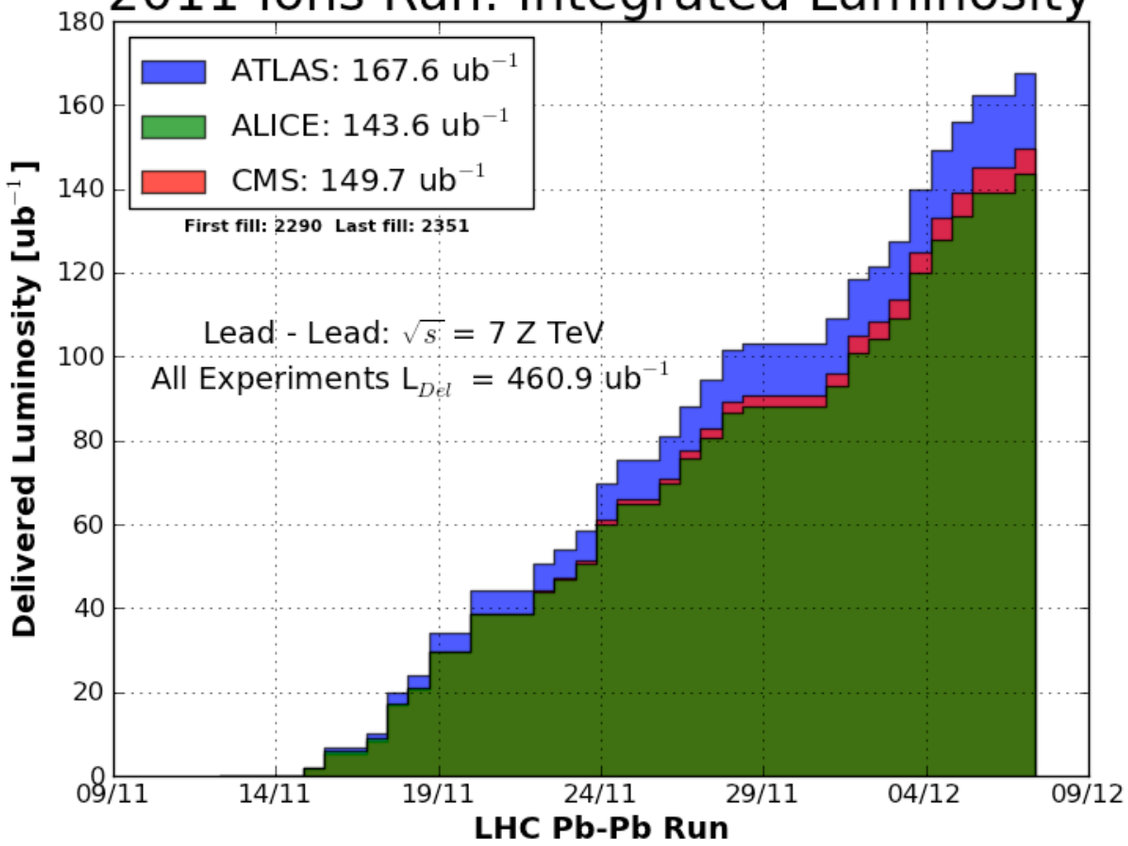
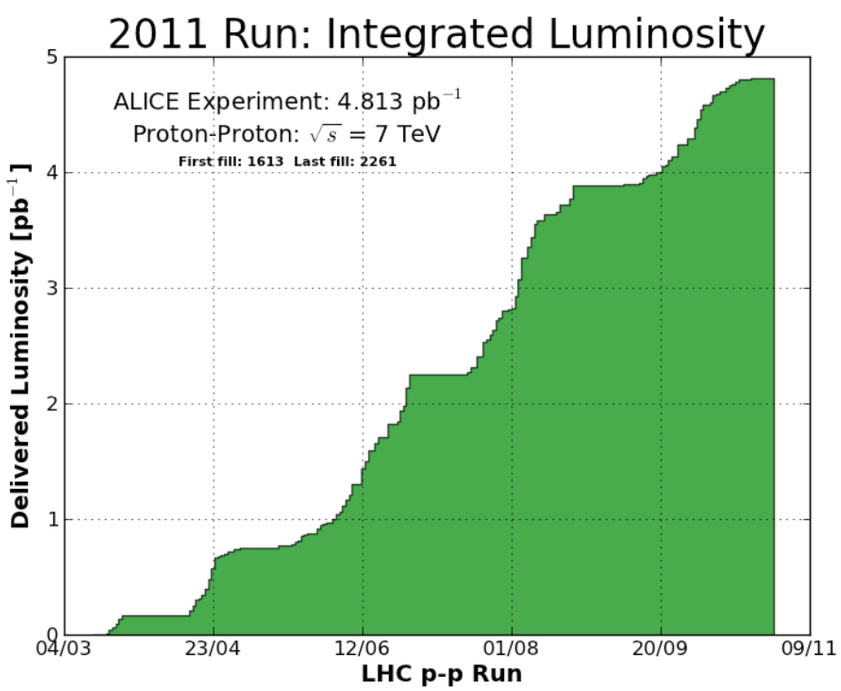






Luminosity Production

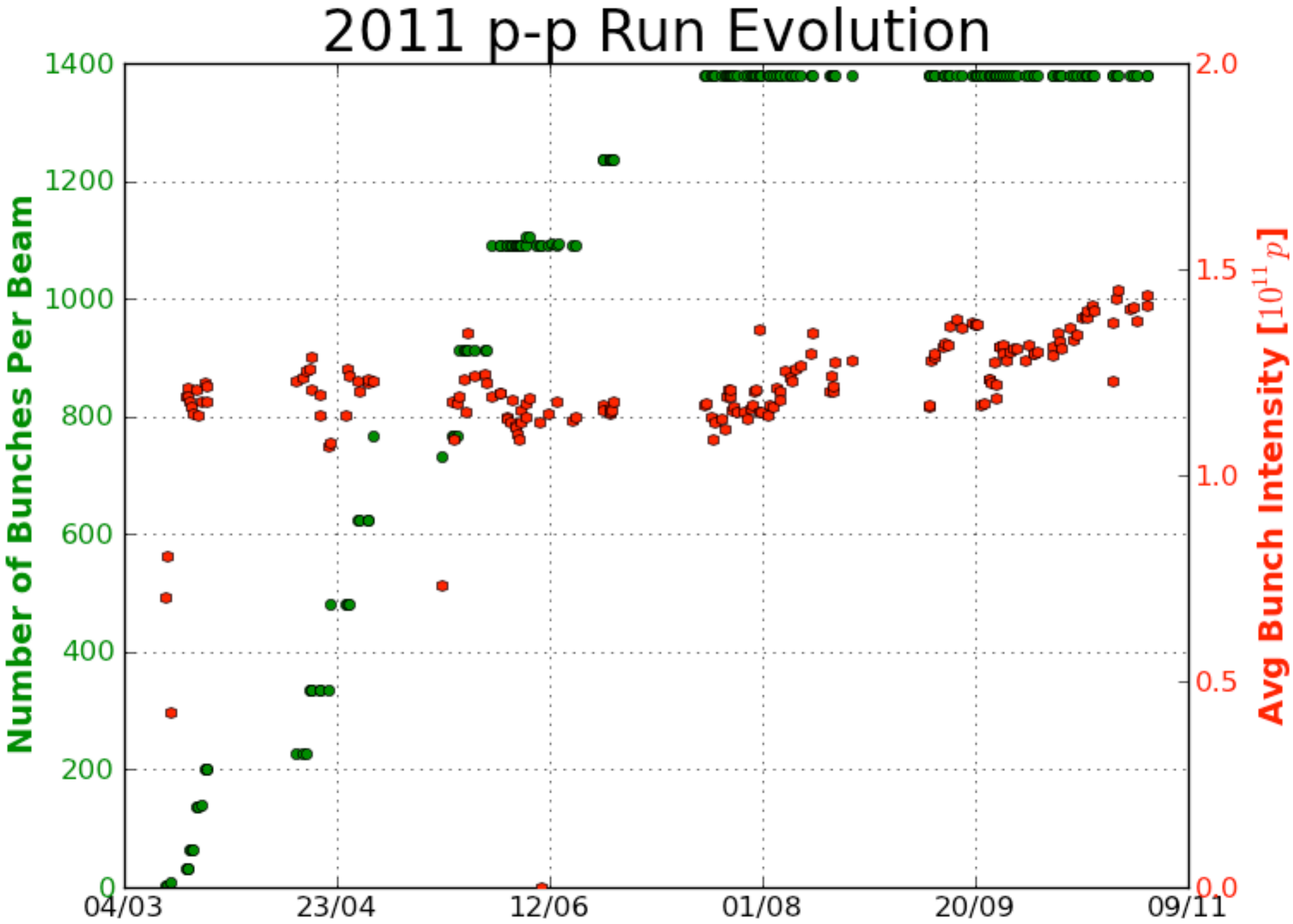
- **Well above Targets set in Evian 2010**
- 2011 Proton Run: **156.6 days** [53.0 days of SB]
  => **123** x(2010 Del Lumi)
- 2011 Ions Run: **28.9 days** [8.0 days of SB]
  =>**16.6** x (2010 Del Lumi)
- **1.38 TeV Proton Run: 3.15** days **L_{Del} = 345.1 µb^{-1}**

2011 Run Records

- **Proton Run: From Fill 1542 - 2267 [15th Feb - 30th Oct]**
  - Most Luminosity delivered in a single Fill: **L_{DEL} = 123.3 pb^{-1} in Fill 2219**
  - Highest Peak Luminosity: **L_{PEAK} = 3693.88 $(\mu b.s)^{-1}$ in Fill 2208**
  - Longest Stable Beams period: **25 hrs 23 min**
  - Shortest Stable Beams period: **0 hrs 3 min 47 sec**
  - Fastest Turn around [SB->SB]: **2 hrs 7 min**
  - Fastest Turn around with 1380 bunches [SB->SB]: **2 hrs 7 min**

- **Ion Run: From Fill 2289 - 2352 [11th Nov - 6th Dec]**
  - Most Luminosity delivered in a single Fill: **L_{DEL} = 6960.0 mb^{-1} in Fill 2330**
  - Highest Peak Luminosity: **L_{PEAK} = 2010.0 $(b.s)^{-1}$ in Fill 2294**
  - Longest Stable Beams period: **8 hrs 4 min**
  - Shortest Stable Beams period: **0 hrs 20 min 48 sec**
  - Fastest Turnaround [SB->SB]: **2 hrs 37min**

Performance: Number of Bunches + Bunch Intensity



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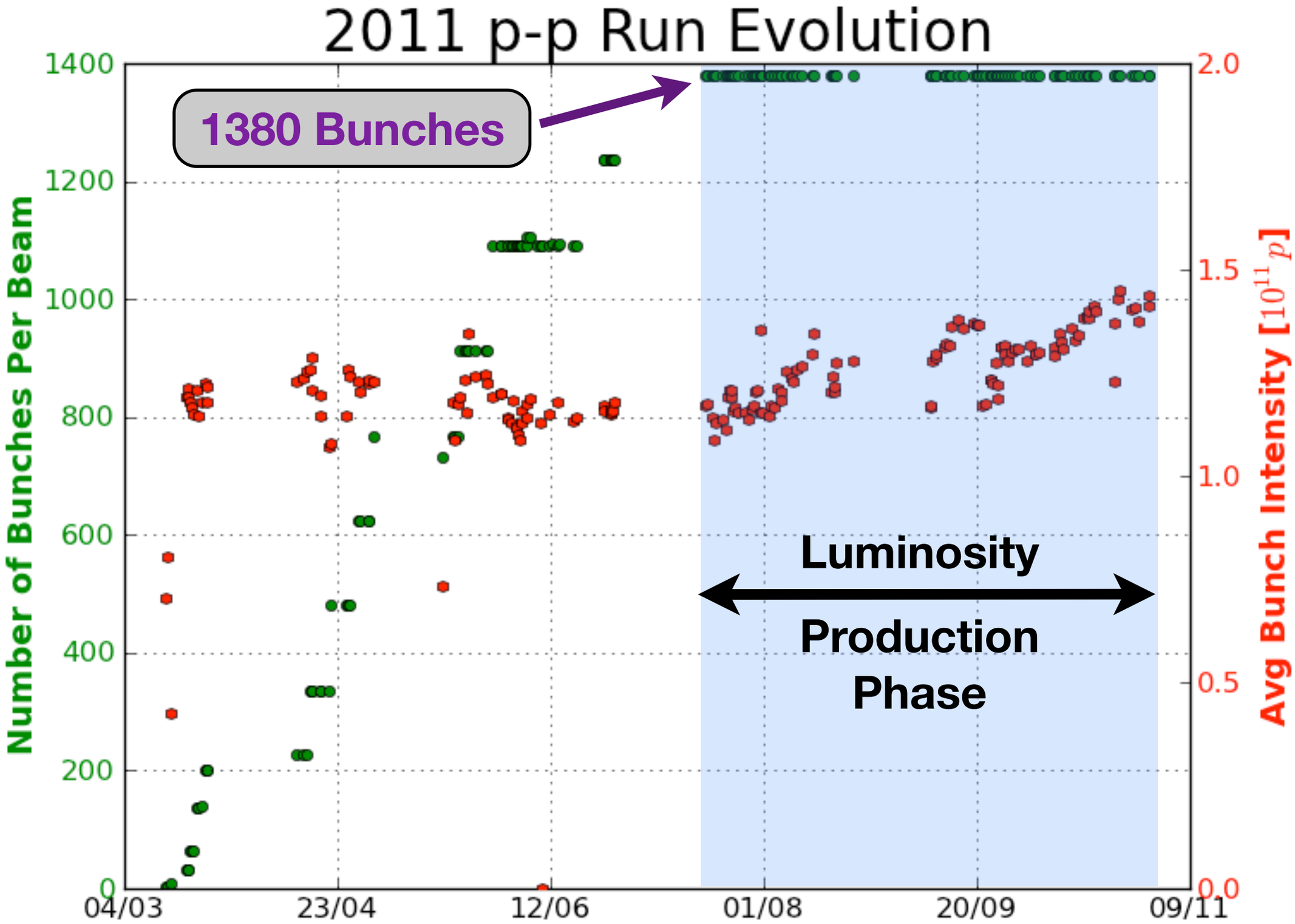

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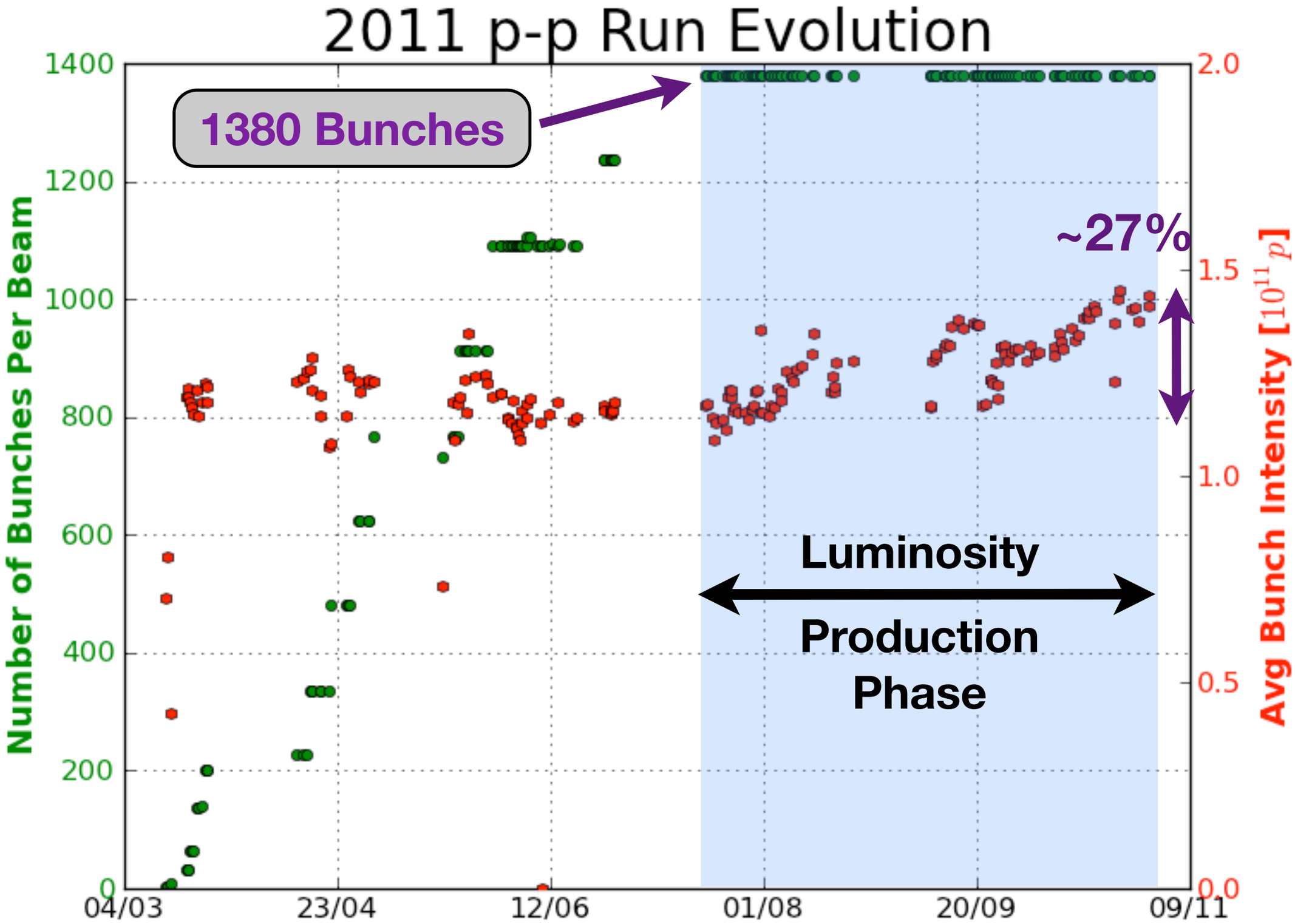
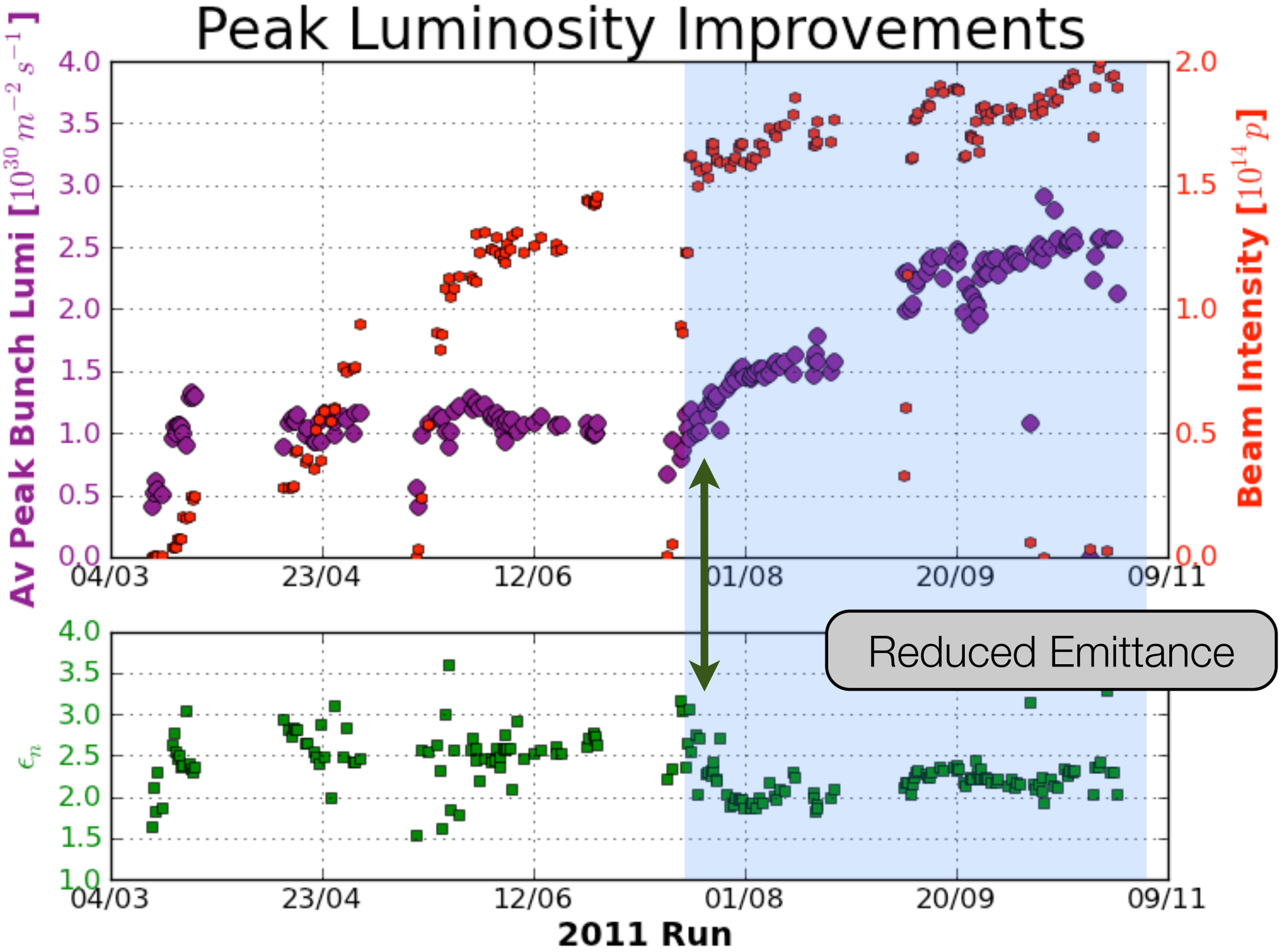
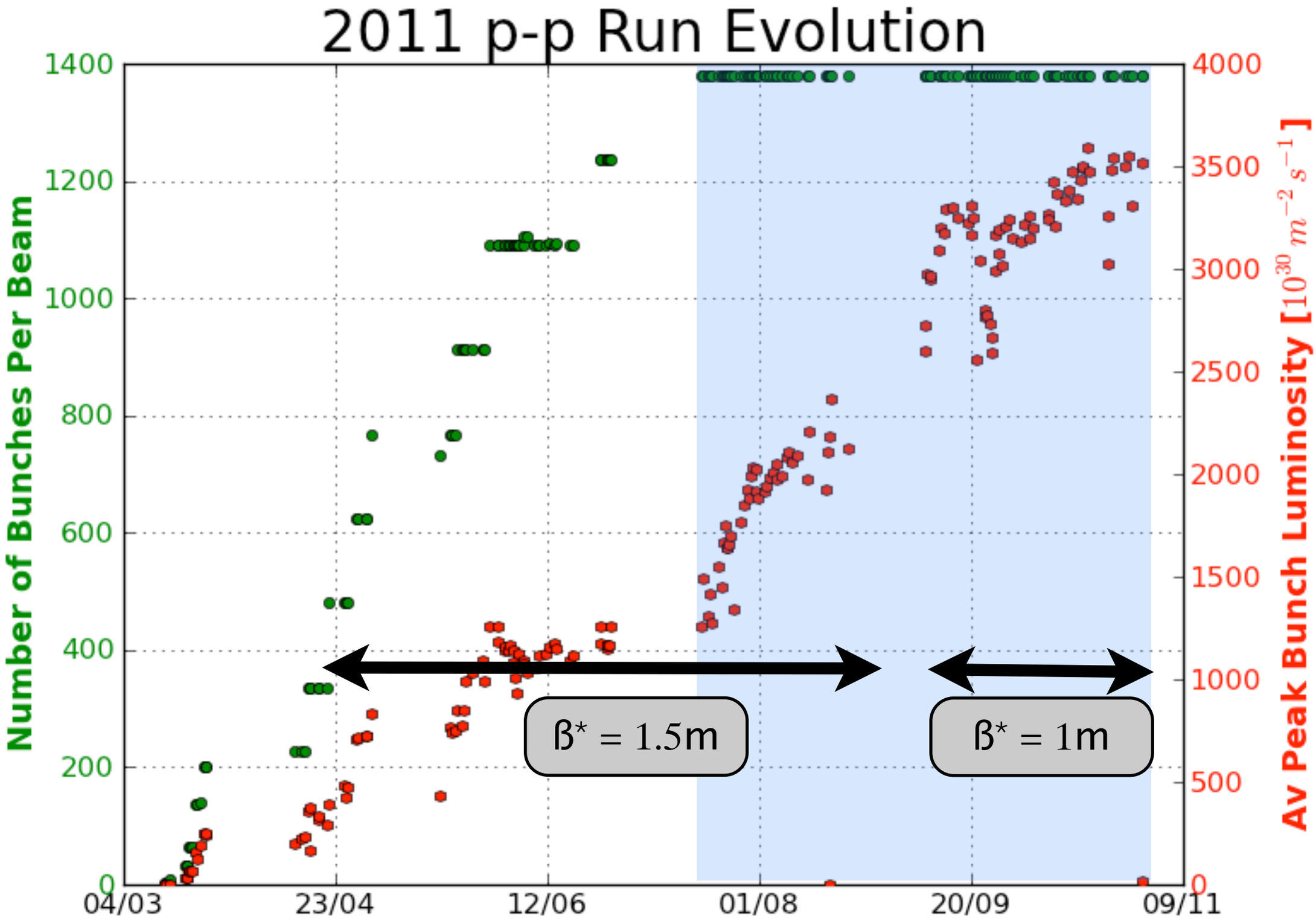


