CERN SPS 800 MHz IOT Progress report

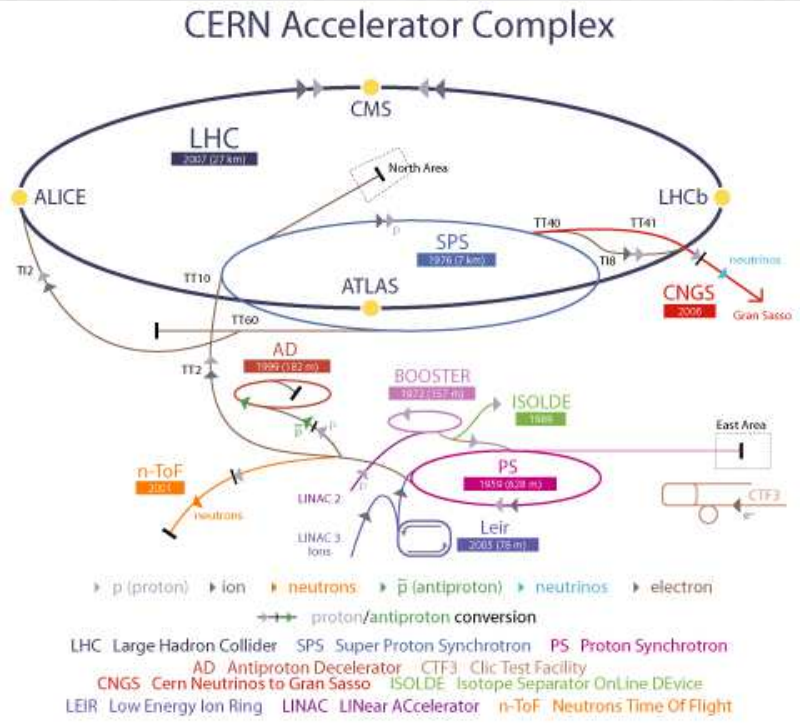
16th ESLS RF Meeting,

9-10 October 2012,

ALBA, Barcelona, Spain

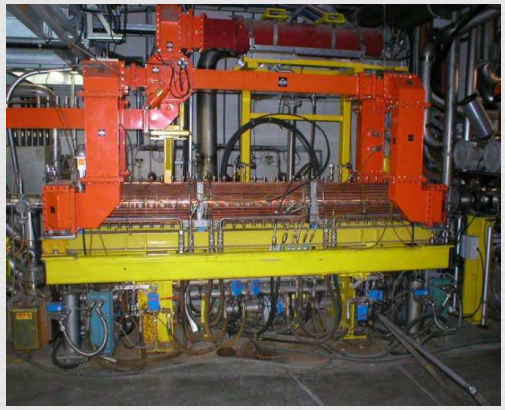
800 MHz RF in the SPS

- SPS is the latest Injector for LHC
- The proton beams for the LHC can become unstable in the SPS
- One of the most important systems to keep beams stable is the 800 MHz RF system
- The RF power source must be of the highest reliability to ensure beams for LHC at all times



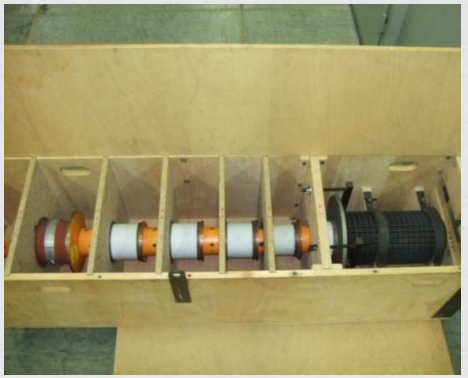
800 MHz system

- Since 1980, the system is composed of :
- 8 x 56 kW Valvo klystrons
- Klystrons are combined using 3 dB hybrids
- 2 transmitters of 225 kW each
- Each transmitter connected via ~ 120 m waveguides to 2 Travelling Wave Cavities



Obsolescence of the system

- This RF power system is getting very old
- We had major difficulties with klystron ceramic failures and with HV transformers
- We now operate with 2 klystrons only feeding one cavity and 2 hot spare klystrons
- The second cavity is unavailable

