



UiO



# The Impact of Machine Protection on Accelerator Reliability and Beam Availability

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[www.europeanspallationsource.se](http://www.europeanspallationsource.se)  
Accelerator Reliability Workshop, 2015

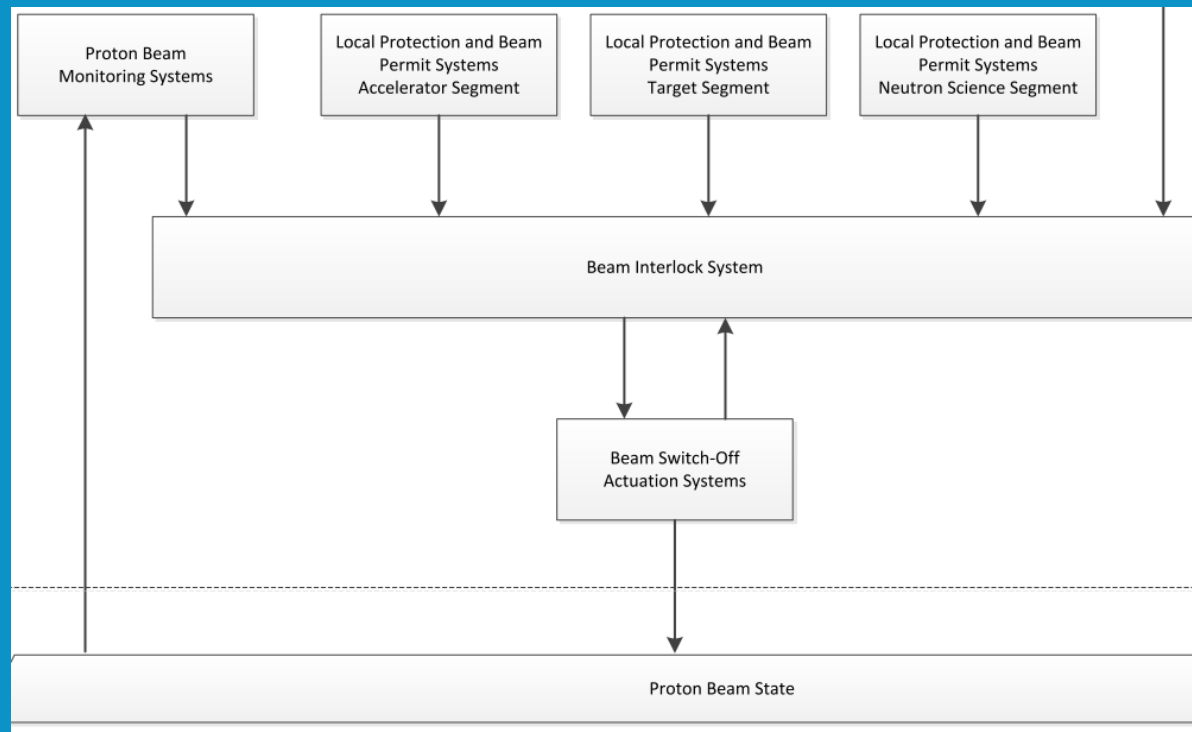
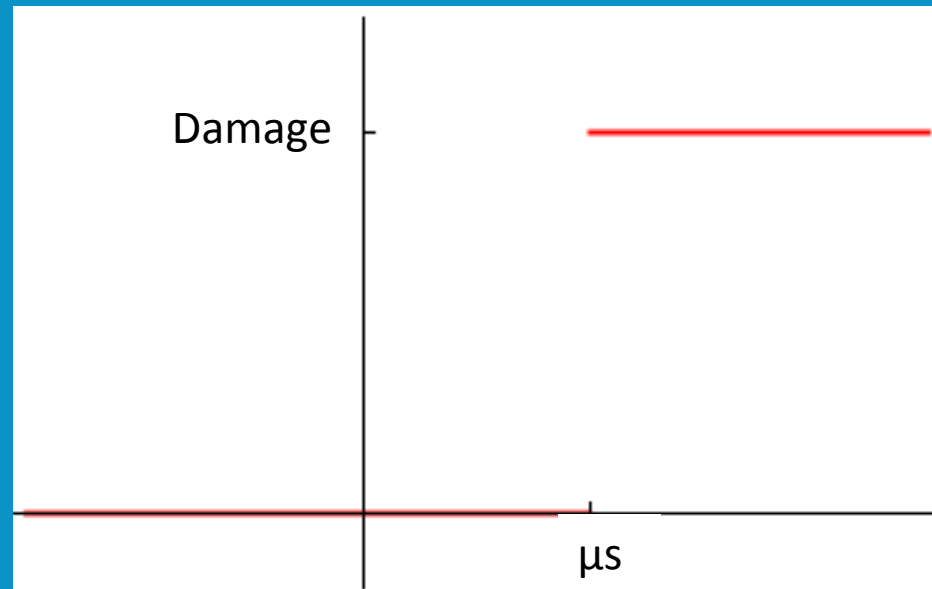
- Reliability =  $e^{-\lambda t}$