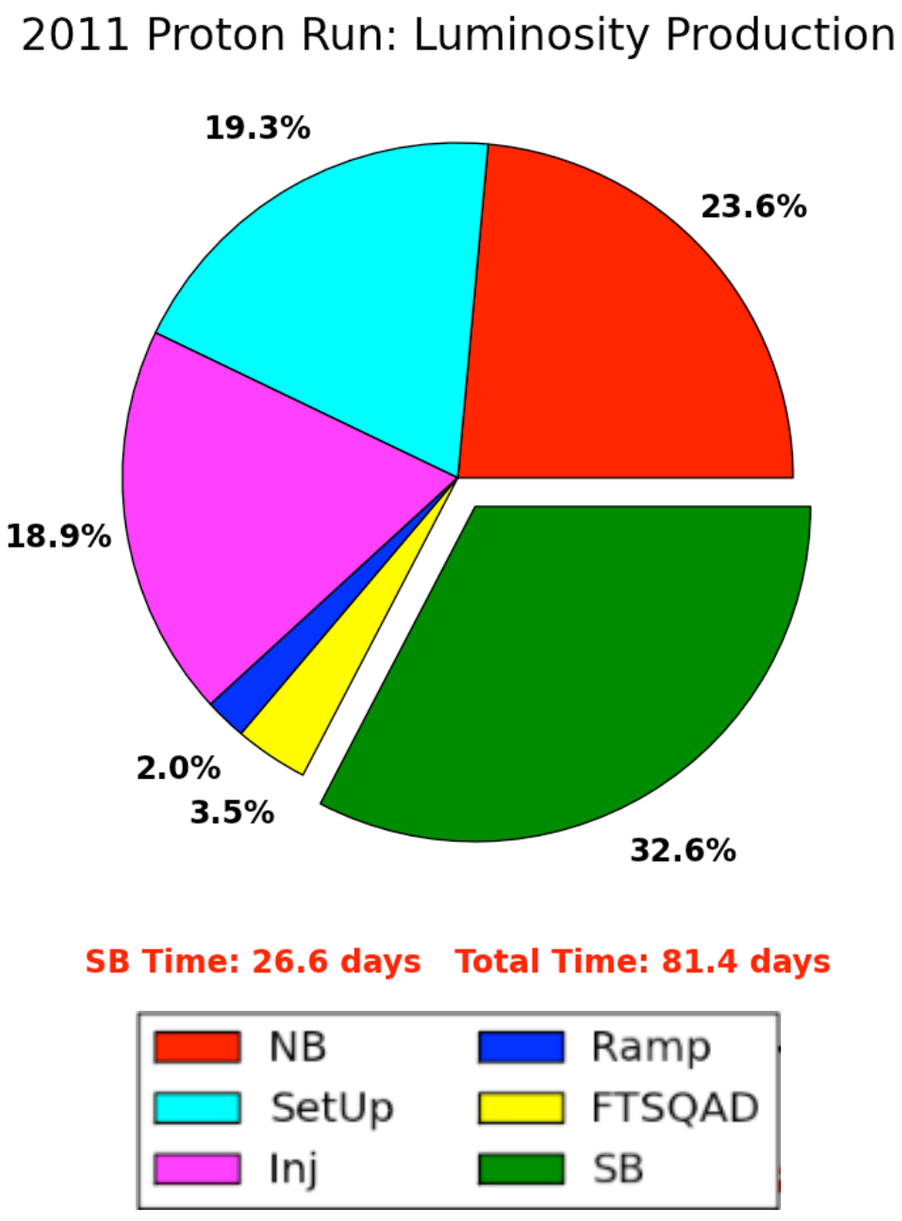
2011 p-p Run: Luminosity Improvements - Emittance



2011 p-p Run: Luminosity Improvements - ß*



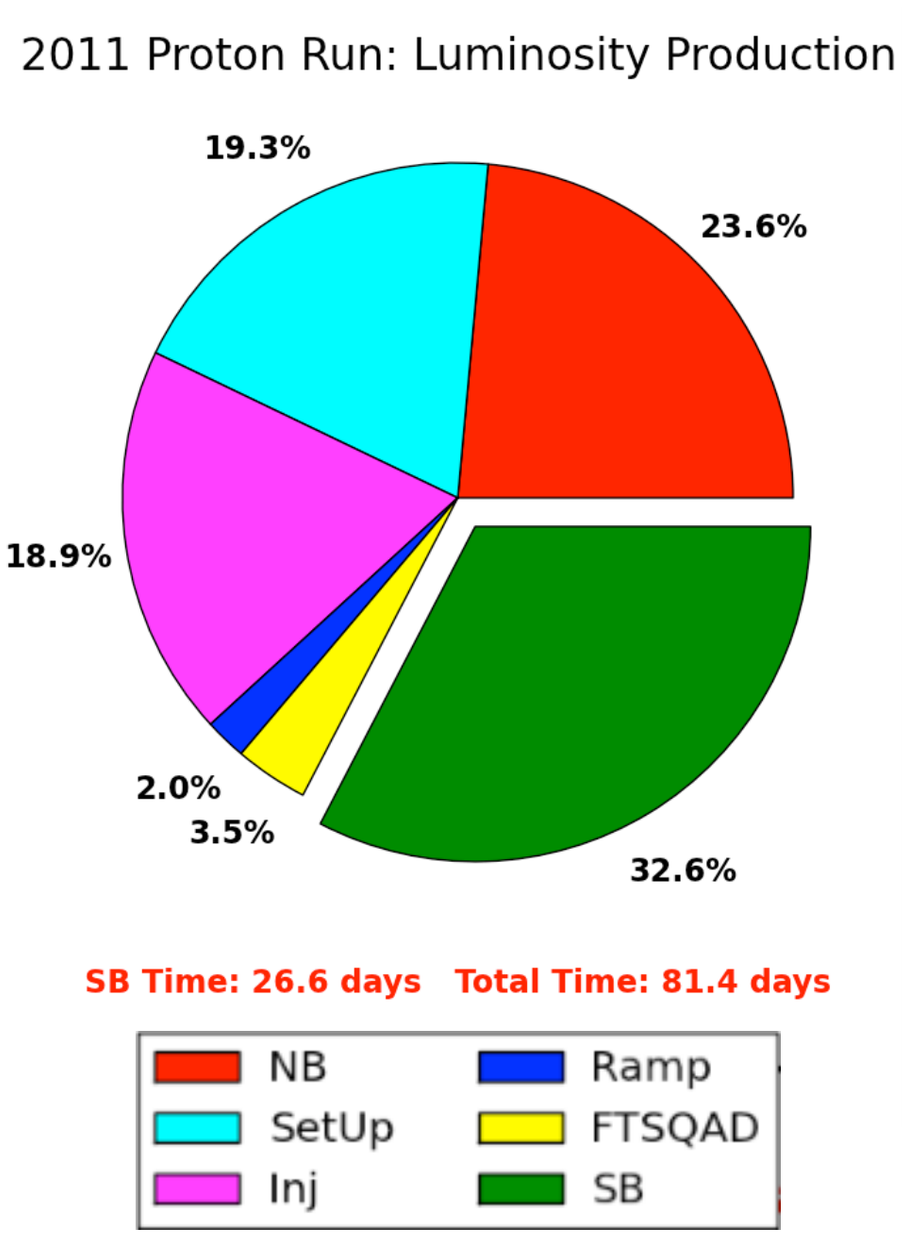
LHC Availability and Performance in 2011



	Days	NB %	SET UP %	INJ %	RAMP %	FT+SQ +AD %	SB %
2011	299.3	25.7	30.5	17.4	1.7	4.3	**20.5**
2011-TS	277.9	23.3	29.5	18.7	1.9	4.7	**22.0**
p-p	156.6	22.0	20.4	19.2	2.2	3.8	**33.8**
p-p LP	**81.4**	23.6	19.3	18.9	2.0	3.5	**32.6**
Pb-Pb	**24.1**	25.0	20.8	13.6	2.2	5.5	**32.9**
MD	33.2	22.9	32.3	36.8	1.2	6.0	**0.8**
High ß	4.2	6.2	43.7	10.3	3.2	35.4	**1.1**

p-p, Pb-Pb runs do not include TS or MD time

LHC Availability and Performance in 2011



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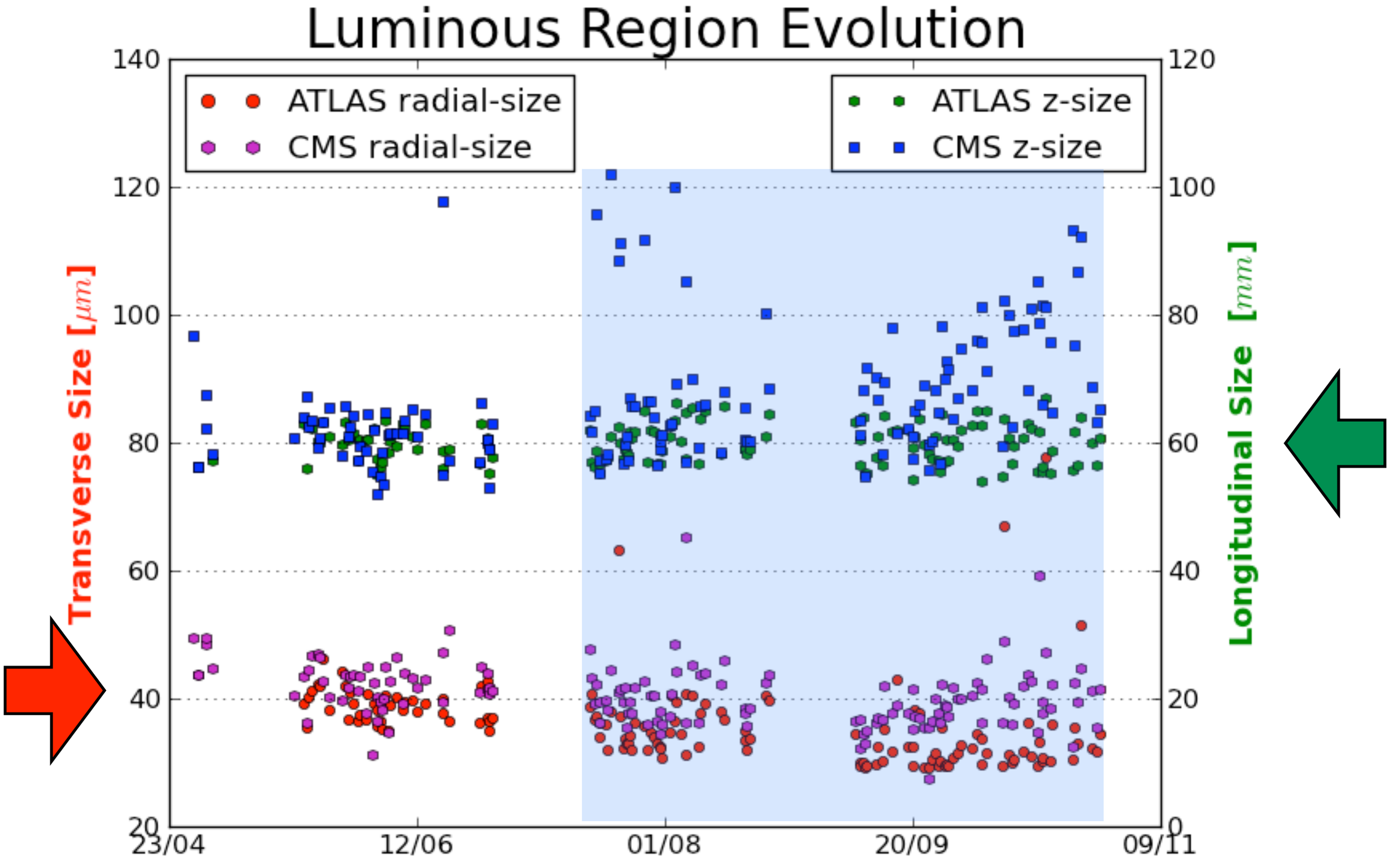
Hubner factor: $H = 11.57 \times L_{Del} / (D \times L_{Peak})$ **$H_{\_Expected} = 0.2$**

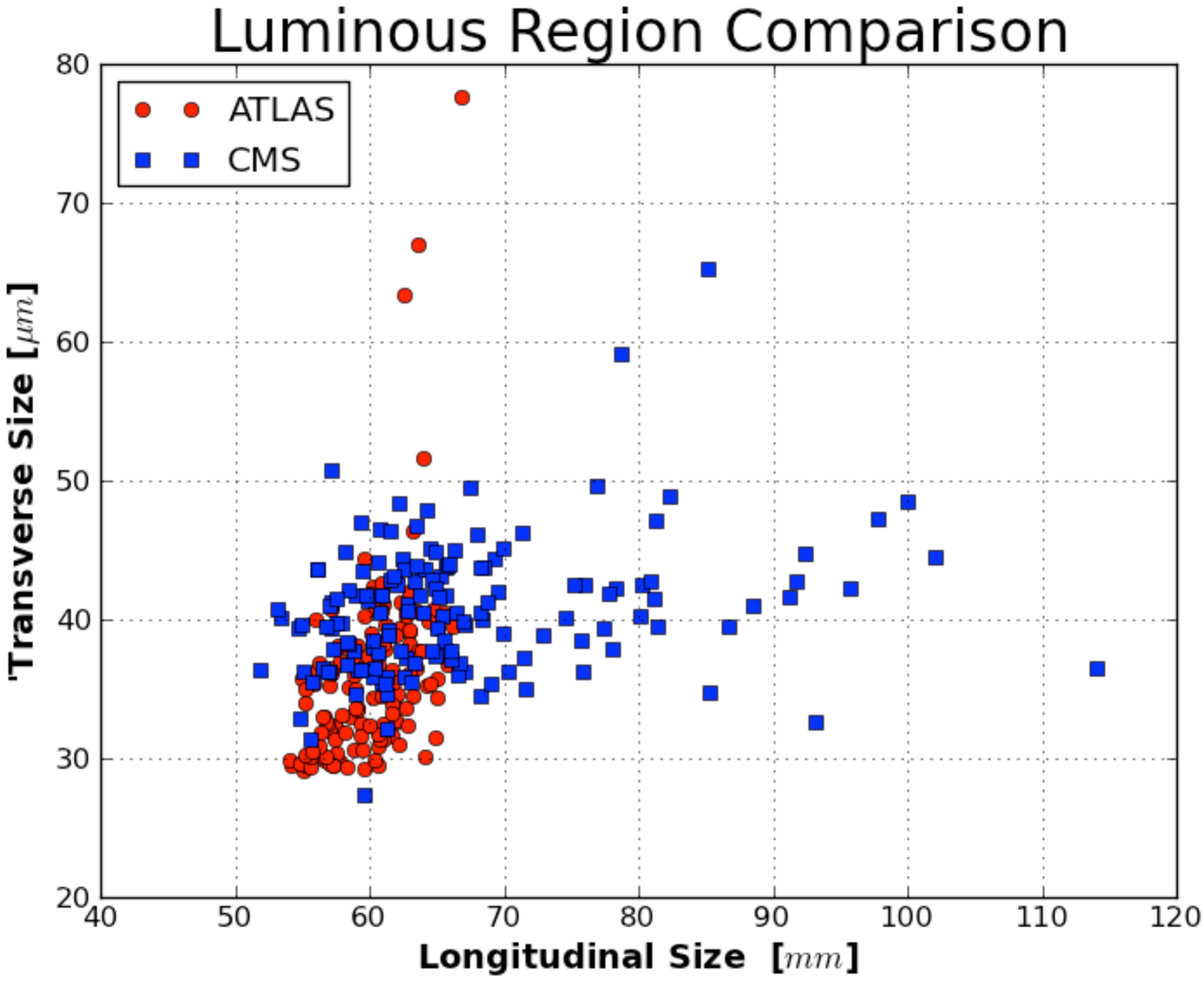
p-p (LP): 81.4 days $L_{Peak} = 2572$ $(\mu b.s)^{-1}$ $L_{Del} = 4.01$ fb^{-1} => **H = 0.22**

Pb-Pb: 24.1 days $L_{Peak} = 512$ $(b.s)^{-1}$ $L_{Del} = 167.6$ μb^{-1} => **H = 0.24**