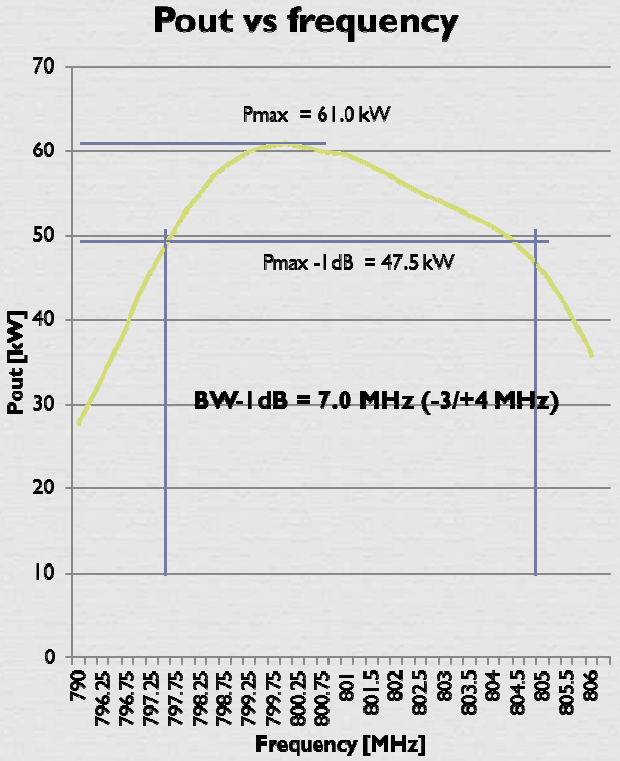


Upgrade proposal

- Replace Klystron Transmitters with IOT Transmitters and re-use all existing ancillaries
- Maximum power will be slightly increased up to 240 kW CW
- BW_{-1dB} will be increased :
  1.0 MHz with Klystrons
  6.0 MHz with IOTs

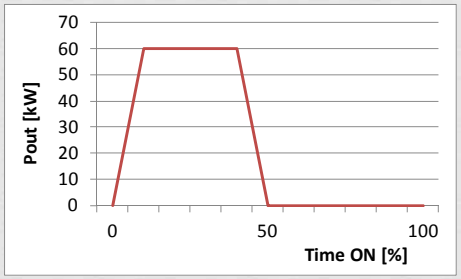
Factory Acceptance Tests

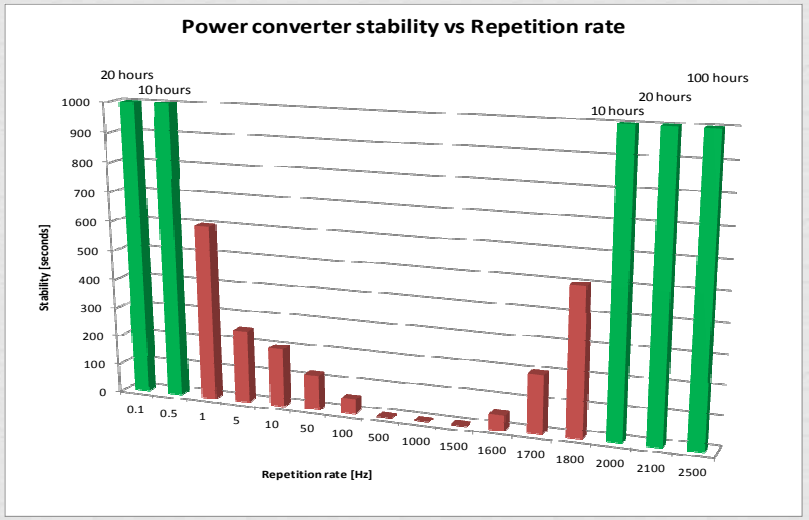
- All factory acceptance tests have shown compliance respect to the specification, and even better :
  - Linearity
  - Monotonous
  - Phase stability
  - Maximum output power
- Pre-series Amplifier has been integrated within CERN operational area
- All tests cycles have been done for 4 hours each, no trouble has been discovered



HVPMPS instabilities

- We tried a 50% AM RF signal, varying repetition rate
- HVPMPS stability was function of the repetition rate !