- Availability =  $MTBF / (MTBF + MDT)$

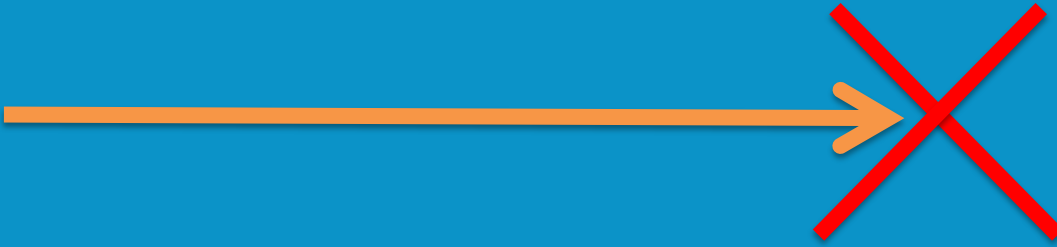


**CAUTION  
WATER ON ROAD  
DURING  
RAIN**



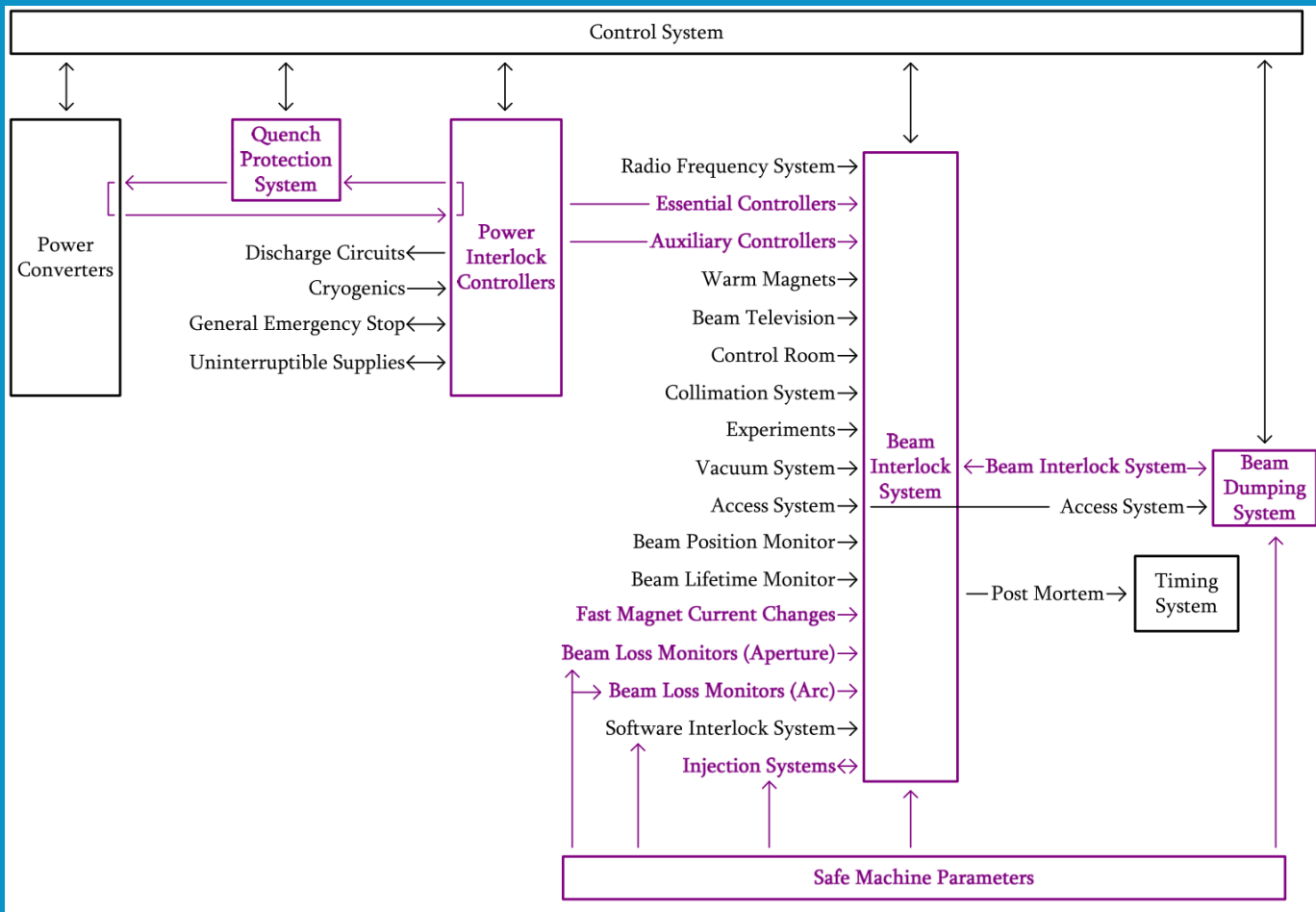


BEAM



Synchrotrons:  
Reliability  $\propto$  Availability

Linacs:  
~~Reliability  $\propto$  Availability~~



Benjamin Todd,  
Maciej Kwiatkowski  
2014

System	prediction 2005	observation		
		2010	2011	2012
LBDS	6.8 ± 3.6	9	11	4
BIS	0.5 ± 0.5	2	1	0
BLM	17.0 ± 4.0	0	4	15
PIC	1.5 ± 1.2	2	5	0
QPS	15.8 ± 3.9	24	48	56
SIS	not studied	4	2	4