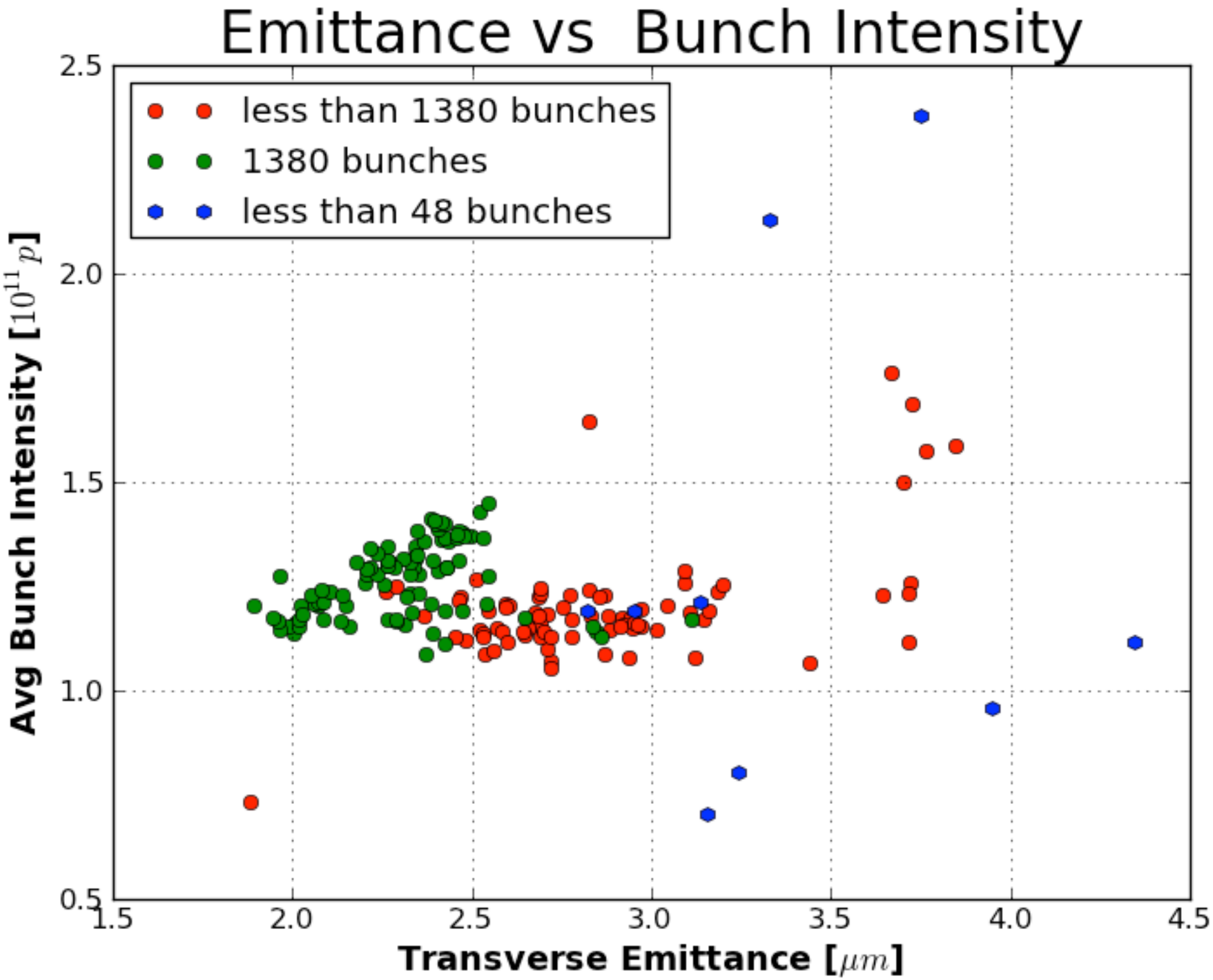
Luminous Region Evolution over the Run



Luminous Regions: ATLAS and CMS



2011 Performance: Emittance vs Intensity



Transverse Emittance determined from luminosity at start of Stable beams

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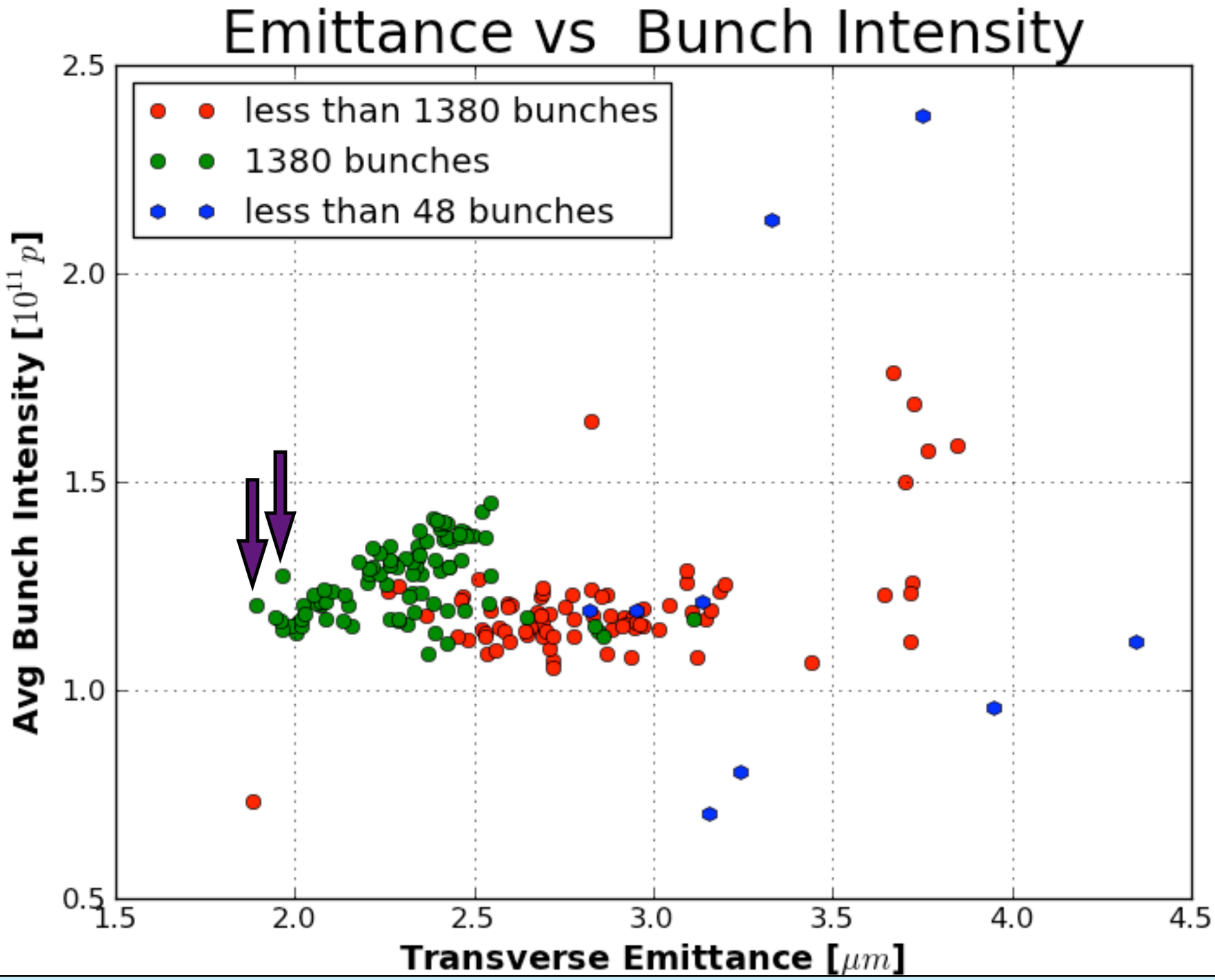
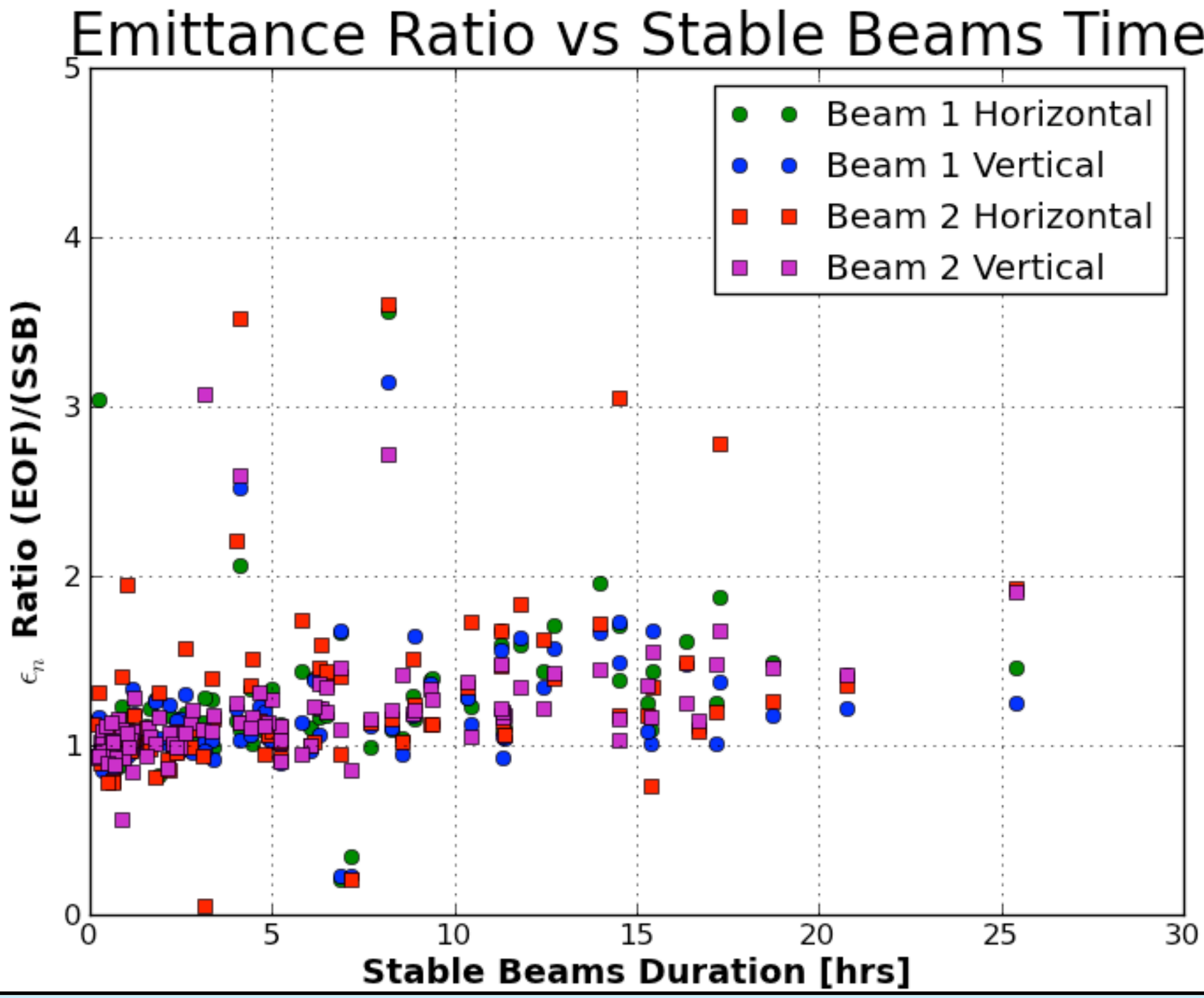


Transverse Emittance determined from luminosity at start of Stable beams

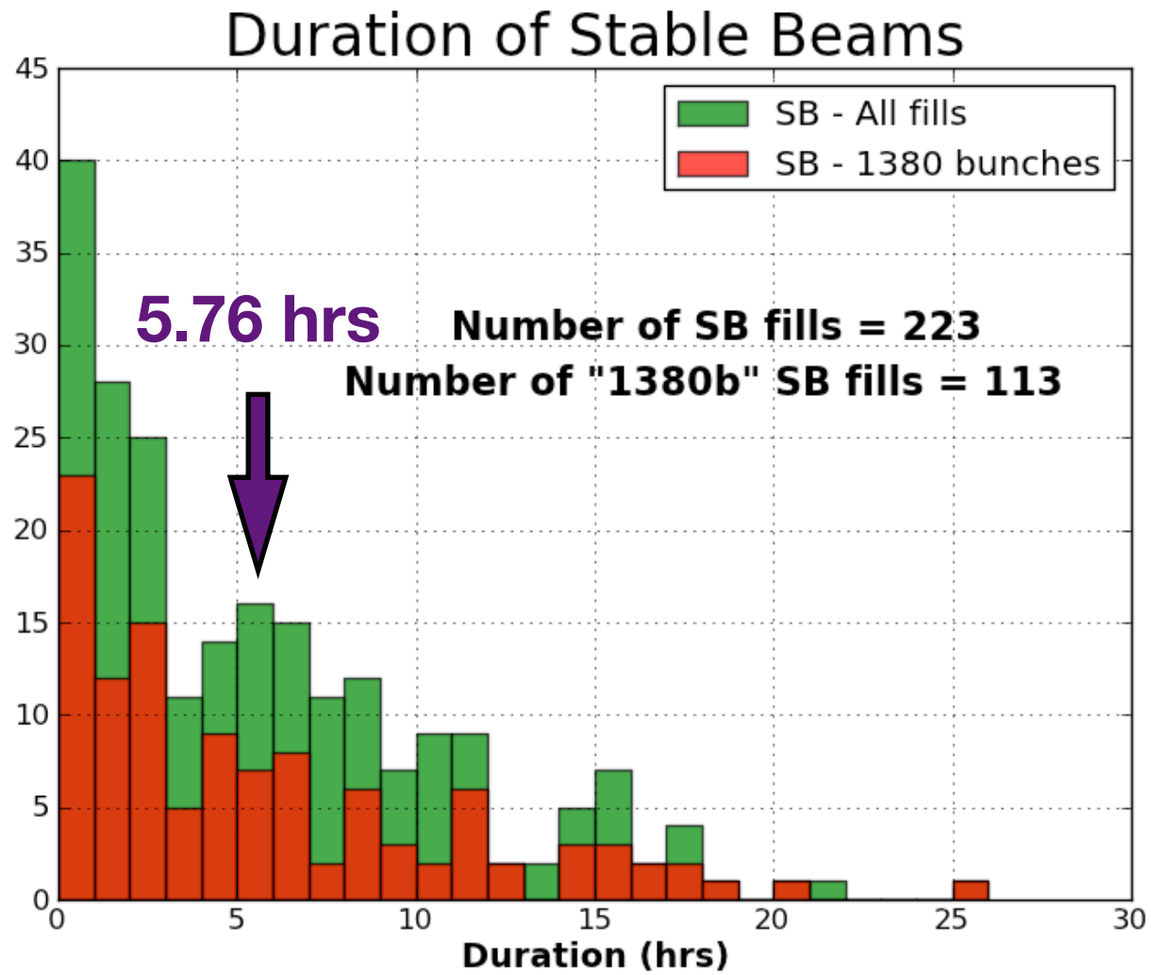
Fill 2030: emit= 1.89 Bunch Intensity = 1.20e11p Bunch length = 1.22ns
Fill 2032: emit= 1.96 Bunch Intensity = 1.28e11p Bunch length = 1.18ns

Evolution of Emittance Variation over a Fill



Both beams show some gentle blowup with fill duration.
Outliers may not be just BSRT measurement artifacts