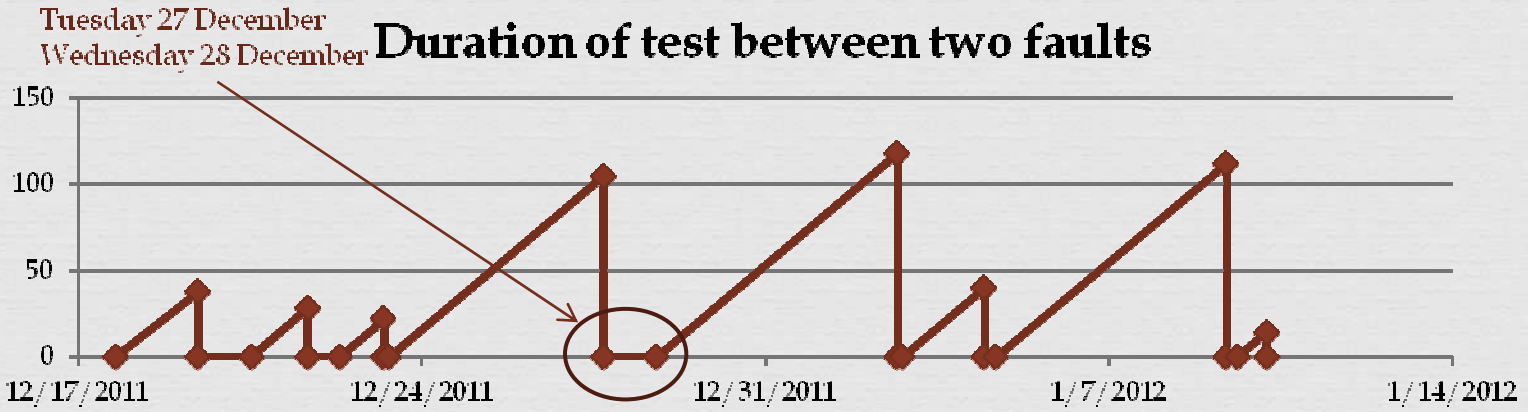
New Rectifier

- We asked for a 'simple' rectifier :
  - Transformer
  - Diode Rectifier
  - Capacitor stack
  - Thyratron (stored energy in capacitors)
- Tests have been performed at CERN in October :
  - Crowbar ssytem was unstable
  - Repetitive triggers without any reason (even without the tube)
- Additional tests in Factory were needed to fix the trouble
- December, the system was ready again for long duration tests at CERN

Unstable during Christmas

- We launched a long duration test during our 2011 CERN Christmas stop:
  - No other users -> Mains Network more stable
  - Nobody at CERN for two weeks, perfect time for long duration tests
- Goal was to perform 360 hours without any stop due to a fault :
  - Maximum achieved between two faults : 117 hours
  - Still unstable !

Unstable during Christmas



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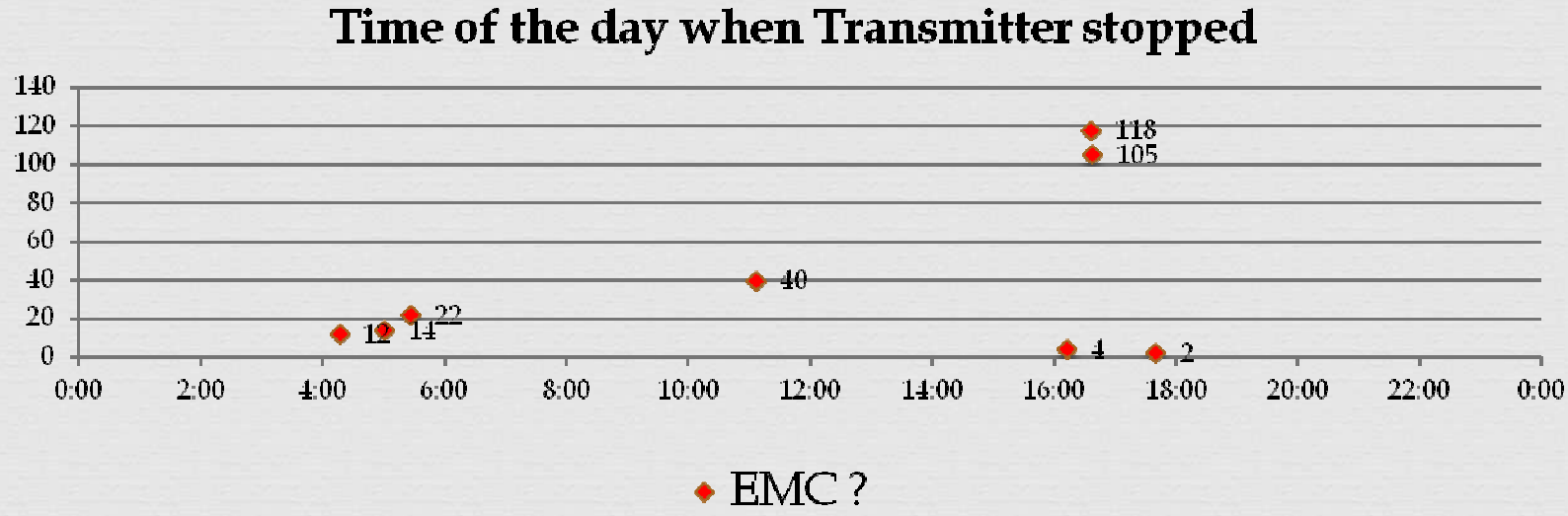