Benjamin Todd, 2012





Signal



Computer  
Control System



MPS Action

# E-logbook



**SHUTDOWN: NO BEAM**

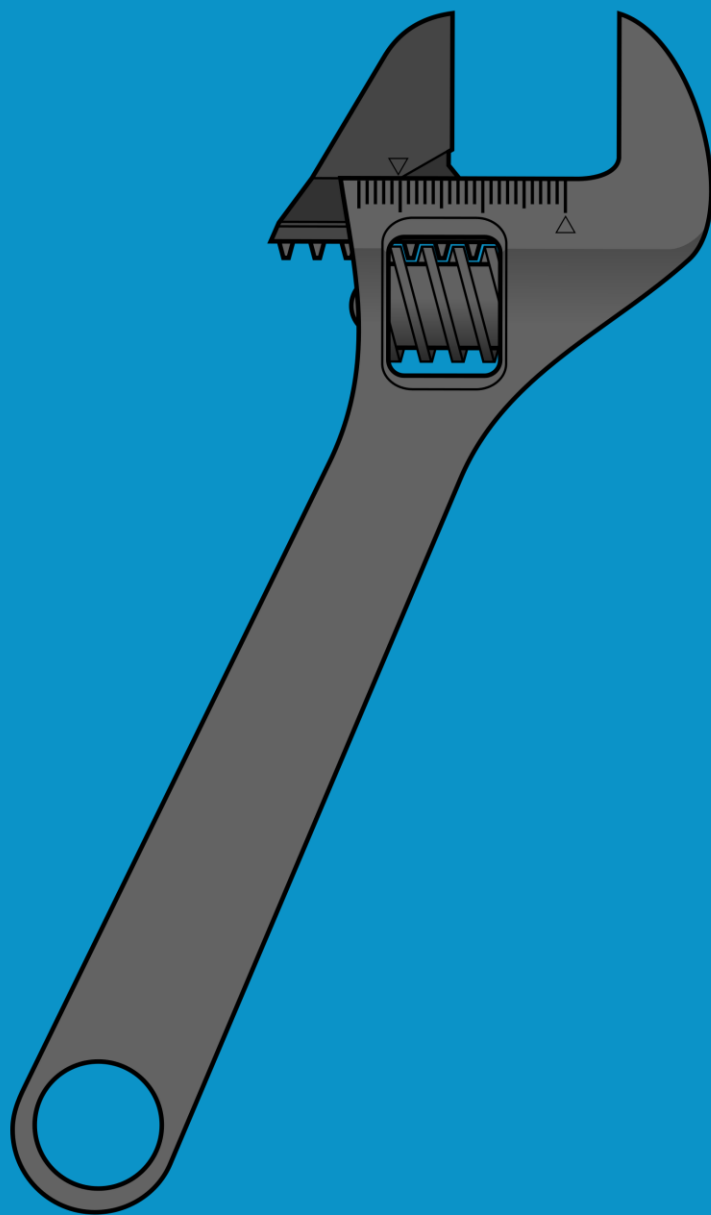
Comments (16-Feb-2013 08:25:13)  
\*\*\* END OF RUN 1 \*\*\*  
No beam for a while. Access required  
time estimate: ~2 years

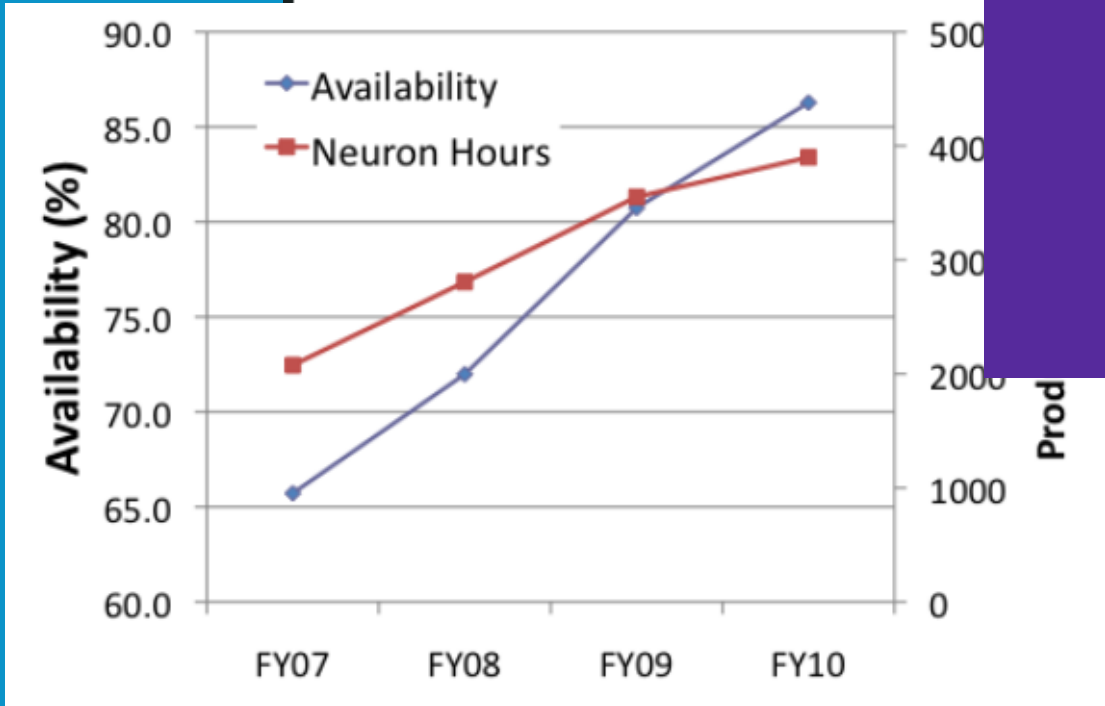
AFS: Single\_36b\_4\_16\_16\_4bpi9inj

BIS status and SMP flags		B1	B2
Link Status of Beam Permits		false	false
Global Beam Permit		false	false
Setup Beam		true	true
Beam Presence		false	false
Moveable Devices Allowed In		false	false
Stable Beams		false	false
PM Status B1	ENABLED		
PM Status B2	ENABLED		