Performance: Stable Beams Duration



Average SB Duration: 5.76 hrs

Consistency Check

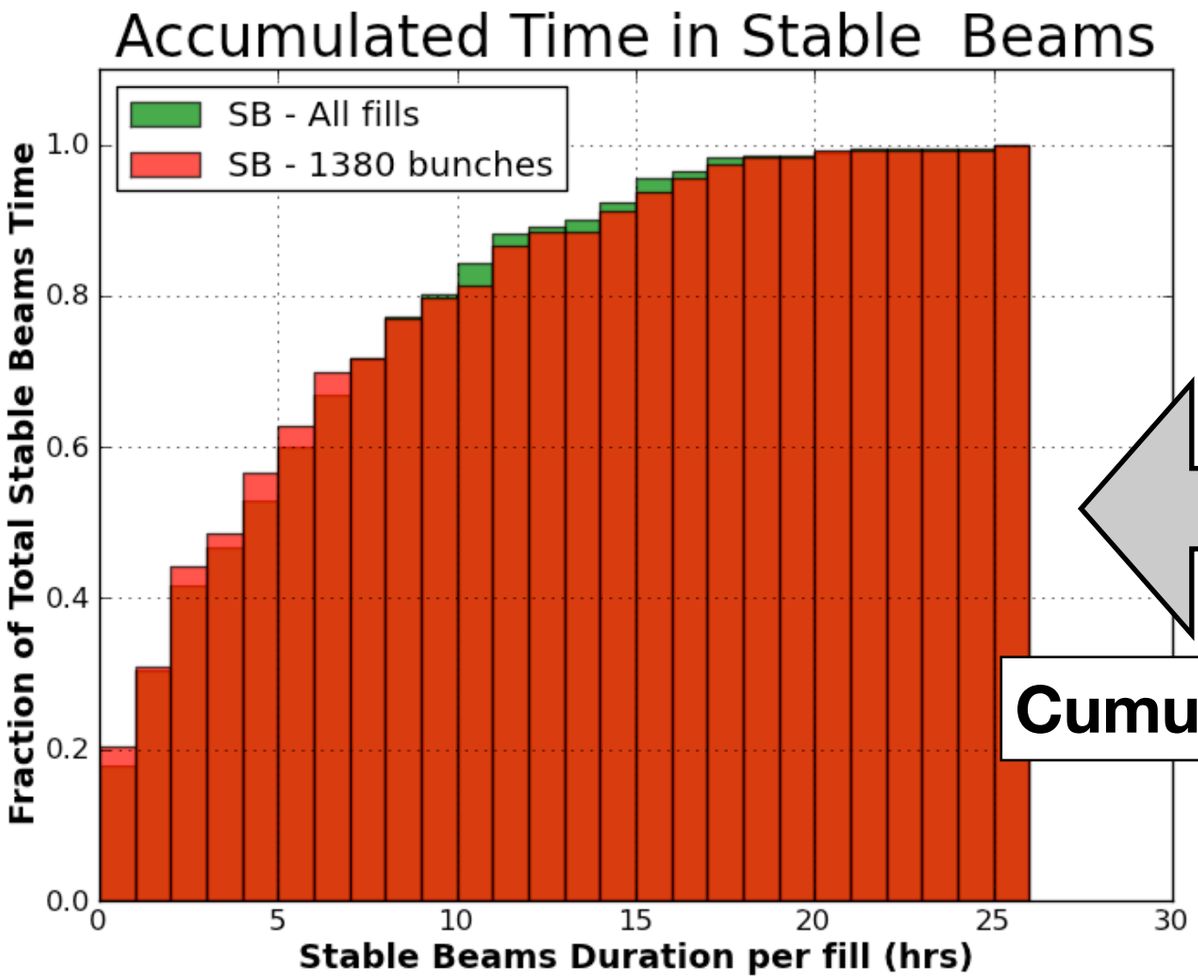
Av Turn around (SB->SB) = **12.62 hrs**

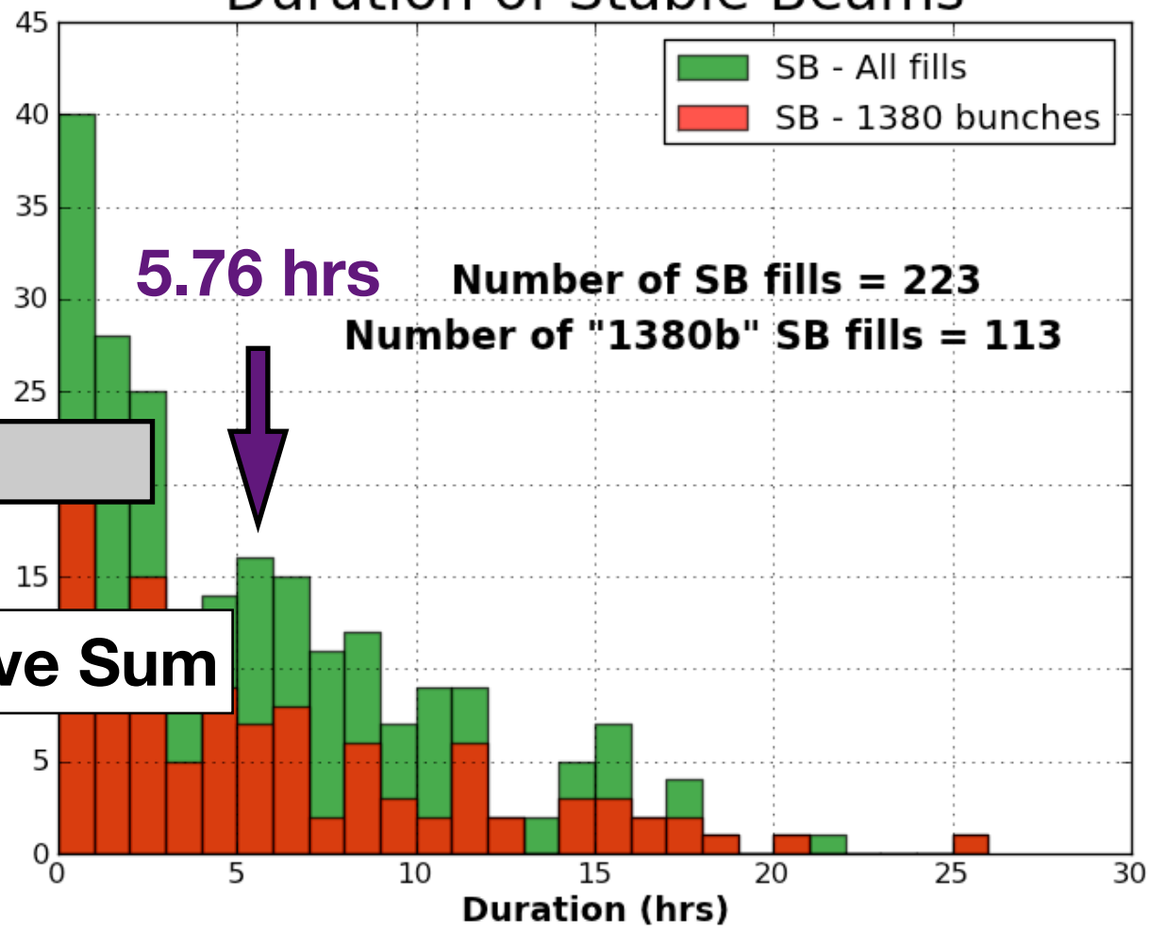
Time in Stable Beams = **33.8%**

Mean SB Time = 12.6 hrs x 33.8/66.2

= 6.44 hrs

Performance: Stable Beams Duration





Cumulative Sum

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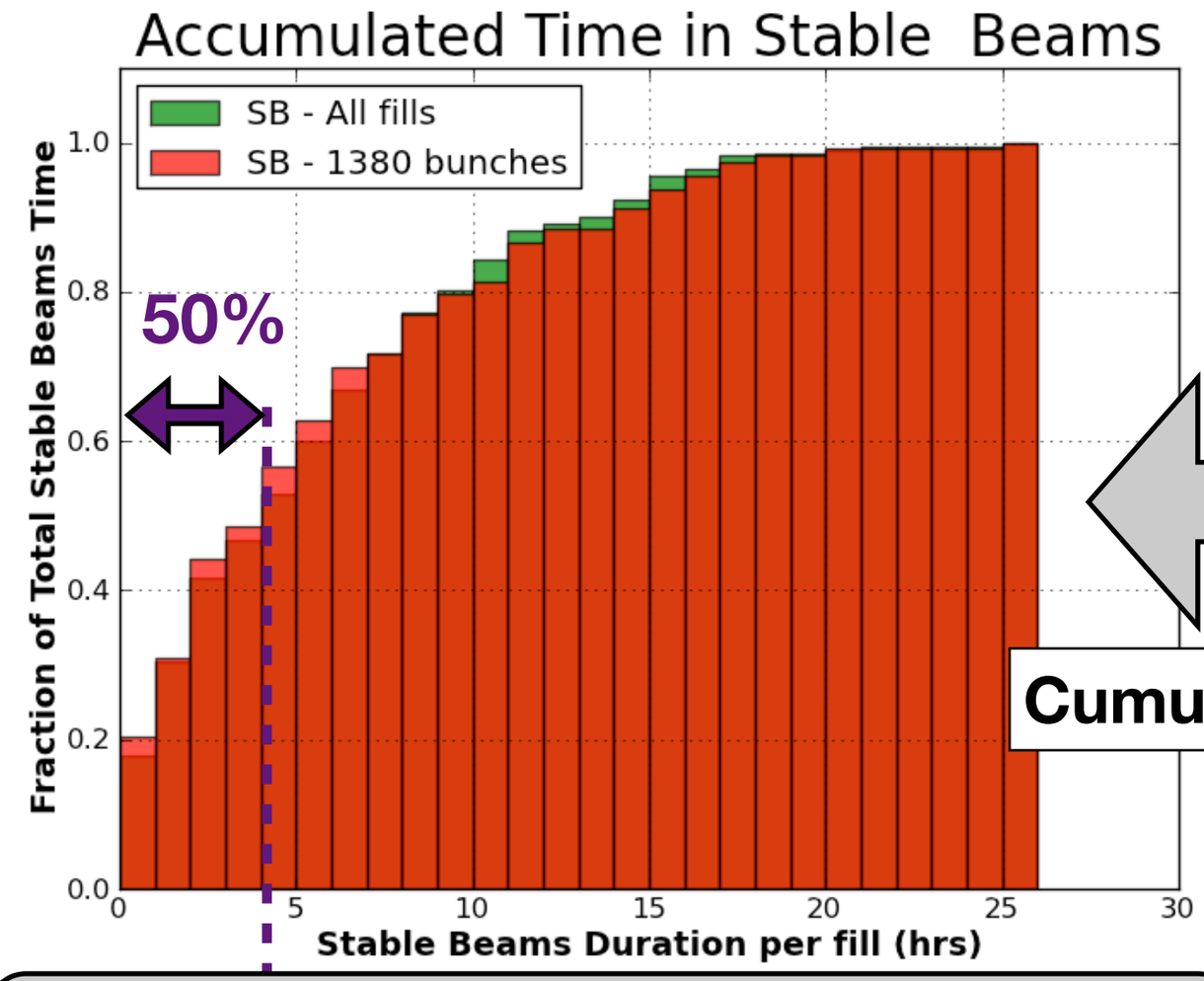

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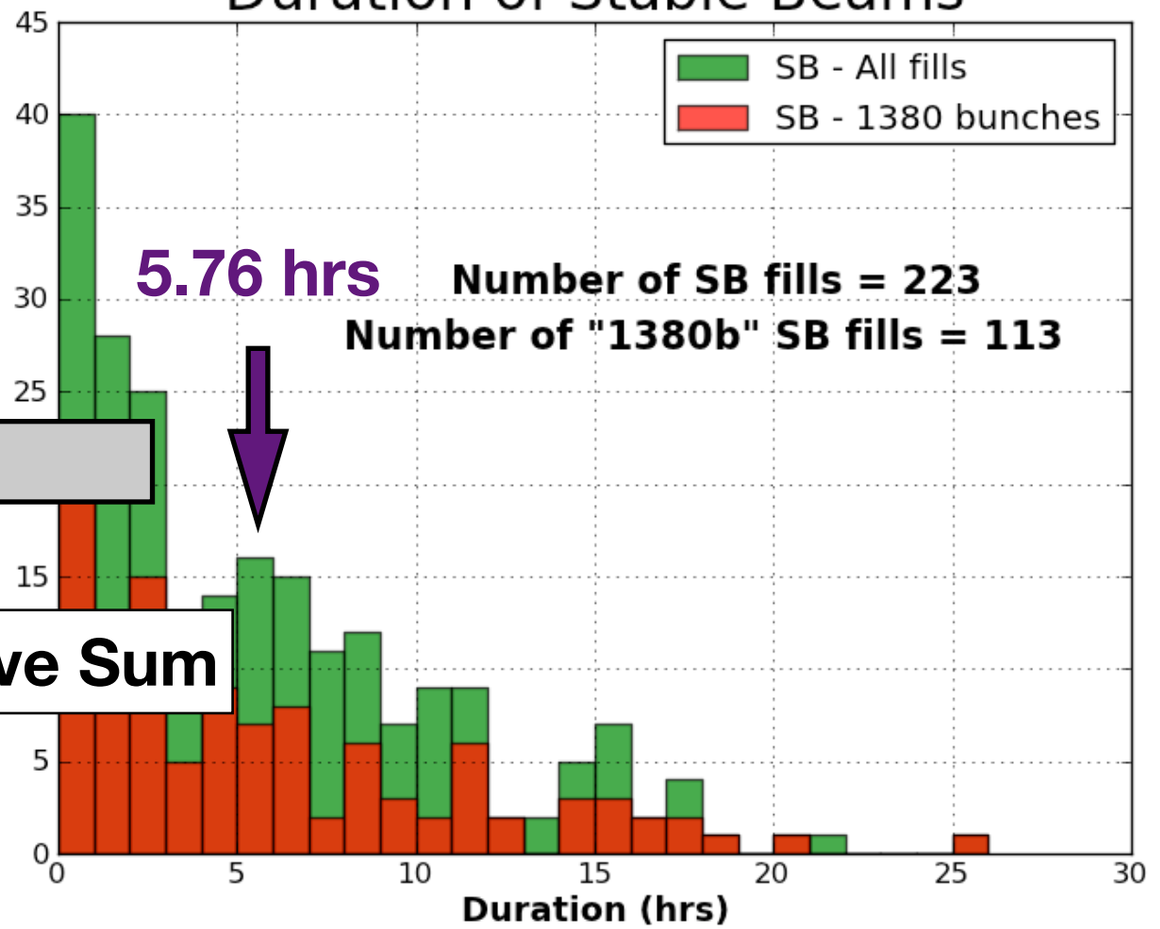

50:50 Point: ~4 hrs

50% of SB time was produced with fills of 4 hrs or less of SB

=> **Optimization of turnaround time can only be beneficial**

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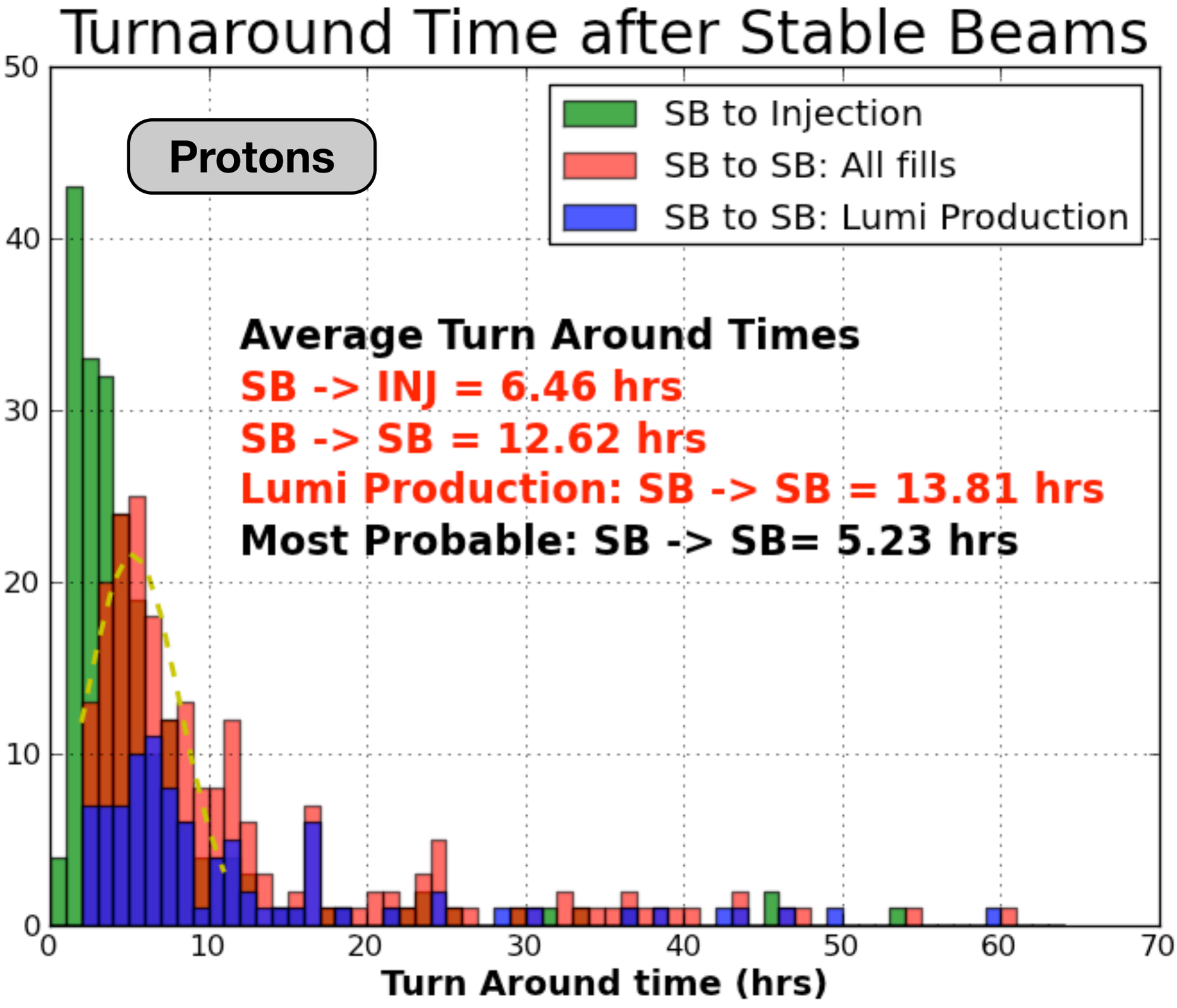

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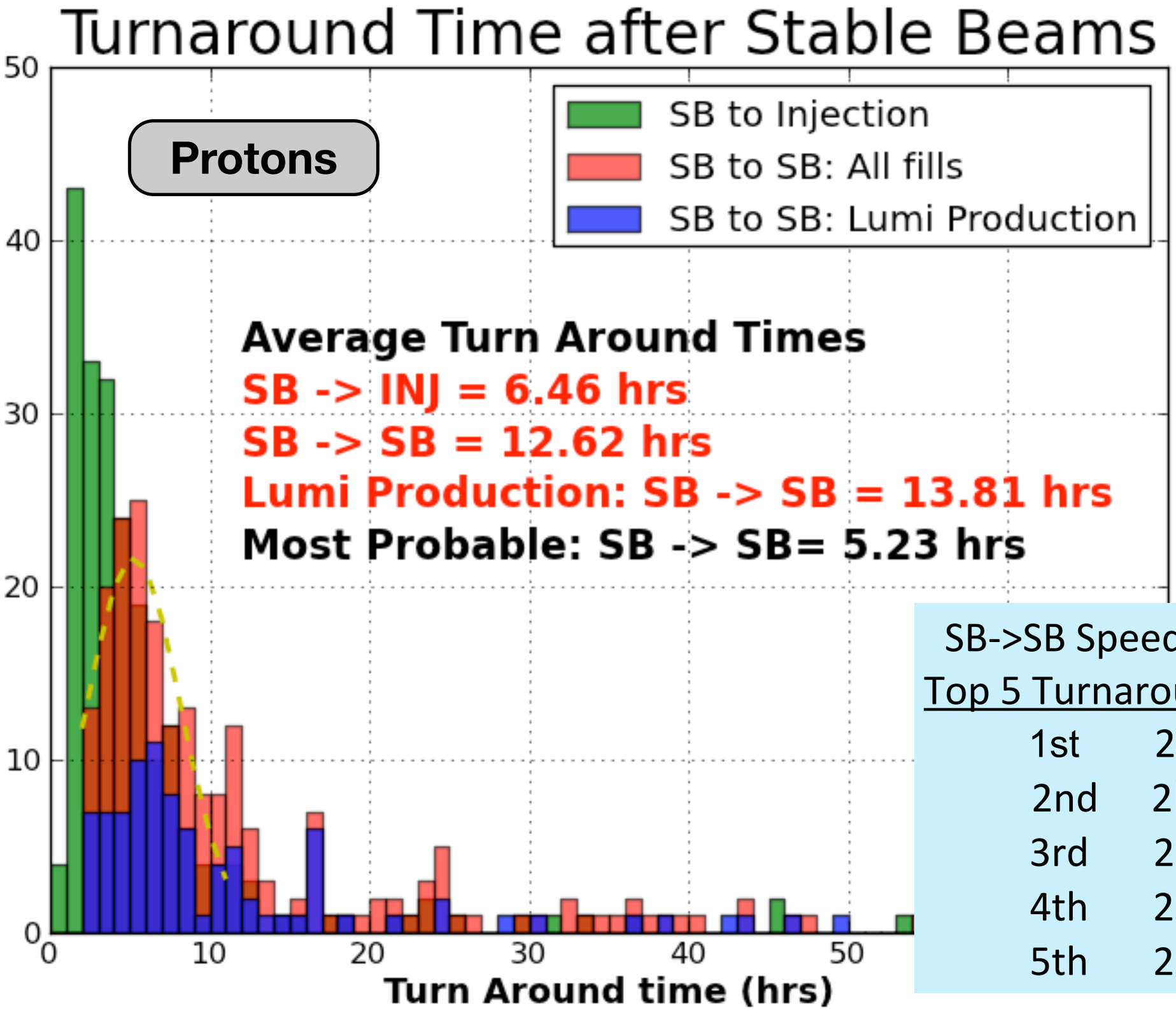
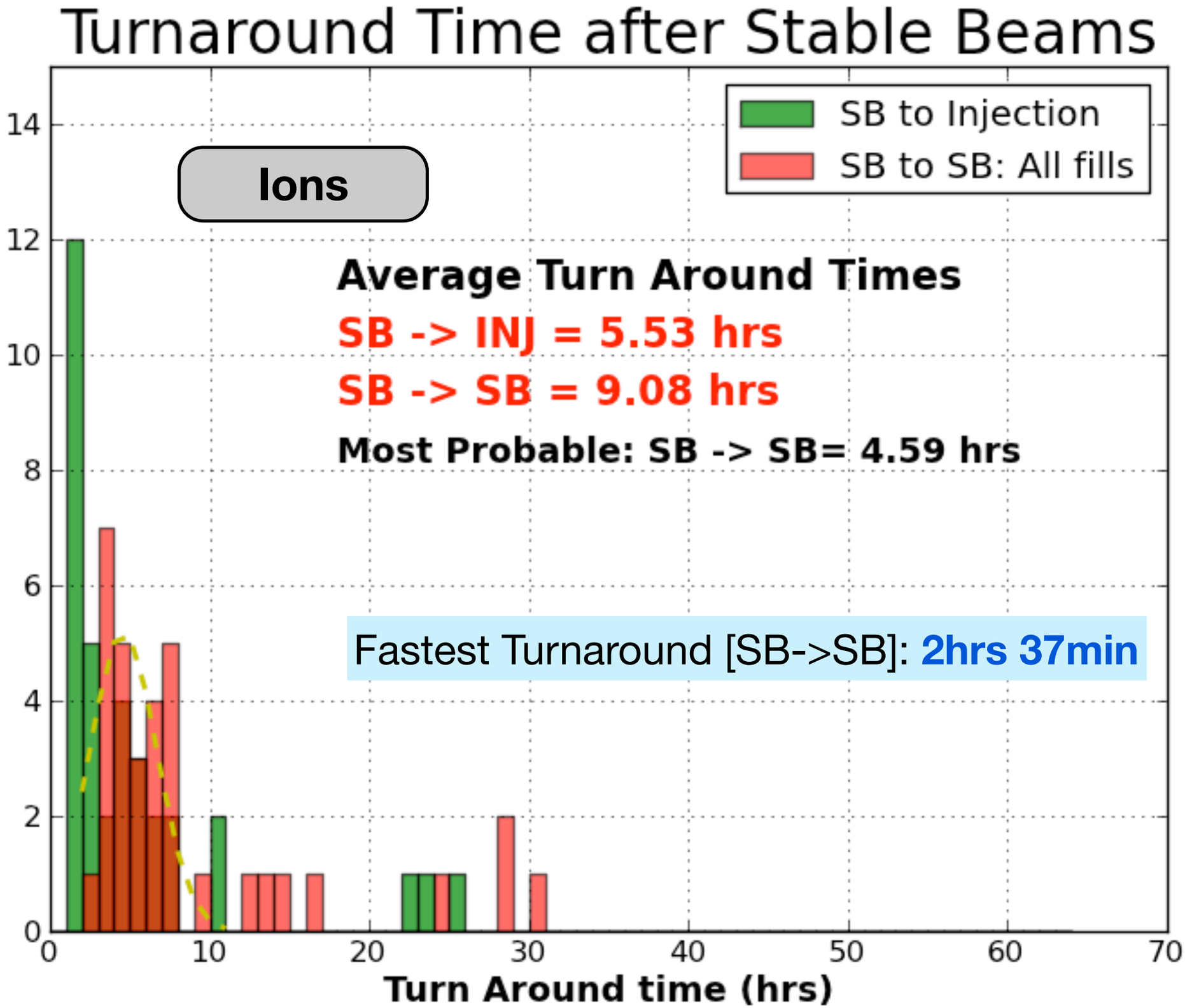
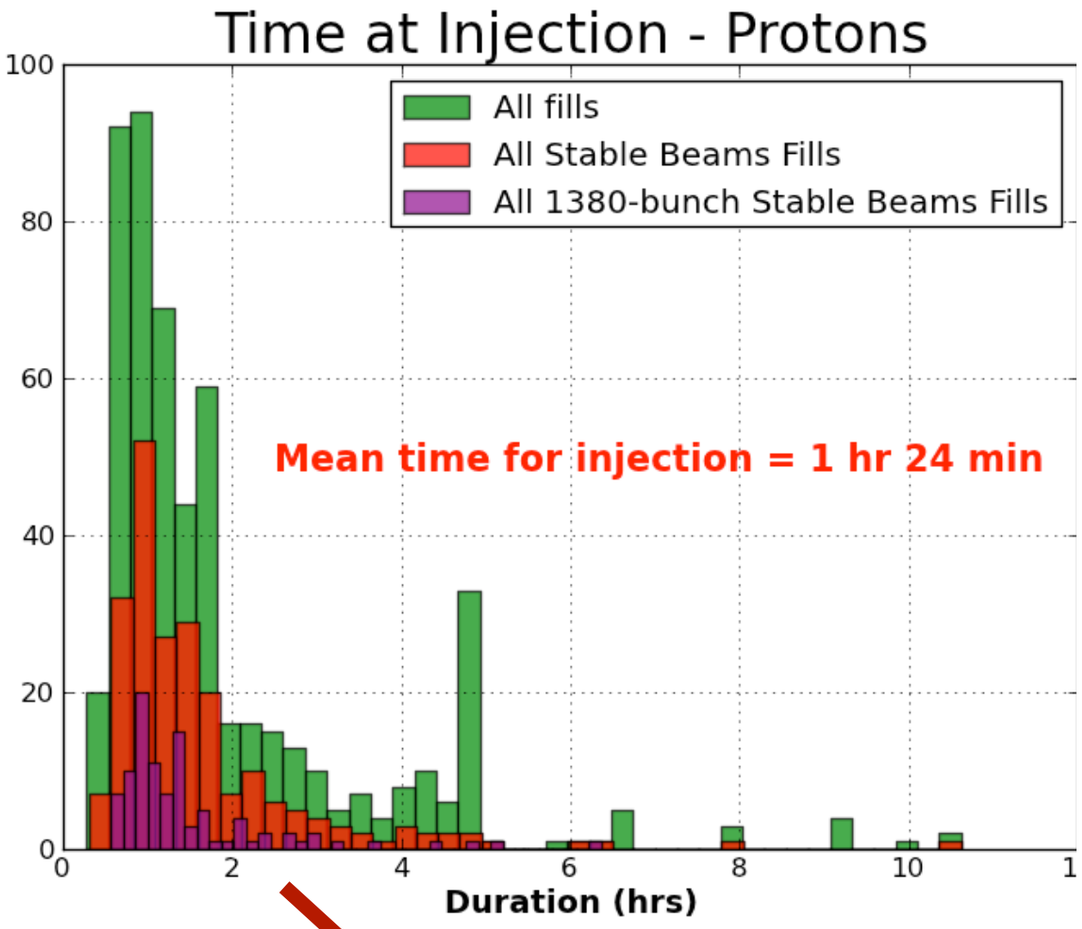