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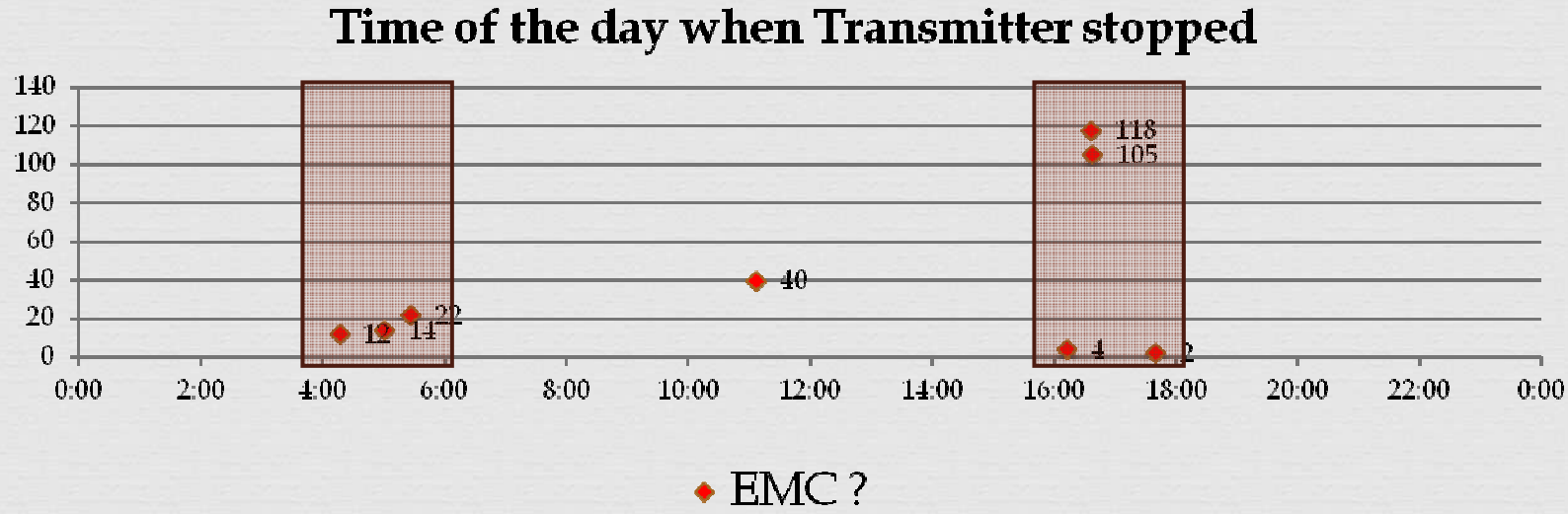
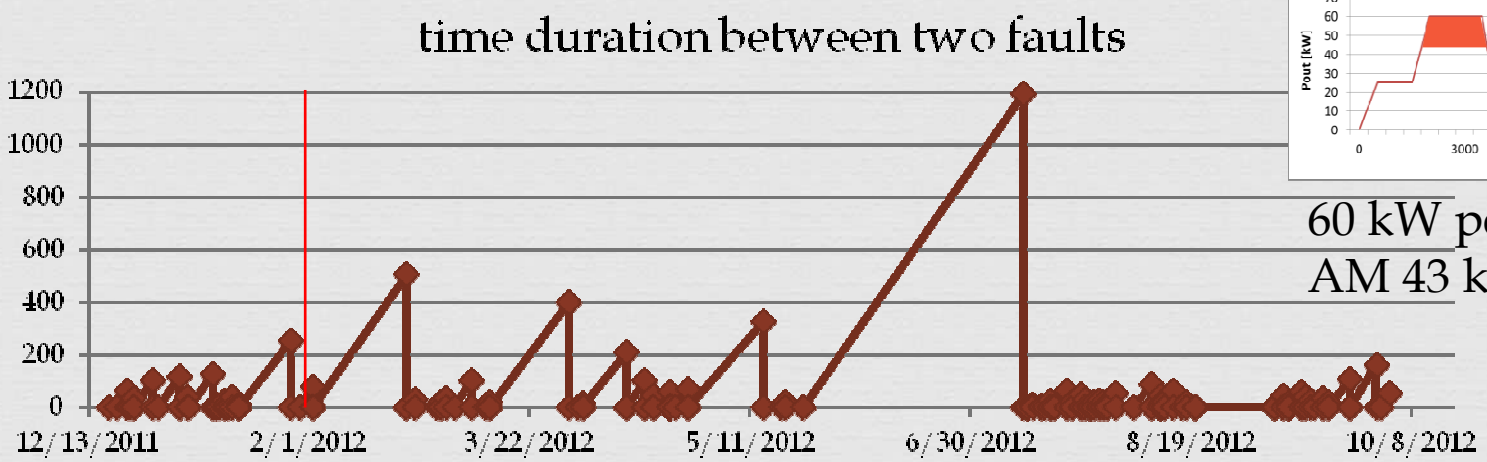