# Post-mortem

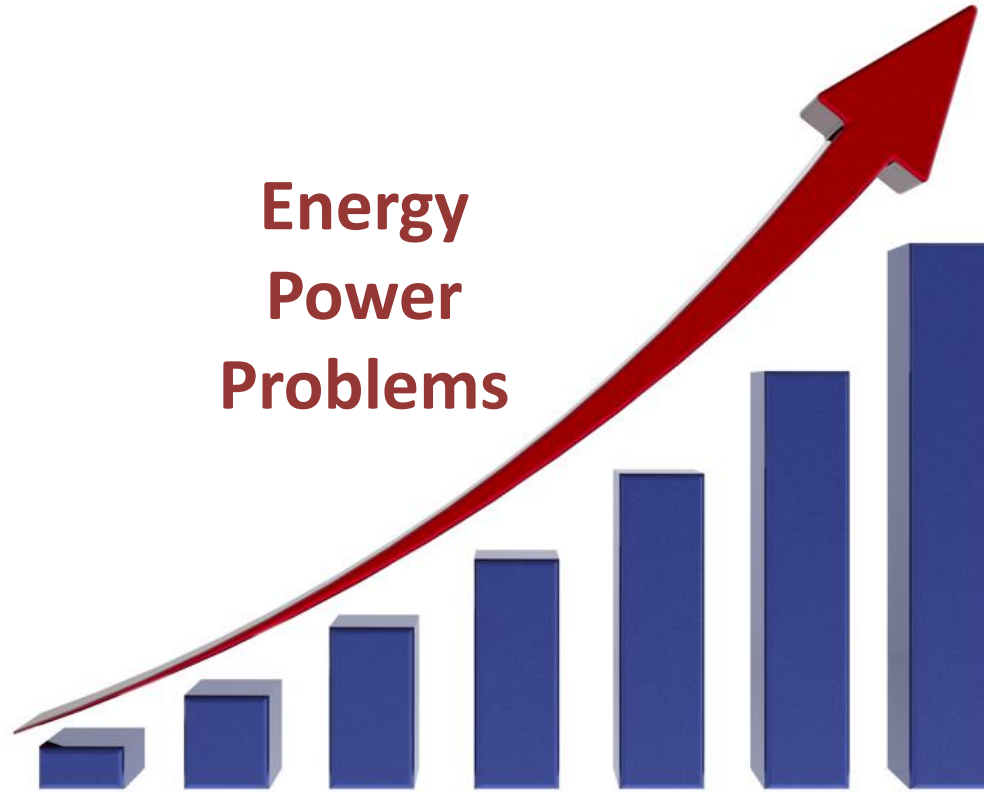






A purple rectangular box with a white crown icon at the top. Below the crown, the text 'KEEP CALM' is written in white, 'IT' in white, 'GETS' in white, and 'BETTER' in yellow.

**Energy  
Power  
Problems**













# REDUNDANCY

Just in case you're totally oblivious.

# Conclusions

- Removing beam
- Relation between reliability and availability
  - Storage Rings
  - Linacs
- Rigorous analyses help
- Unexpected faults
  - UFOs at LHC
  - Integrated losses at SNS
- Redundancy