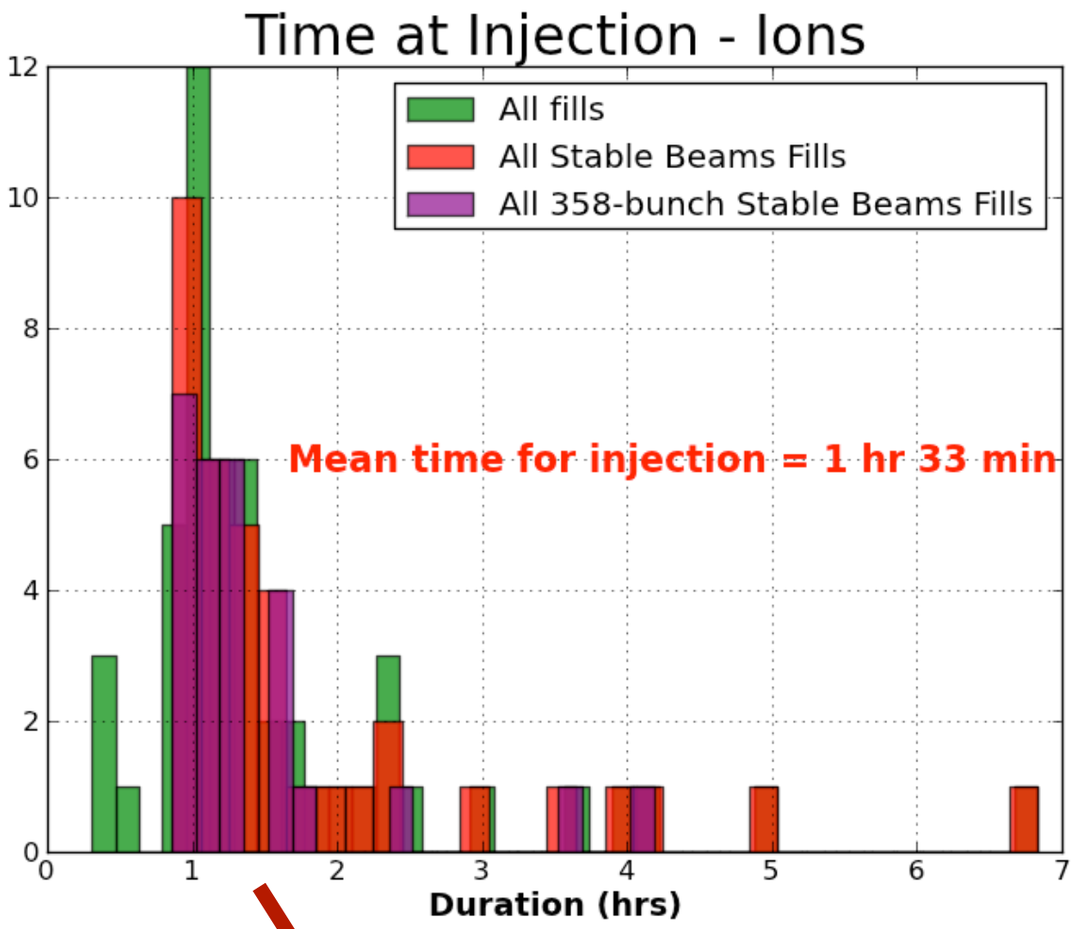
SB->SB Speed records	
Top 5 Turnaround times	
1st	2h07
2nd	2h13
3rd	2h28
4th	2h29
5th	2h29

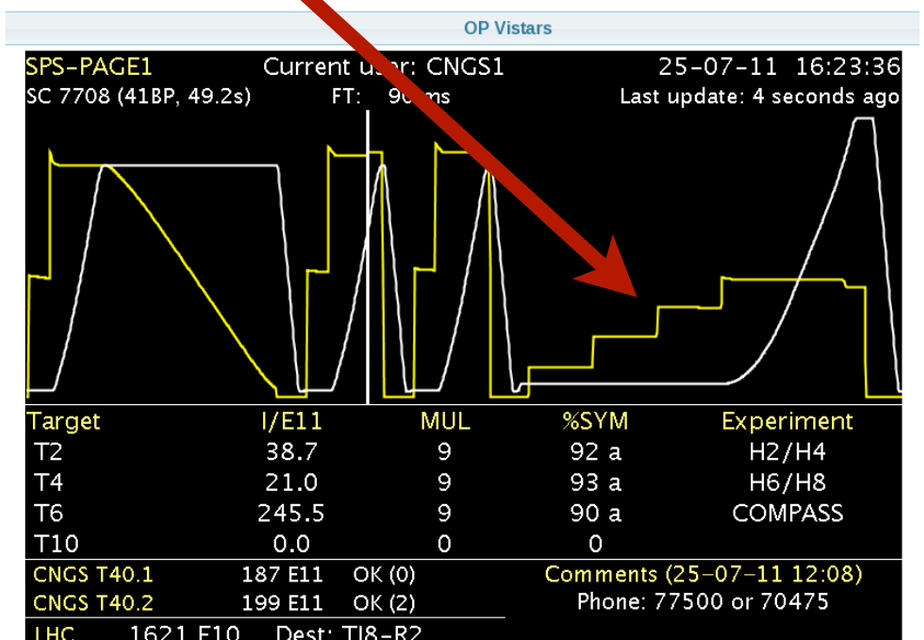
Performance: Turnaround

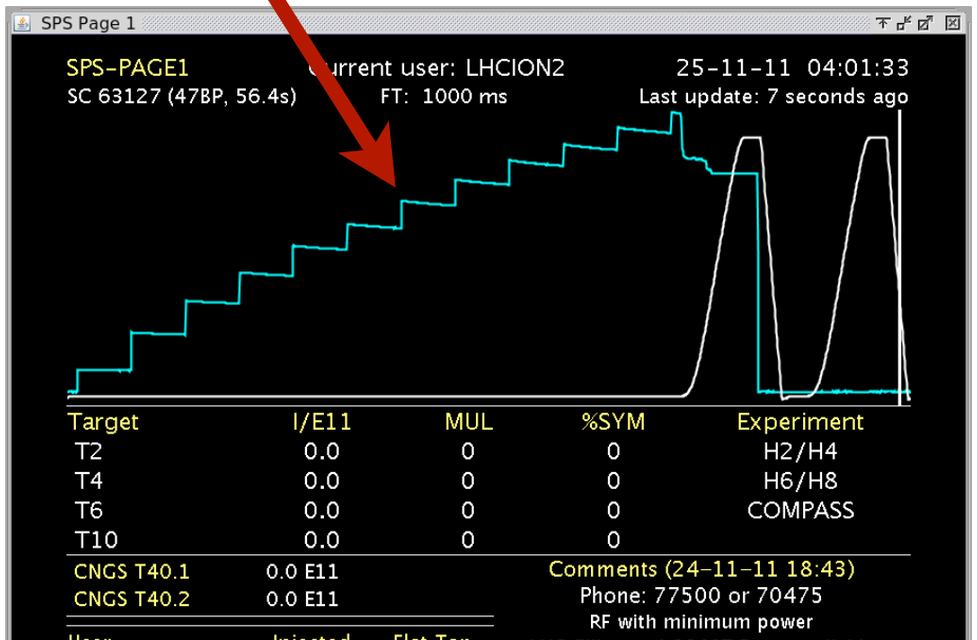


Performance: Time at Injection









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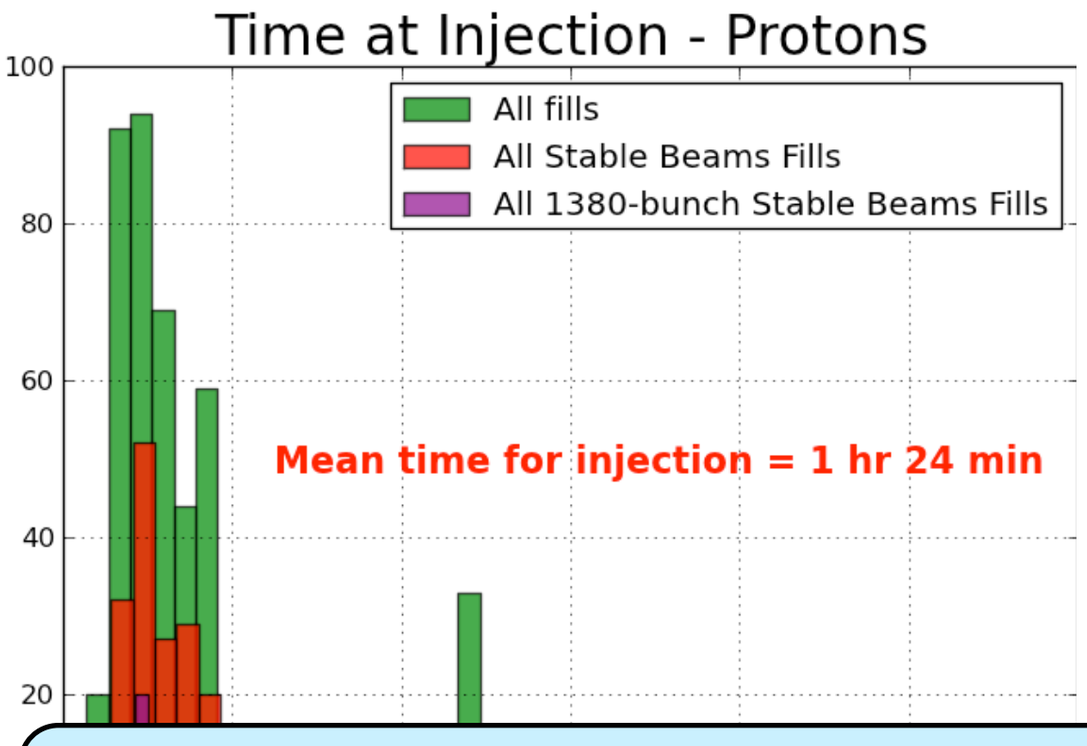
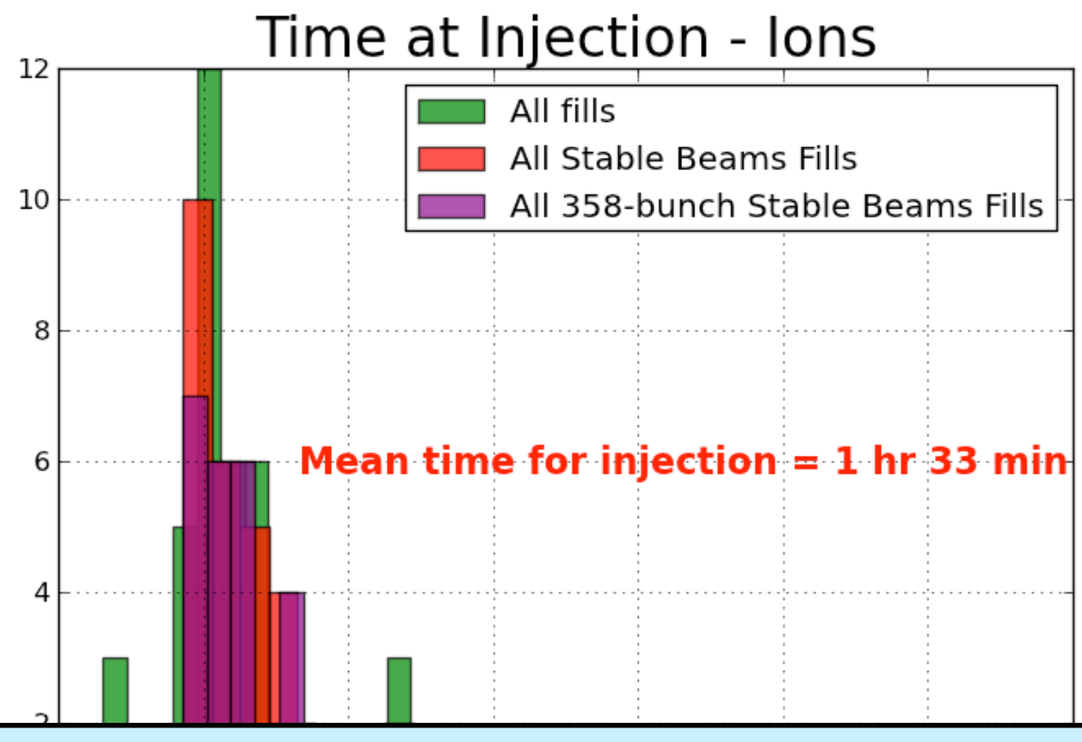
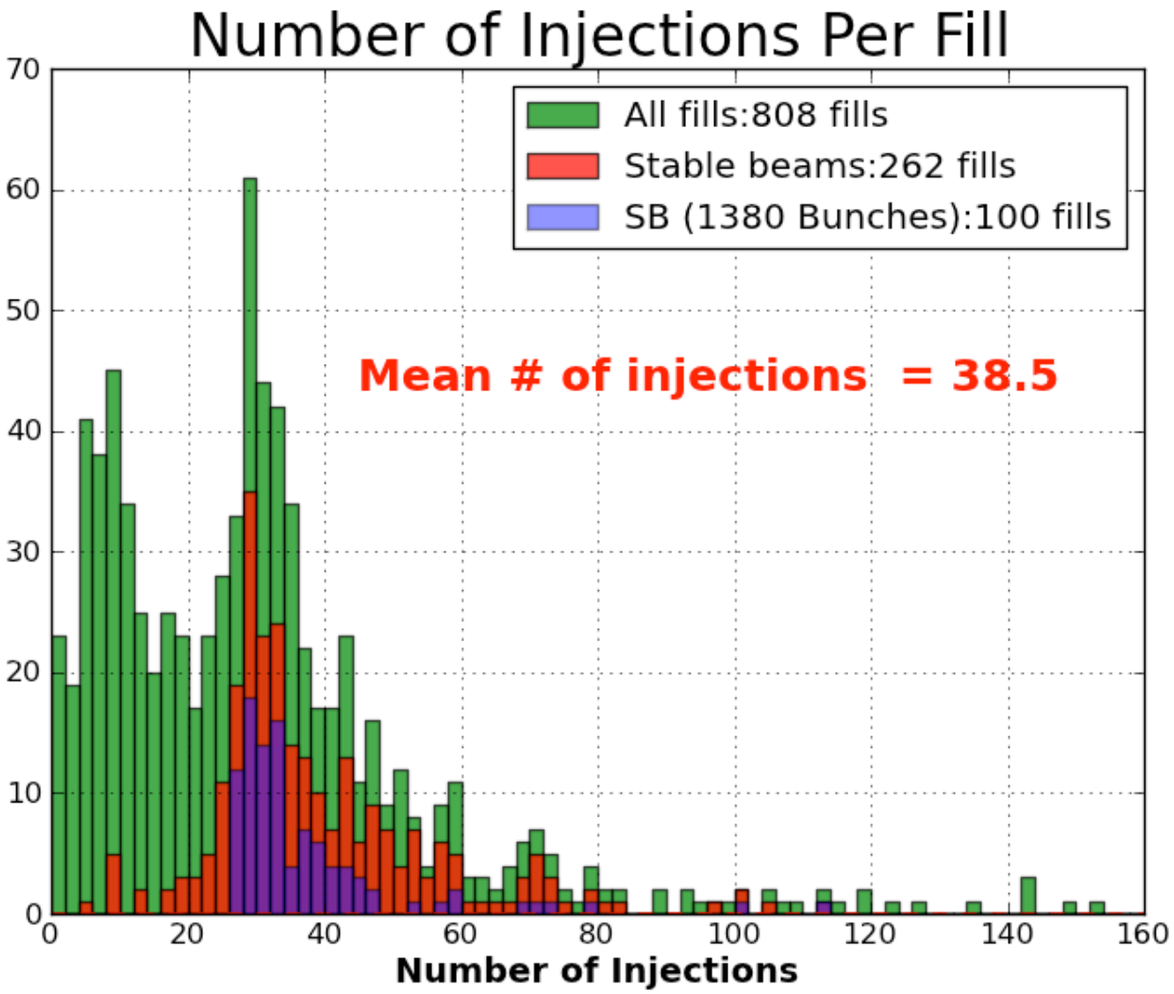


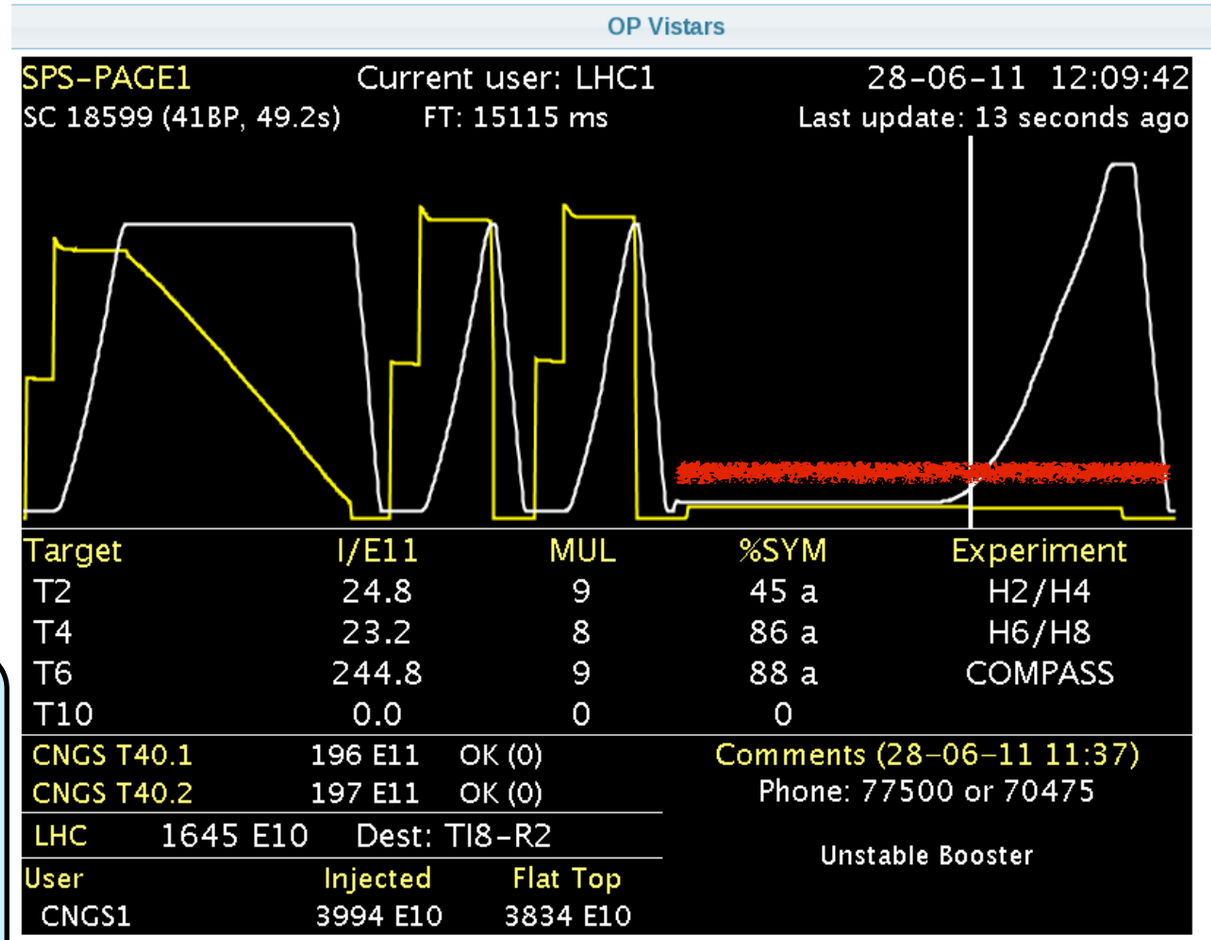


In 2011 filling for protons and filling for Ions took about the same time! (Ions just felt slower ...)
Dedicated LHC filling (protons) could improved turnaround time