- Decided to look differently at the data
- From 4 to 6, AM and PM, our transmitter was unstable

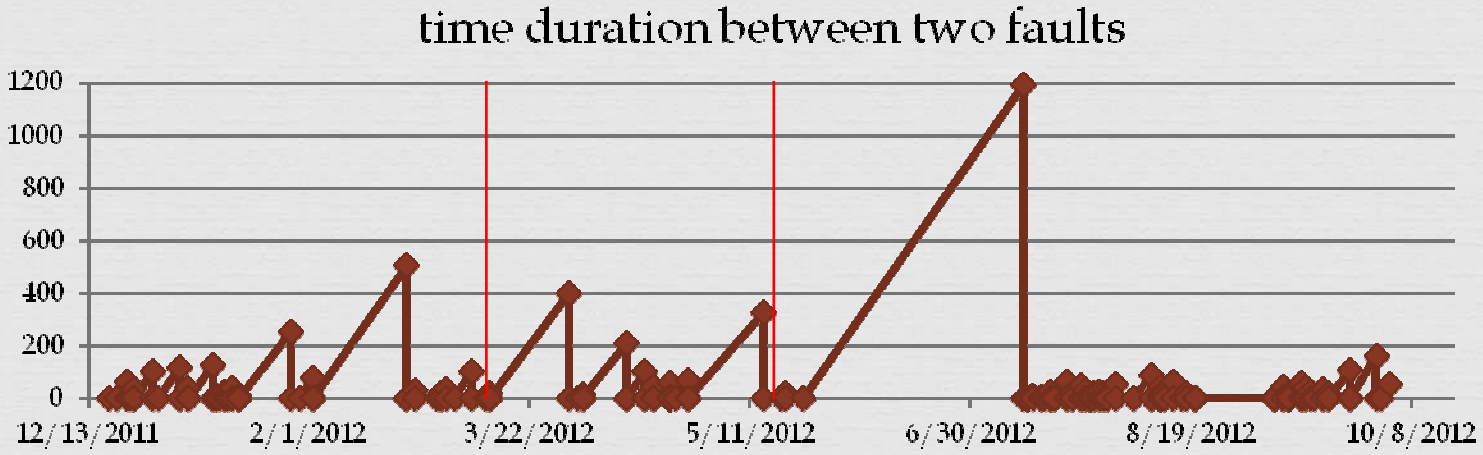
2012 Long duration test



60 kW peak
AM 43 kHz 25%

- January : Thales modified ferrites in input circuit

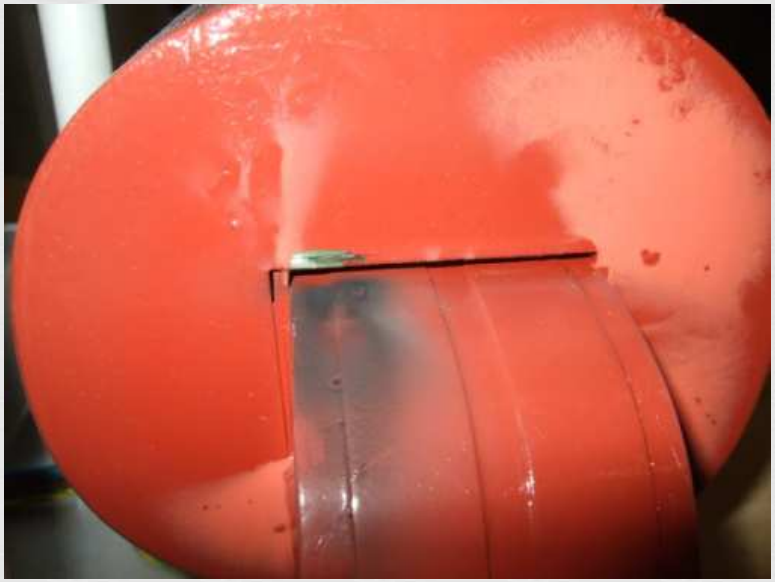
2012 Long duration test



- March & May : HV Thyratron monitoring transformer burnt

Faulty HV monitoring transformer

- A first HV Thyratron monitoring transformer burnt in March
- Two additional transformers burnt in April
- In May, we received a new designed transformer
  - Better HV insulation
  - Better cooling
  - no more troubles with it