KISS

*Keep. It. Simple. Stupid.*



**“Simplicity  
is the  
ultimate  
sophistication.”**

# Thank you!

ESS, April 10



# References

## Papers etc.

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## Pictures

- SNS plot: John Galambos, SNS Operational Experience at the MW Level, 2010
- ESS MP concept: Christian Hilbes, ESS Machine Protection Functional Architecture Concept, 2015
- Sibley's on MP: Benjamin Todd, Risk and Machine Protection for Stored Magnetic and Beam Energies
- Prediction table: Benjamin Todd, A Look Back on 2012 LHC Availability, 2012
- Gets better: <http://1wdojq181if3tdg01yomaof86.wpengine.netdna-cdn.com/wp-content/uploads/2014/07/getsbetter.jpg>
- Too many cooks: <https://cdn.urbantimes.co/wp-content/uploads/2014/01/too-many-cooks-21.jpg>
- Crawl, walk, run: <http://atlasfid.com/wp-content/uploads/2014/05/Crawl-Walk-Run-750px.jpg>
- Inov8: <http://cdn.runlogger.com/images/2013/01/inov-8-trailroc-235-trail-running-shoe-review.jpg>
- Haglöfs: [http://i.stpost.com/haglofs-solid-lite-g-gore-tex-hiking-boots-waterproof-for-women-in-lead-p-6541d\\_03~1500.2.jpg](http://i.stpost.com/haglofs-solid-lite-g-gore-tex-hiking-boots-waterproof-for-women-in-lead-p-6541d_03~1500.2.jpg)
- Knee pads: [http://www.watersportswarehouse.co.uk/images/product/full/gul-pro-knee-pads\\_GM0019.jpg](http://www.watersportswarehouse.co.uk/images/product/full/gul-pro-knee-pads_GM0019.jpg)
- Ostrich: <https://vardagslivochtankar.files.wordpress.com/2012/03/huvudet-i-sanden.jpg>
- Pizza hut: <http://benmabey.com/presentations/pca-tutorial/assets/img/redundancy.jpg>
- Simplicity: <http://chromblog.thermoscientific.com/Portals/49739/images/Simplicity.jpg>
- KISS: <http://www.forexcandle.com/wp-content/uploads/kiss-principle.png>
- Common sense: <http://blog.songcastmusic.com/wp-content/uploads/2014/01/bigstock-Common-Sense-Concept-33933608.jpg>
- Water on road: <https://s-media-cache-ak0.pinimg.com/736x/68/23/b9/6823b902d6b499ddec2c0b7fcdc582c8.jpg>
- Increasing needs: <http://blog.backupify.com/wp-content/uploads/2011/08/Screen-shot-2011-08-02-at-4.53.45-PM.png>
- CERN page 1: [http://cms.web.cern.ch/sites/cms.web.cern.ch/files/styles/large/public/field/image/LS1\\_LHCPage1.png?itok=y1gAwM6s](http://cms.web.cern.ch/sites/cms.web.cern.ch/files/styles/large/public/field/image/LS1_LHCPage1.png?itok=y1gAwM6s)
- Post-mortem: <http://www.maintenanceassistant.com/wp-content/uploads/2012/03/monitor-280x280.jpg>
- Logbook: <https://lh6.ggpht.com/9DxKLAMiXmo3CeXyLkH19ZwG8pMR3JNm4nBMS1zETDIqfjiMk7PxAfz8HfBhqzQKQY=w300>
- Pilot: [https://lifewayvbs.files.wordpress.com/2012/02/girl\\_pilot.png](https://lifewayvbs.files.wordpress.com/2012/02/girl_pilot.png)
- Flexible: [http://images.sodahead.com/slideshows/000017171/2740142261\\_most\\_flexible\\_people\\_picture\\_5043-70907291886\\_xlarge.jpeg](http://images.sodahead.com/slideshows/000017171/2740142261_most_flexible_people_picture_5043-70907291886_xlarge.jpeg)
- Simple: [http://weibull.com/hotwire/issue2/ht2\\_2.gif](http://weibull.com/hotwire/issue2/ht2_2.gif)
- Monkey wrench: [http://upload.wikimedia.org/wikipedia/commons/thumb/5/55/Adjustable\\_wrench.svg/2000px-Adjustable\\_wrench.svg.png](http://upload.wikimedia.org/wikipedia/commons/thumb/5/55/Adjustable_wrench.svg/2000px-Adjustable_wrench.svg.png)