Turnaround improvements: Injection



SPS supercycle: **41 BP** => **49.2 sec**
Could be reduced to **28 BP**



Dedicated LHC filling (SPS): 28 BP =>33.6 sec

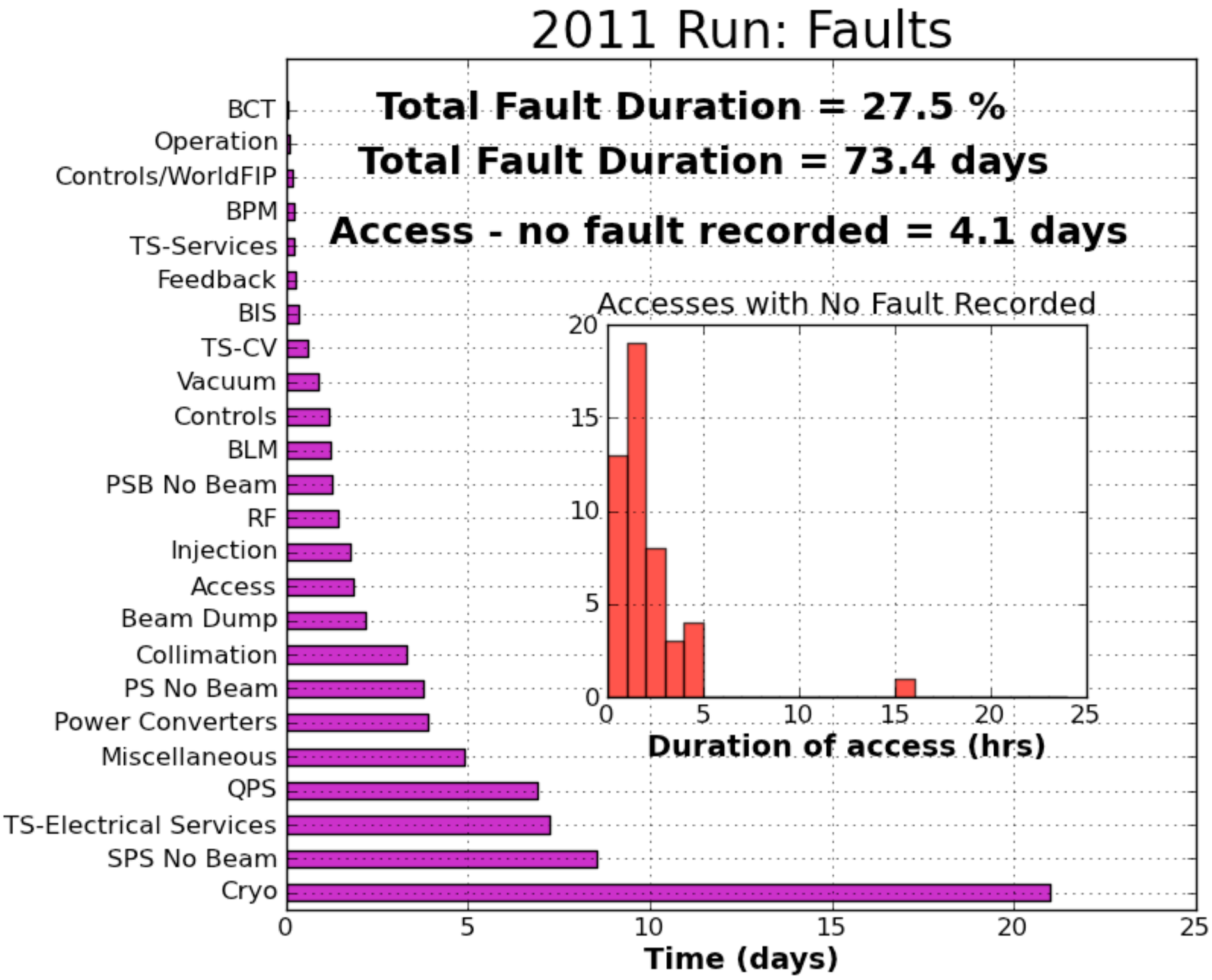
Recoverable Time = 38.5 x 800 x 15.6sec
= **5.6 days**

Dedicated LHC filling:

Not just a technical issue: **Sharing beam time with other CPS and SPS Users**

Faults and Downtime

2011 Faults tracking: As seen by the e-logbook



48 accesses with no fault registered: Typically for QPS

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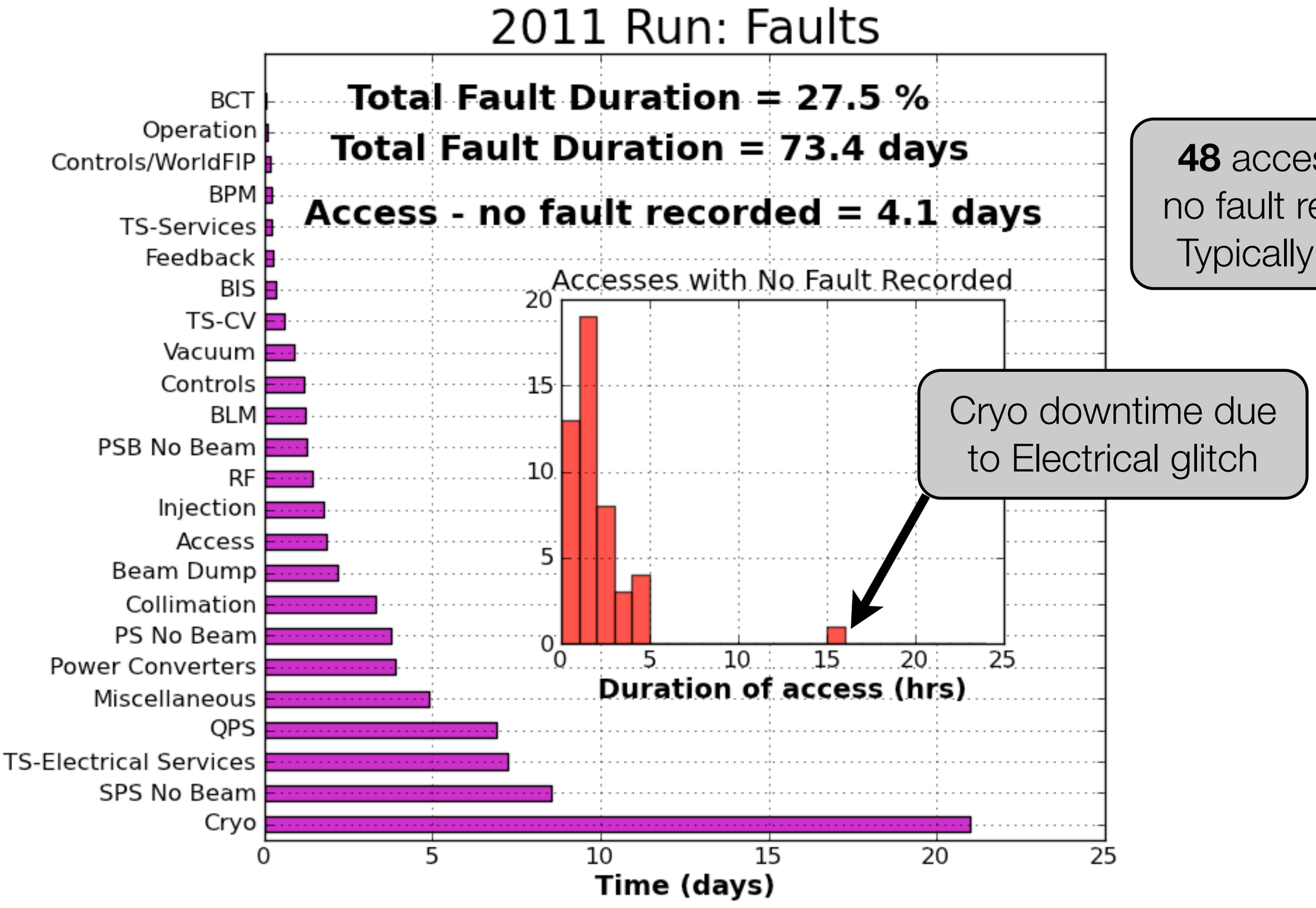

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Cryo downtime due to Electrical glitch

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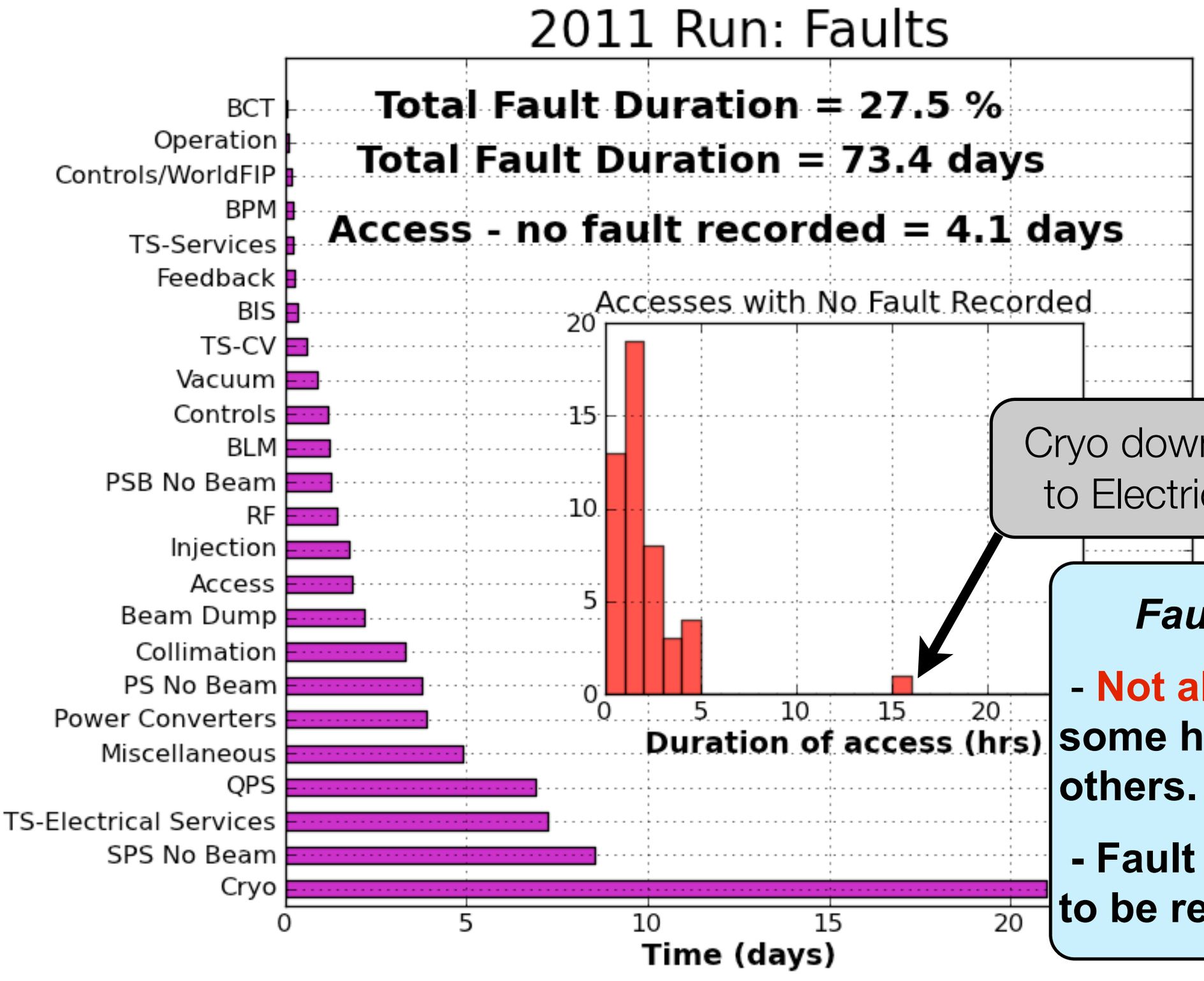


48 accesses with no fault registered: Typically for QPS

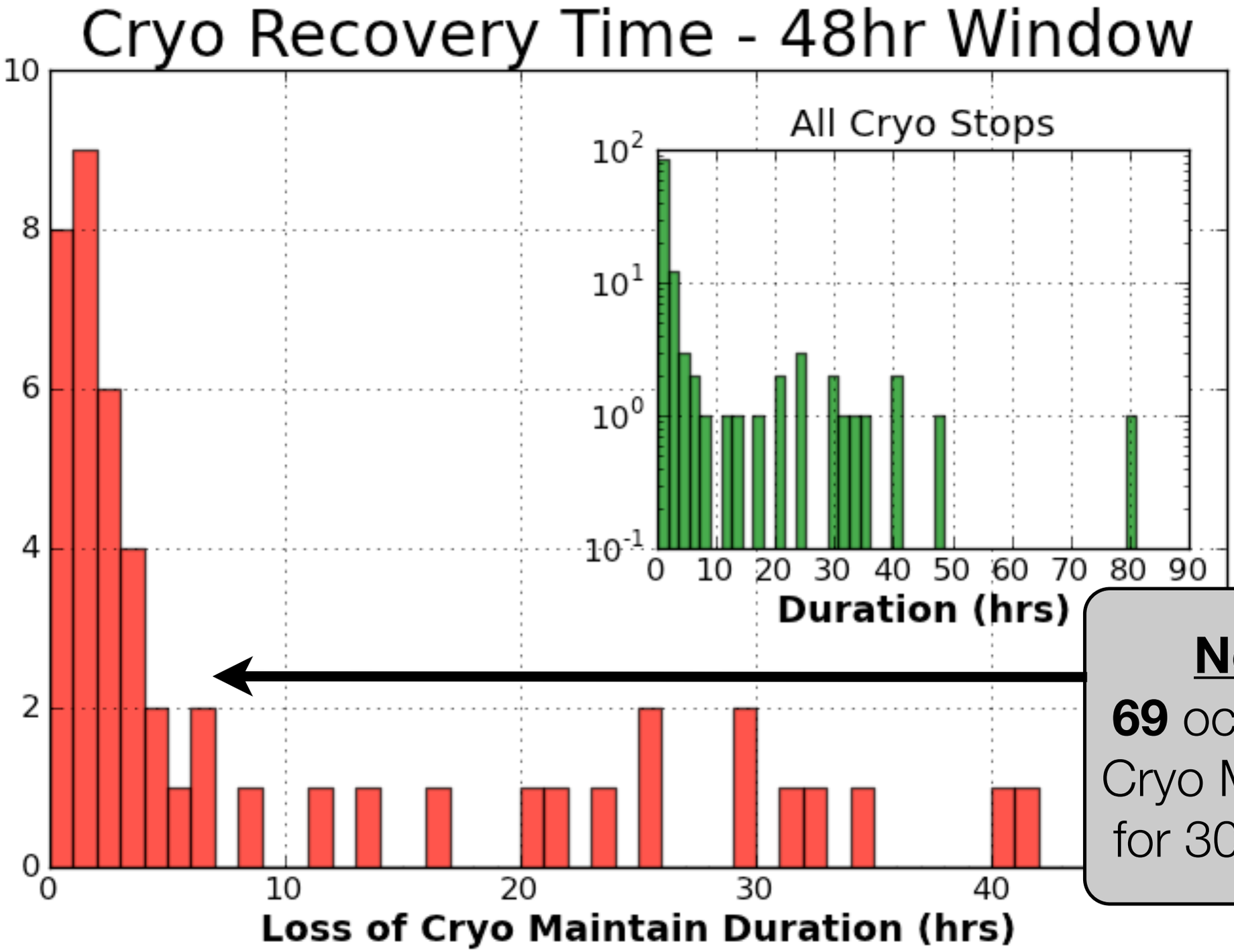
Cryo downtime due to Electrical glitch

Fault tracking Issues

- Not all faults registered: some hidden in shadow of others.