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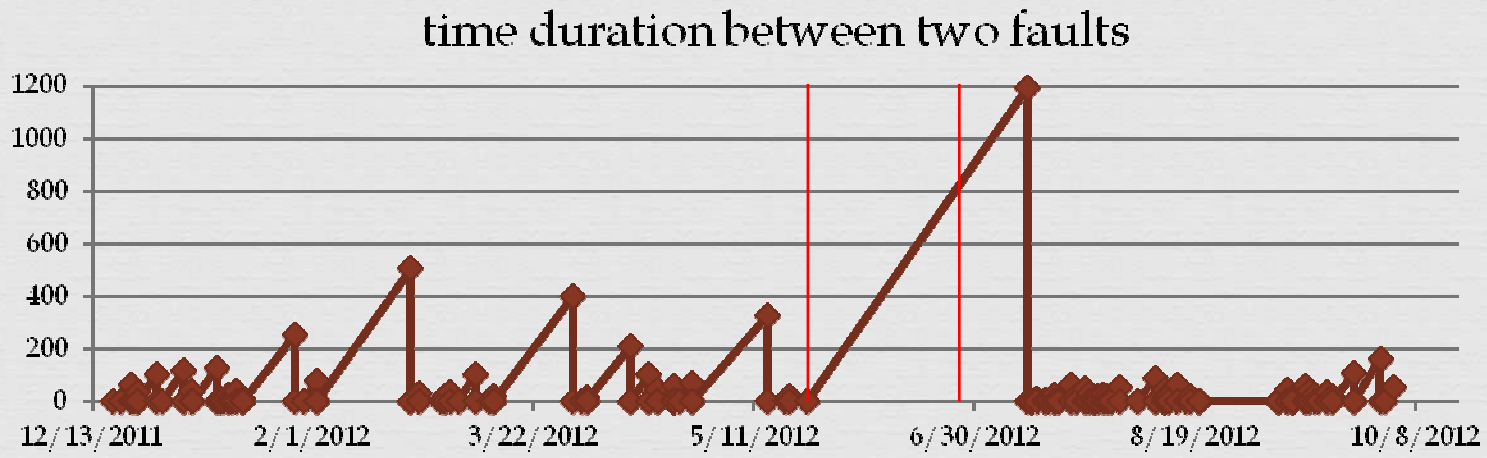

- From 23 May to 28 June : Not a single event !

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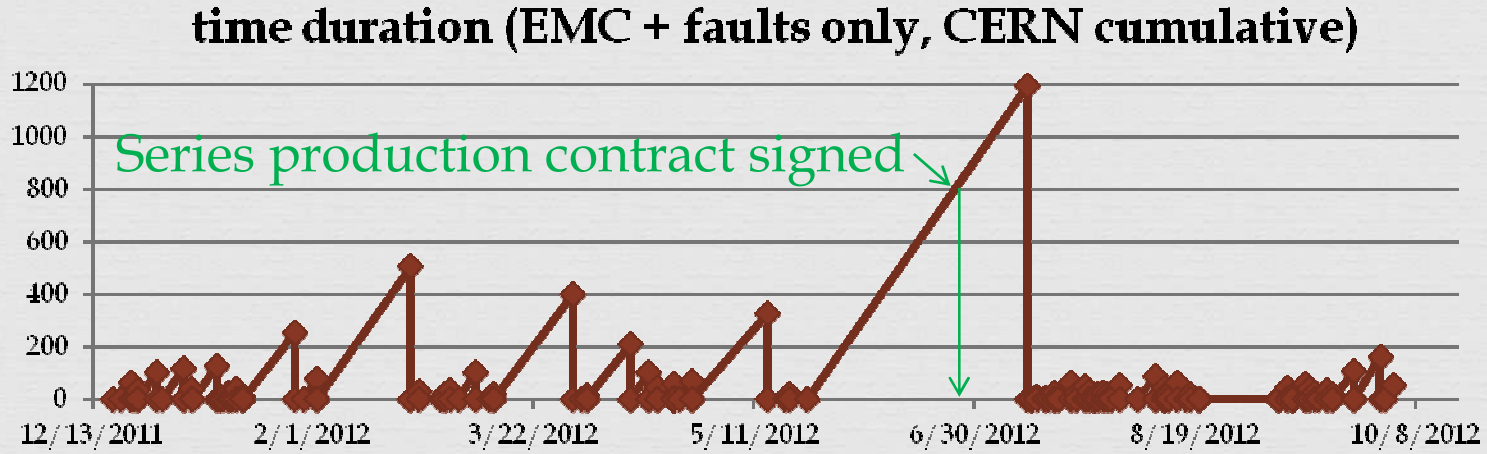


- From 23 May to 28 June : Not a single event !
- 28 June : Contract signed for Series production

2012 Long duration test

- 10 July : after 1192 hours of test without a trip, IOT crowbar
- July – August were Very unstable :
  - Driver Controls (few trips)
  - IOT itself (a lot of cuts)

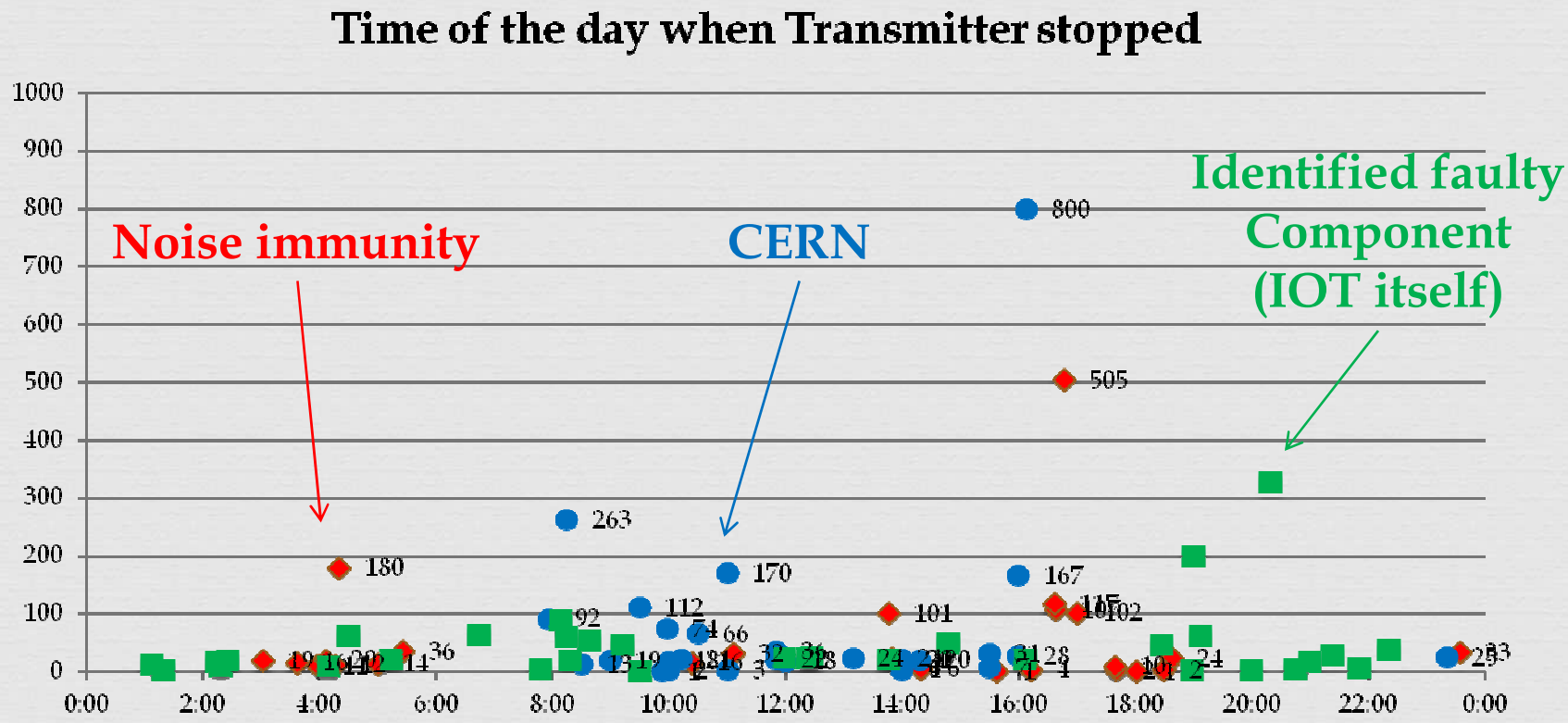
2012 Long duration test

- End of August Thales HV reconditioned our IOT
- Thales comment :
  - 'Gun ceramic has been contaminated by evaporation of material due to some arcs at a time'
  - All inspected characteristics are within specifications