- Fault tracking mechanism to be revised/upgraded

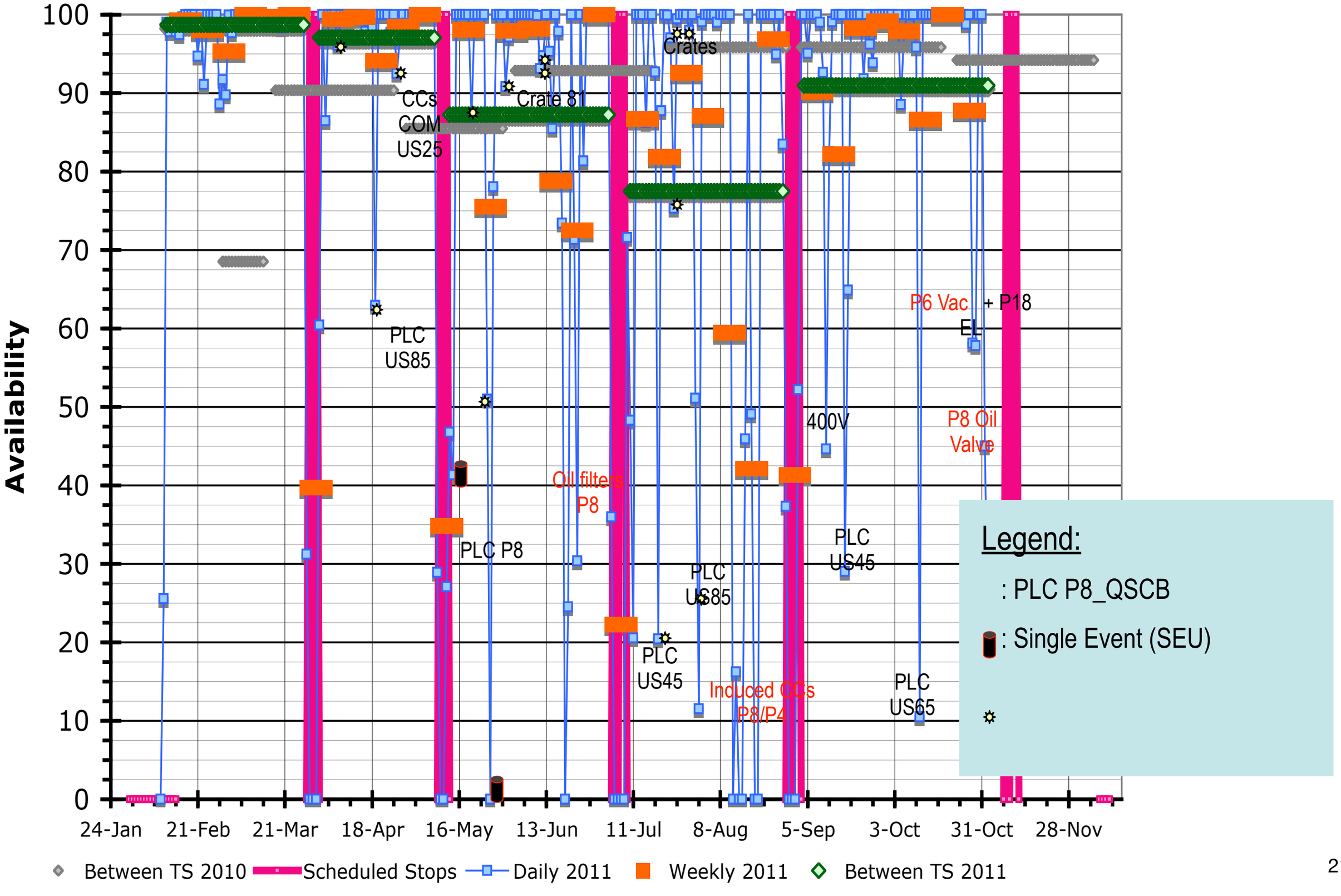
Downtime: Recovery of Cryo Conditions



Not Included

69 occurrences when Cryo Maintain was lost for 30 minutes or less

Cryo Global Availability



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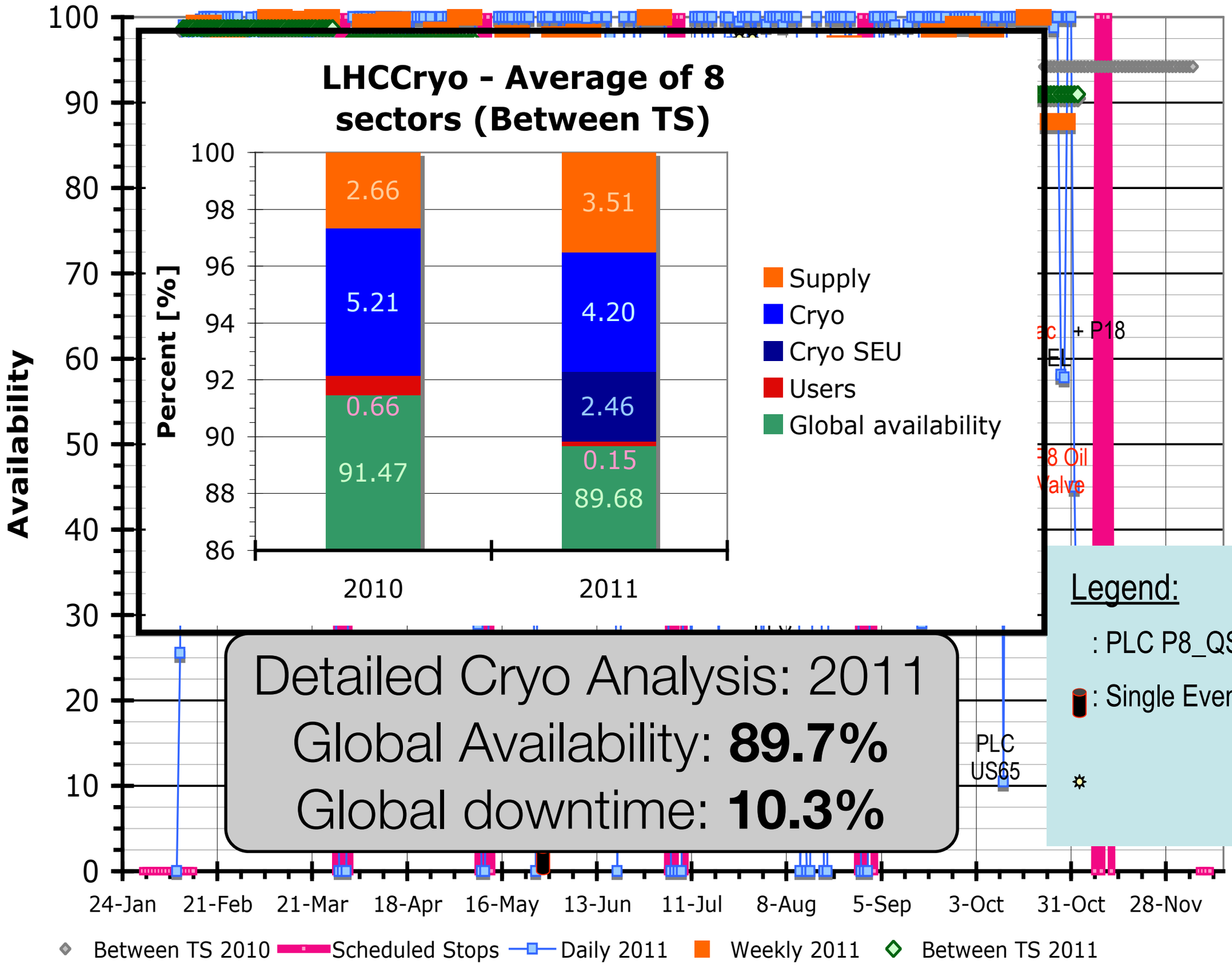
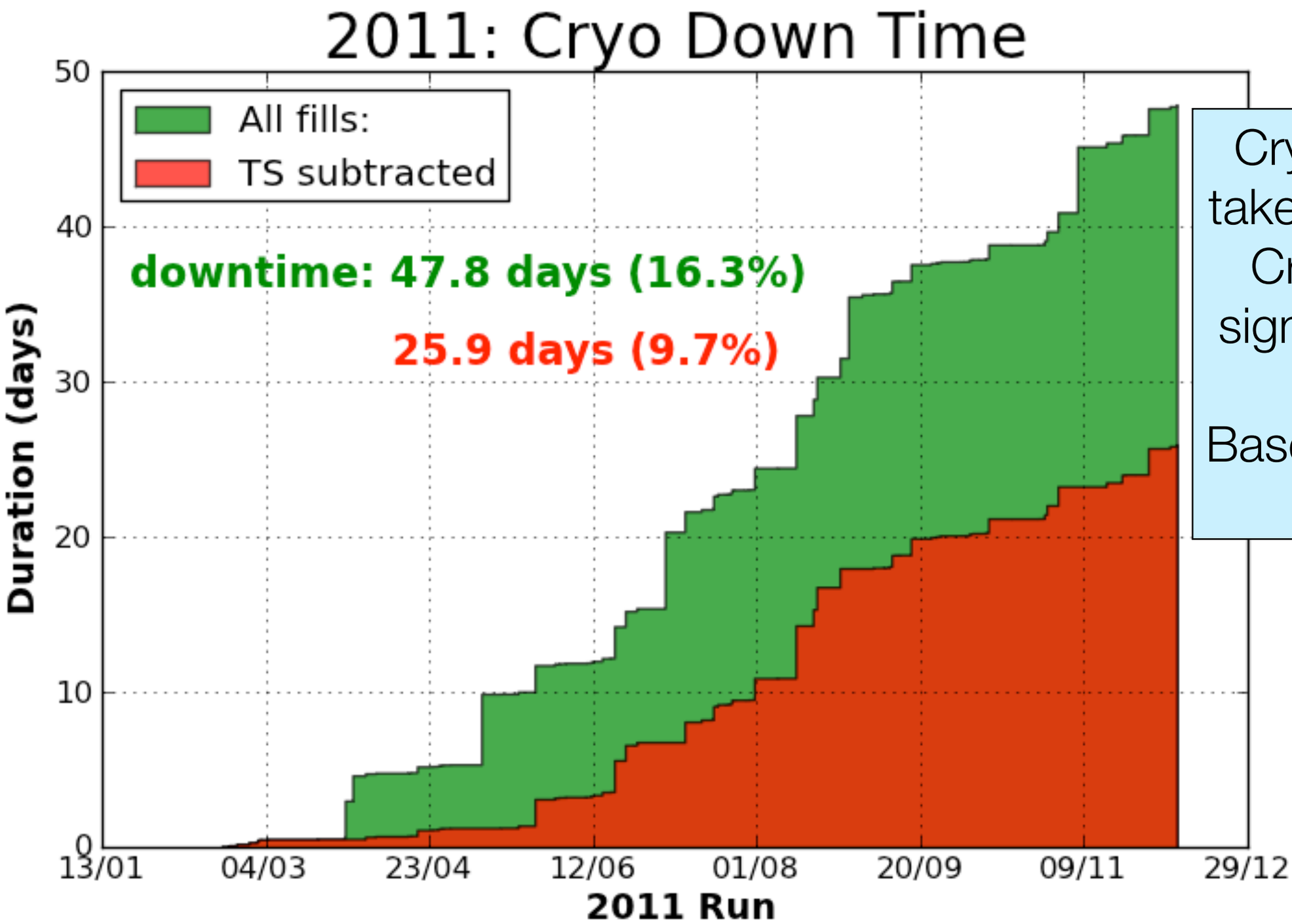


Global Cryo Downtime: Online Monitoring



Cryo availability taken from Global Cryo Maintain signals in Timber

Based on fill-by fill analysis

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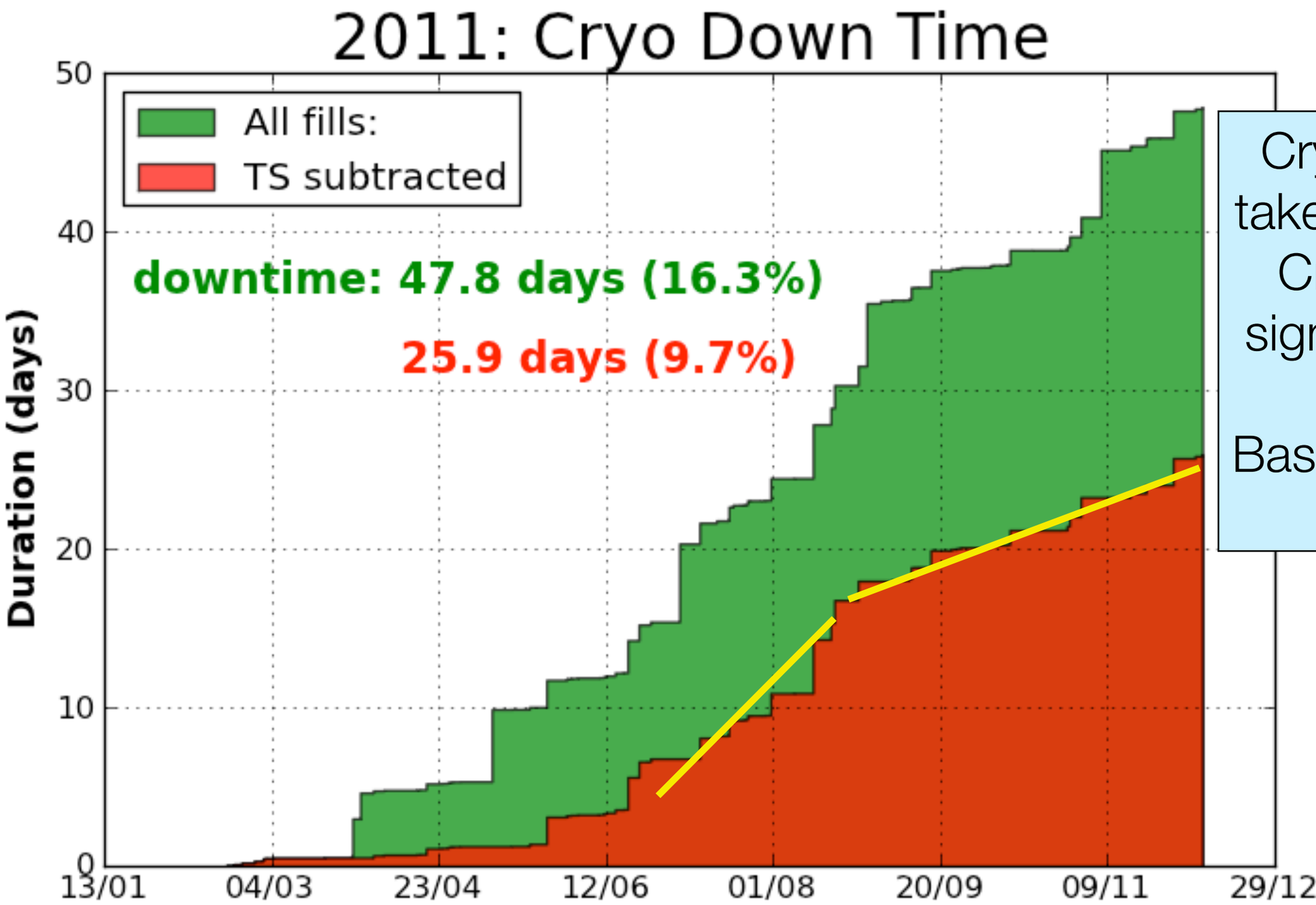


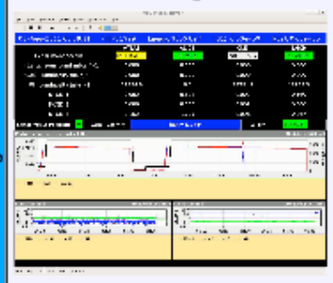
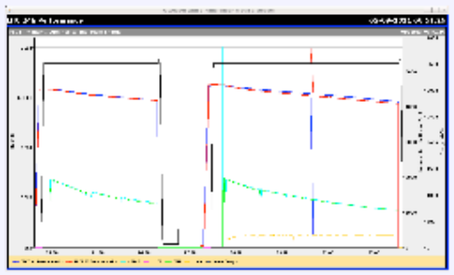
Cryo availability taken from Global Cryo Maintain signals in Timber

Based on fill-by fill analysis

5th August Intervention to improve PLC Redundancy against SEUs
Intervention appears to have been beneficial!

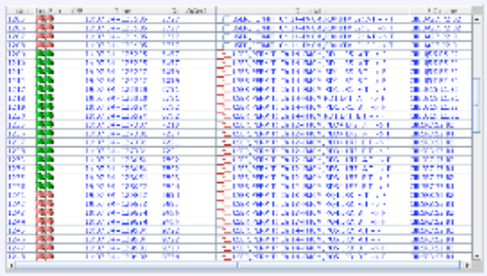
... Unaccounted Faults: Examples

Fill 1999
Electrical Glitch
~ 2 hrs down

13	0		/ STABLE BEAMS arges] TION_DUMP / MULTIPLE_SYSTEM_DUMP RMIT change: Ch 14-FMCM_RD1.LR1: A T -> F on CIB.US15.L1.B2
14	06:36	SB	Dump Classification: Electrical Distribution Operator / Comment: mpojer / Glitch on the electrical network.
15	06:37	SUP	**BEAM MODE > BEAM DUMP** LHC RUN CTRL: BEAM MODE changed to BEAM DUMP electrical glitch seen by FMCM
16	06:38	SUP	Screenshot captured from lhcop  20110803063833.png  24h.png
17	06:42	SUP	**BEAM MODE > RAMP DOWN** LHC RUN CTRL: BEAM MODE changed to RAMP DOWN
18	06:42	SUP	LHC RUN CTRL: New FILL NUMBER set to 2000

... Unaccounted Faults: Examples

Fill 1999
Electrical Glitch
~ 2 hrs down

13	0					/ STABLE BEAMS arges] TION_DUMP / MULTIPLE_SYSTEM_DUMP RMIT change: Ch 14-FMCM_RD1.LR1: A T -> F on CIB.US15.L1.B2
14	06:36	SB				Dump Classification: Electrical Distribution Operator / Comment: mpojer / Glitch on the electrical network.
15	06:37	SUP				**BEAM MODE > BEAM DUMP** LHC RUN CTRL: BEAM MODE changed to BEAM DUMP electrical glitch seen by FMCM
						Screenshot captured from lhcop
16	06:38	SUP	35	19:07	SB	Global Post Mortem Event Event Timestamp: 23/07/11 19:07:34.120 Fill Number: 1968 Accelerator / beam mode: PROTON PHYSICS / STABLE BEAMS Energy: 3500160 [GeV] Intensity B1/B2: 15411 / 16157 [e^10 charges] Event Category / Classification: PROTECTION_DUMP / MULTIPLE_SYSTEM_DUMP First BIC input Triggered: First USR_PERMIT change: Ch 14-FMCM_RBXWTV.L2: A T -> F on CIB.UA27.R2.B2
						Global Post Mortem Event Confirmation
						Mains disturbance (EDF) pojer / Glitch on the electrical network seen by the FMCM on many warm magnets.
						 20110723194550.png  20110723194618.png
			37	19:09	SB	Electrical glitch! RQ10.R4B1 and RQ10.R4B2 tripped!
			38	19:11	SUP	**BEAM MODE > BEAM DUMP** LHC RUN CTRL: BEAM MODE changed to BEAM DUMP
			39	19:26	SUP	**BEAM MODE > RAMP DOWN** LHC RUN CTRL: BEAM MODE changed to RAMP DOWN
			40	19:26	SUP	LHC RUN CTRL: New FILL NUMBER set to 1969

Fill 1968
Electrical Glitch
~ 2.5 hrs down

... Unaccounted Faults: Examples

Fill 1999
Electrical Glitch
~ 2 hrs down

Fill 2110
nQPS Fault
~ 4 hrs down

Fill 1968
Electrical Glitch
~ 2.5 hrs down

13 0 / STABLE BEAMS
arges]
TION_DUMP / MULTIPLE_SYSTEM_DUMP
RMIT change: Ch 14-FMCM_RD1.LR1: A T -> F on CIB.US15.L1.B2

14 06:36 SB Dump Classification: Electrical Dis
Operator / Comment: mpojer / Glitch

15 06:37 SUP BEAM MODE > BEAM DUMP
LHC RUN CTRL: BEAM MODE changed to
electrical glitch seen by FMCM

Screenshot captured from lhcop

16 06:38 SUP 35 19:07 SB Global Post Mortem Eve
Event Timestamp: 23/07
Fill Number: 1968
Accelerator / beam mod
Energy: 3500160 [GeV]
Intensity B1/B2: 15411
Event Category / Class
First BIC input Trigge

Global Post Mortem Eve

20110723194550

37 19:09 SB Electrical glitch!
RQ10.R4B1 and RQ10.R4B2 tripped!
create

38 19:11 SUP BEAM MODE > BEAM DUMP
LHC RUN CTRL: BEAM MODE changed to BEAM DUMP
create

39 19:26 SUP BEAM MODE > RAMP DOWN
LHC RUN CTRL: BEAM MODE changed to RAMP DOWN
create

40 19:26 SUP LHC RUN CTRL: New FILL NUMBER set to 1969

LHC OP [Thursday 15-Sep-2011 Night]

FILTERS: LOCATIONS CIRCUITS ACCESS INFO INFO:Shift Summary OPERATION
PIQUETS EXPERTS BEAM MODE
Clear

#	Time	PROTONPHY	Comment
1	06:59	BI	INFO > Shift Summary Received a nice fill that got dumped at 2:15 by a trip of the RB.A78. At first the cause of the trip was not obvious but as soon as we started the precycle it was understood to be a nQPS crate which needed a power cycle. The second precycle went through correctly and we could carry on with injection. Passed the machine on with 12 bunches circulating per ring. To be noted: - adth/vb1/2 crates crashed after the PM, to be followed up by the experts during the day; - loading the rampdown function on RQX.L8 and RQTX1.L8 took a while. created by lhcop on cwo-ccc-dtls

Faults

#	Group	Fault	Element	Description	Begin	End	Duration
NO FAULTS							

... Unaccounted Faults: Examples

Fill 1999
Electrical Glitch
~ 2 hrs down

Fill 2110
nQPS Fault
~ 4 hrs down

Fill 1968
Electrical Glitch
~ 2.5 hrs down

Example: some electrical glitches

- Beam dumped + no loss of Cryo + no Access
- TI Major Event created => TIOC followup
- **No fault recorded**

Example: Some QPS faults:

- Beam dumped + No Access
- **No fault recorded**

Proposal:

- **Structure and standardize** fault recording + tracking
  - Requires new database tool set across OP
- **Re-model interface/procedure** for entering faults
- **Regular review** of LHC-OP faults
  - with feedback from equipment teams

Beam Dumps

Beam Dumps in 2011 Proton Run

- Number of Beam Dumps in 2011 p-p Run: **482**
- Number of Non-Programmed Beam Dumps: **375 (78%)**
- Number of Non-Programmed Beam Dumps in Stable Beams: **168 (35%)**

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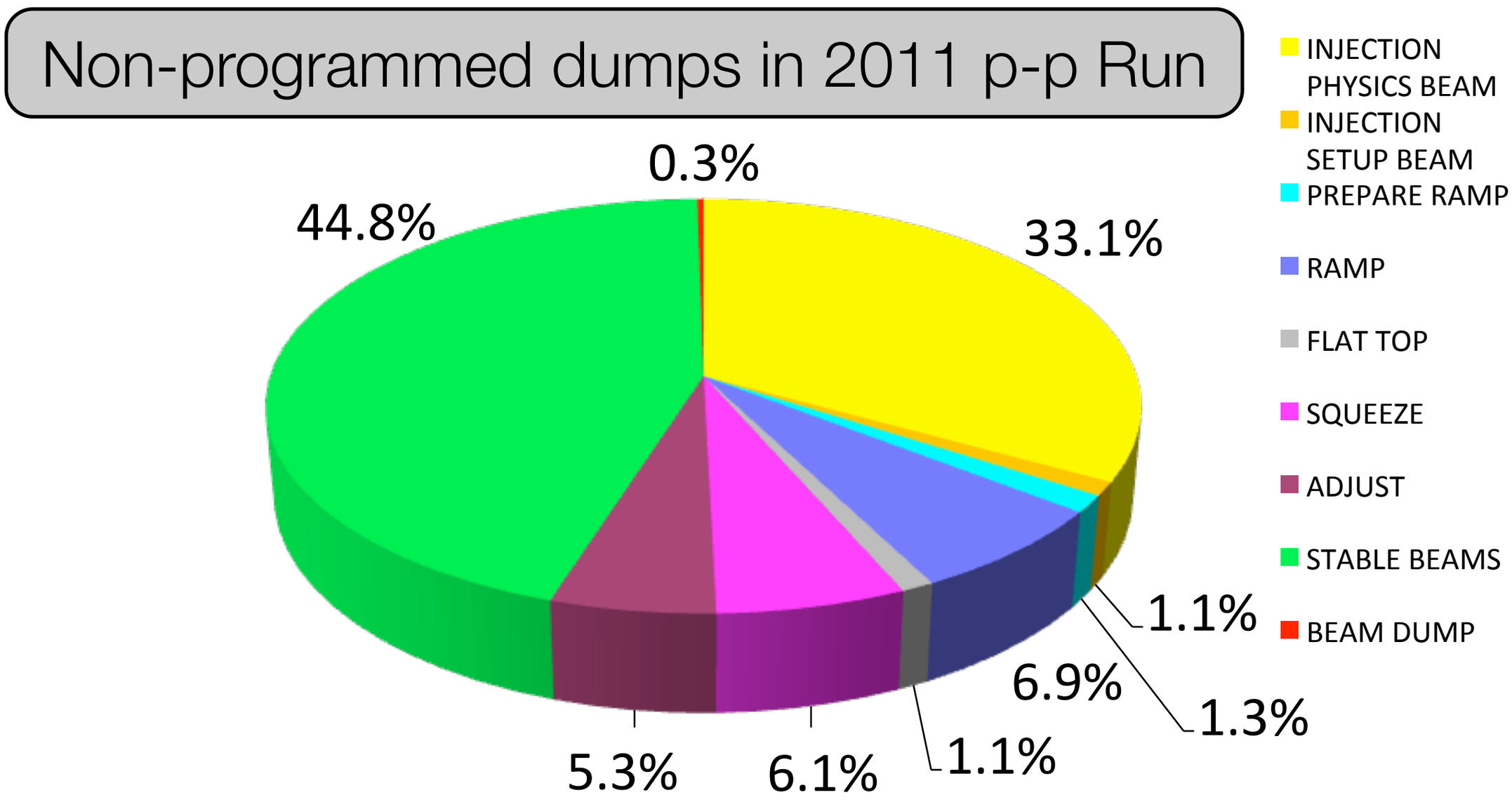
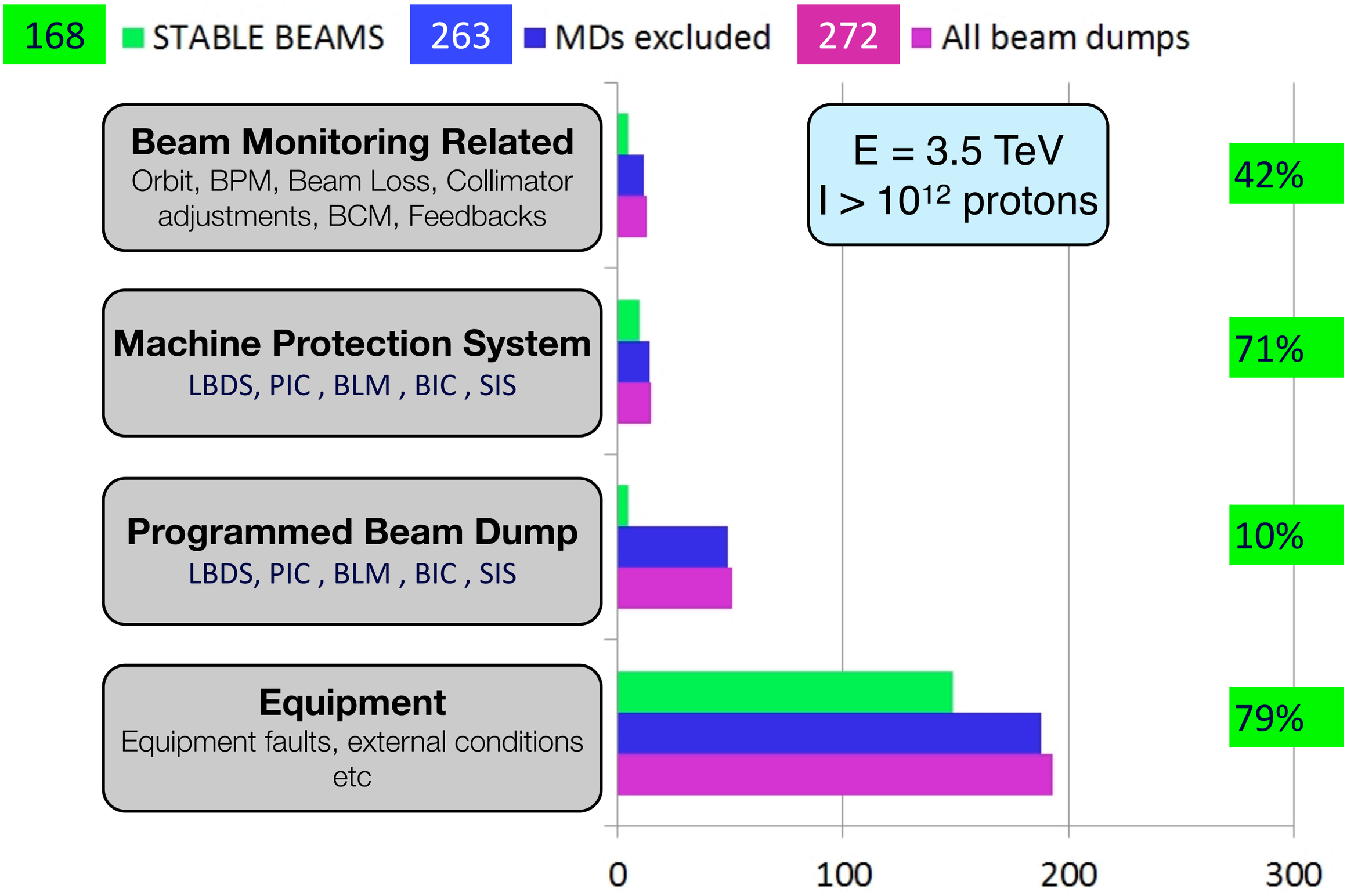
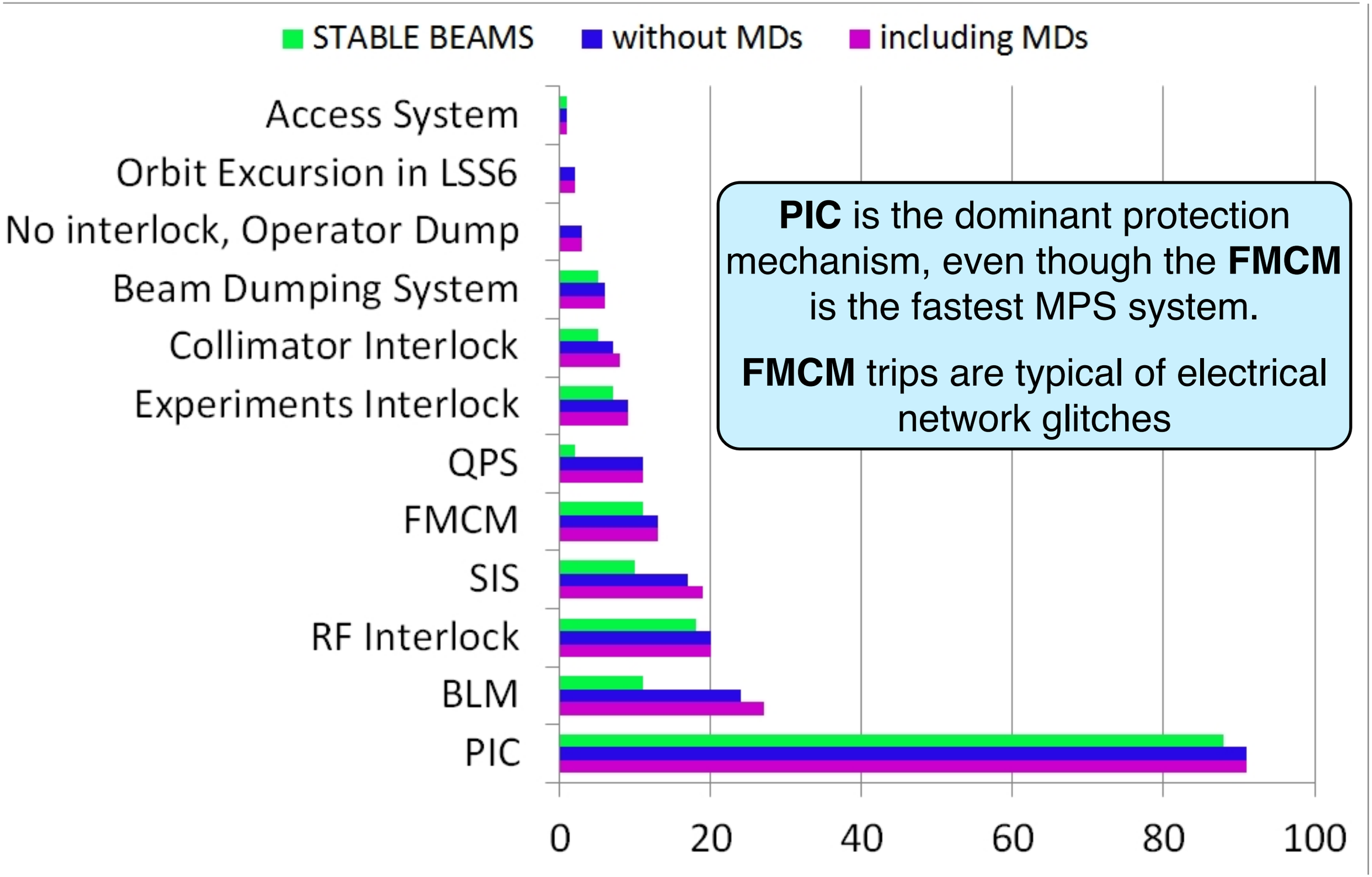


2011 Proton Run: Beam Dump Causes



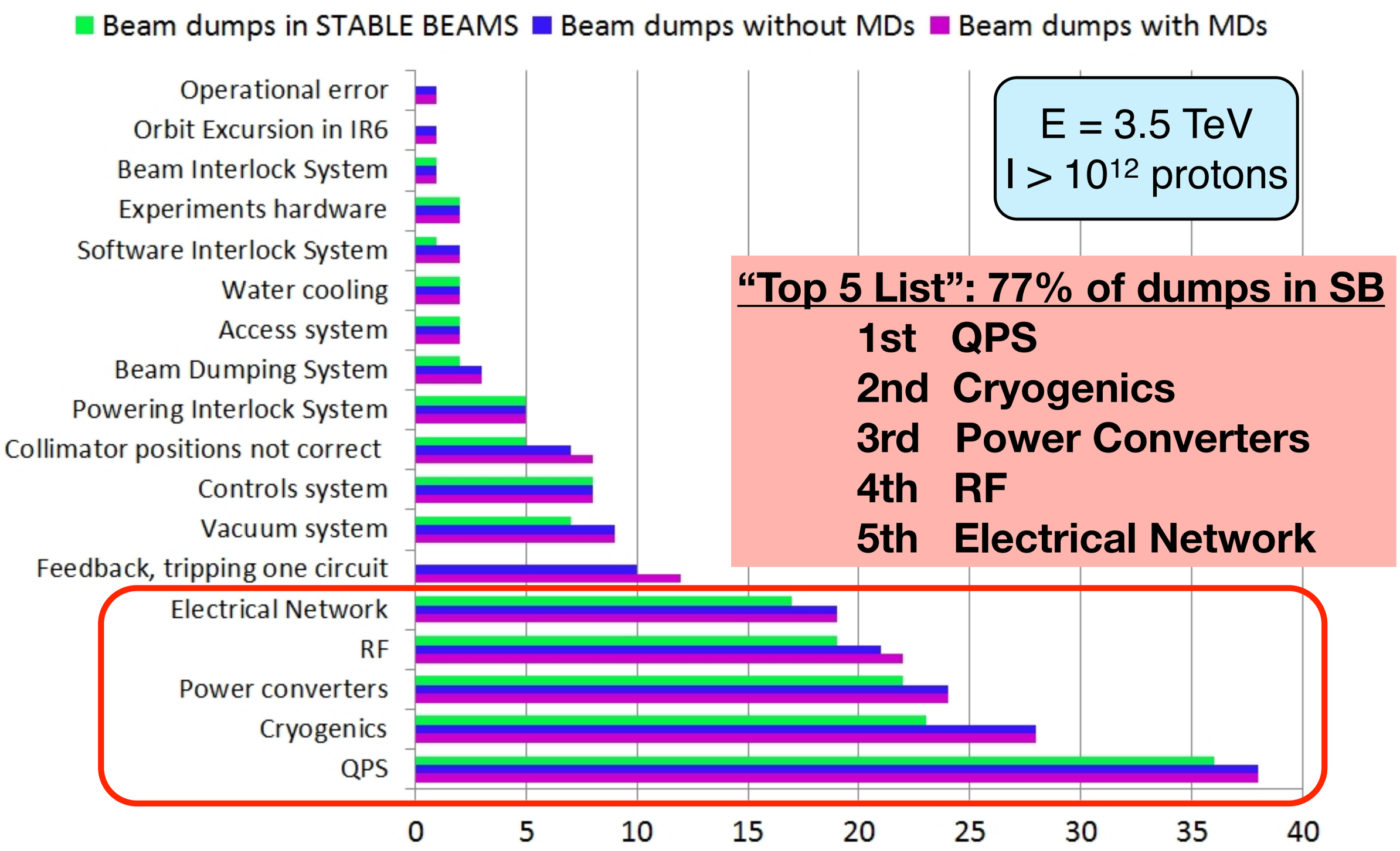
2011 Proton Run: Beam Dumps by First Trigger



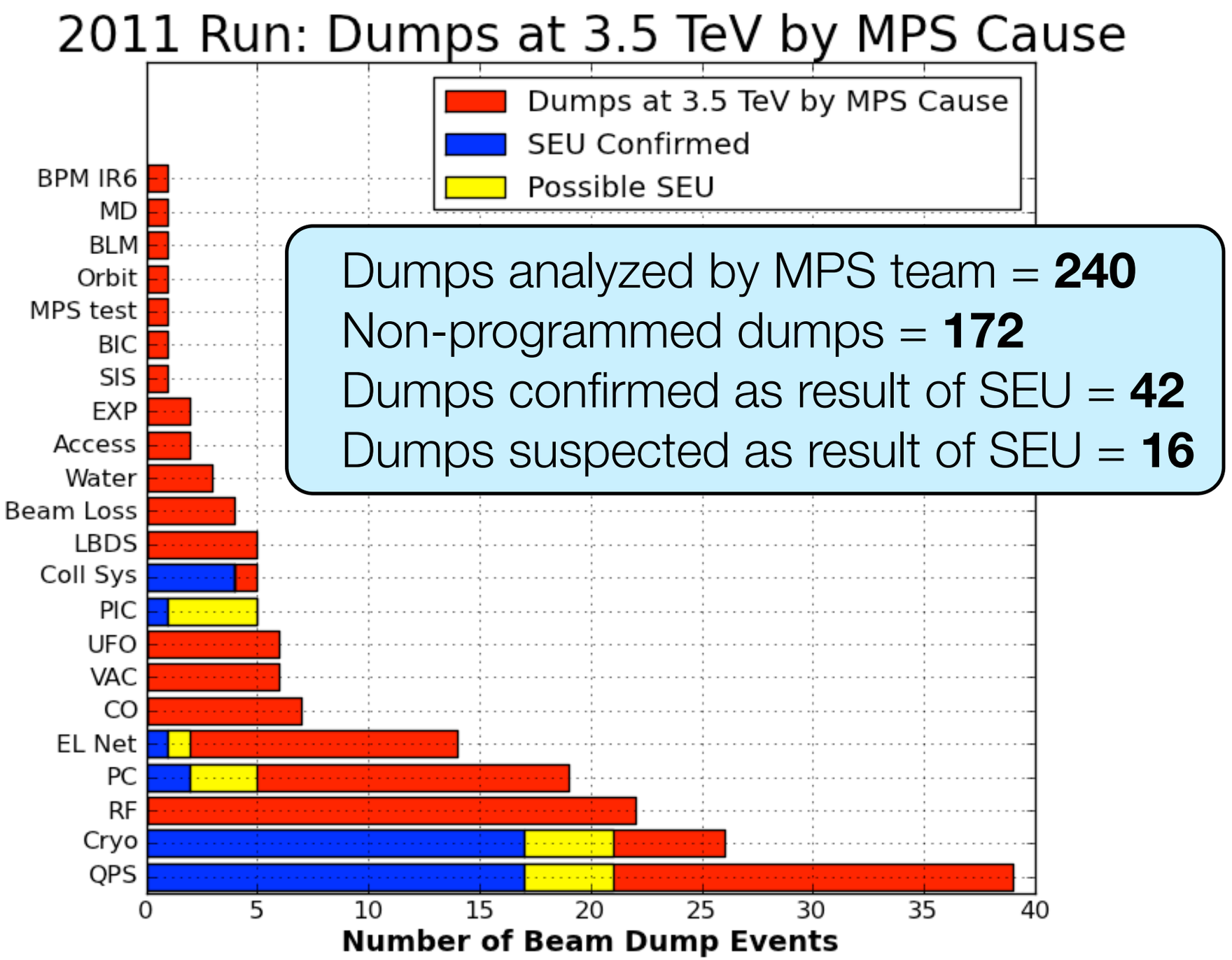
PIC is the dominant protection mechanism, even though the **FMCM** is the fastest MPS system.

FMCM trips are typical of electrical network glitches

2011 Proton Run: Beam Dumps By Cause



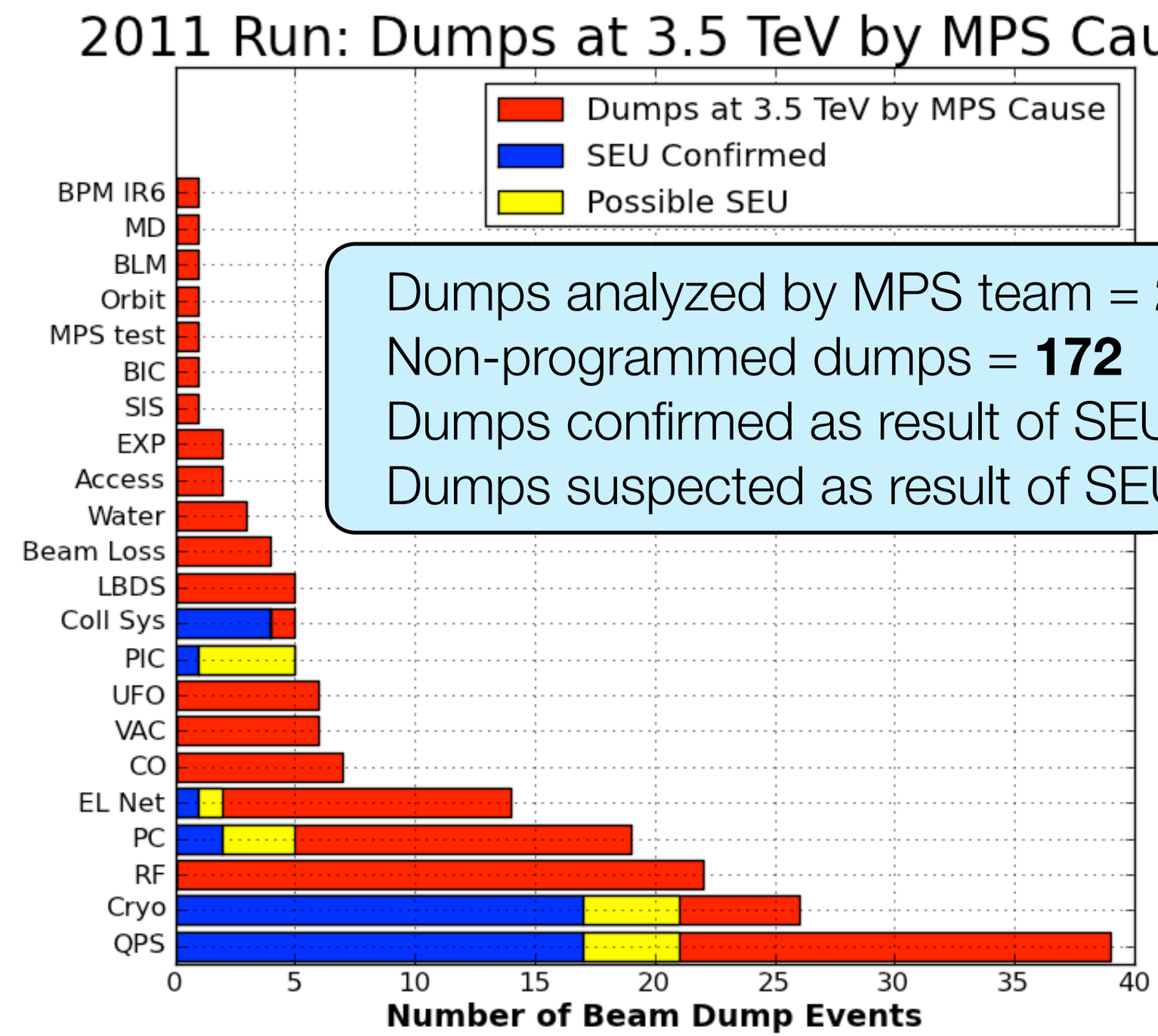
2011 Run: Machine Protection Expert Analysis



Dumps analyzed by MPS team = **240**
Non-programmed dumps = **172**
Dumps confirmed as result of SEU = **42**
Dumps suspected as result of SEU = **16**

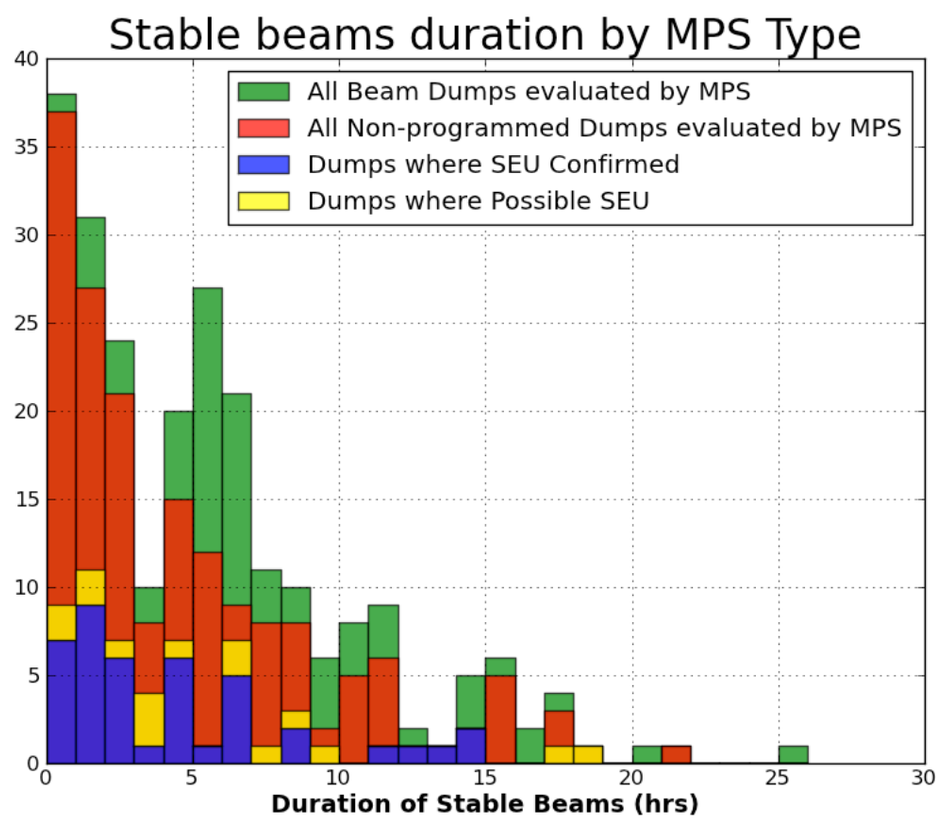
Note: Blue and yellow histogram bars are stacked.
Red and green bars are not

2011 Run: Machine Protection Expert Analysis



Dumps analyzed by MPS team = **240**
Non-programmed dumps = **172**
Dumps confirmed as result of SEU = **42**
Dumps suspected as result of SEU = **16**

Low Statistics, but no abnormalities in SEU distribution



Note: Blue and yellow histogram bars are stacked.
Red and green bars are not

Summary and Comments

- **Performance:**
  - **Machine Availability: 76.7 %** (213.2 out of 277.9 days)
  - **Time with beam in the LHC: 47.2 %** (131.2 out of 277.9 days)
  - Percentage of allocated **Physics time in Stable Beams**: **33%**

  - Stable Beams Duration
    - **Most probable = 6.44 hrs**
    - **Average = 5.56 hrs**
    - **50:50 Point = ~ 4hrs**

  - Turnaround Time
    - **Most probable (SB->SB) = 4.59 hrs**
    - **Average (SB->SB) = 13.81 hrs**

Summary and Comments

- **Downtime and Turn Around**
  - **Cryogenics recovery time** still the biggest factor
    - **25.9 days or 9.7 %**
  - Cryogenics SEU Mitigations show benefits
  - Faults need proper recording/tracking.
    - Proposal to upgrade tools/procedures
    - Injection has potential for improvement of turnaround time

- **Beam Dumps**
  - **Non programmed dumps:** 375 (78%)
    - **During Stable Beams (p-p Run): 168 (35%)**
  - **Equipment failures still dominant MPS dump cause**
    - QPS still at the top of the MPS dump cause list
  - **2011 Run: Stable beams fills dumped by SEUs: 24%**
    - SEU mitigation should improve 2012 performance (eg Cryo, QPS)

Spare Slides

Evolution of Emittance Variation over a Fill

Emittance variations more prevalent for Beam 2.

Both beams show increased variations in luminosity production phase.

Caution: further analysis of BSRT dat is needed.