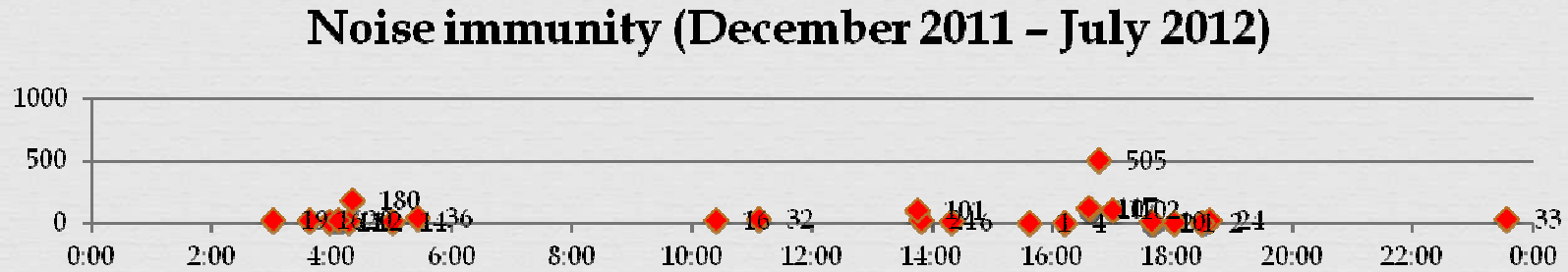
2012 Long duration test

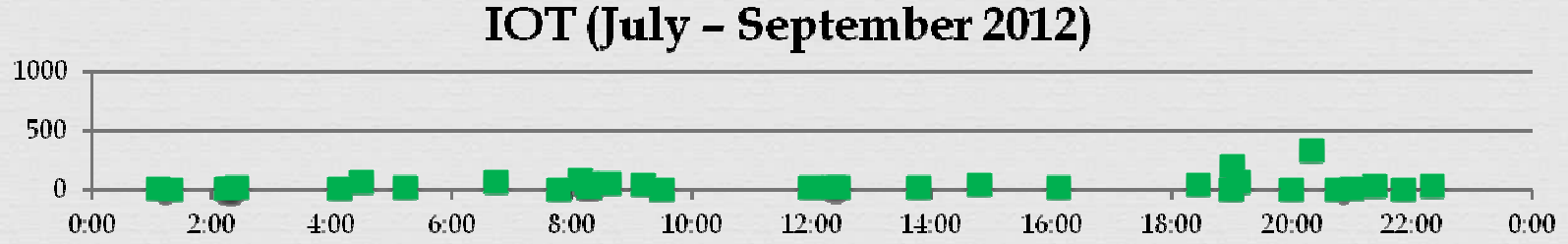
- Since beginning of September
  - Reduced peak power to 40 kW, still AM 43 kHz 25%
  - average of 48 hours between two faults, always an IOT crowbar, Improving
  - In addition, we implemented an Automatic Restart

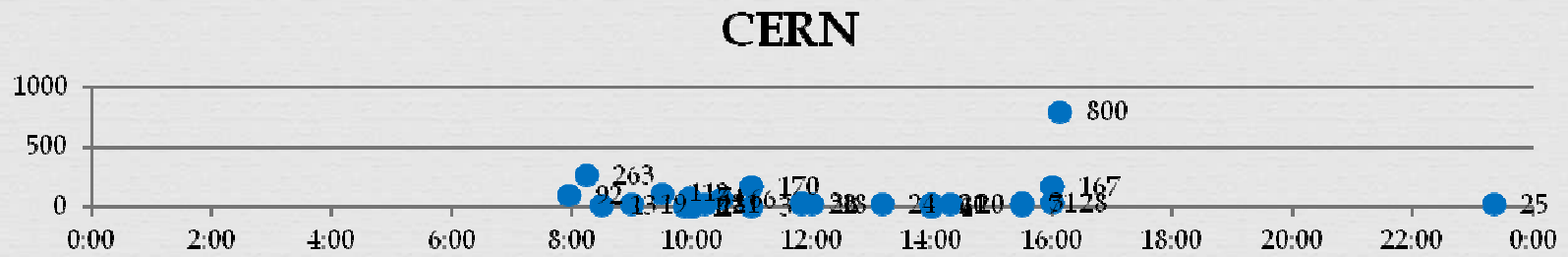
December 2011 to September 2012



Identification of faults

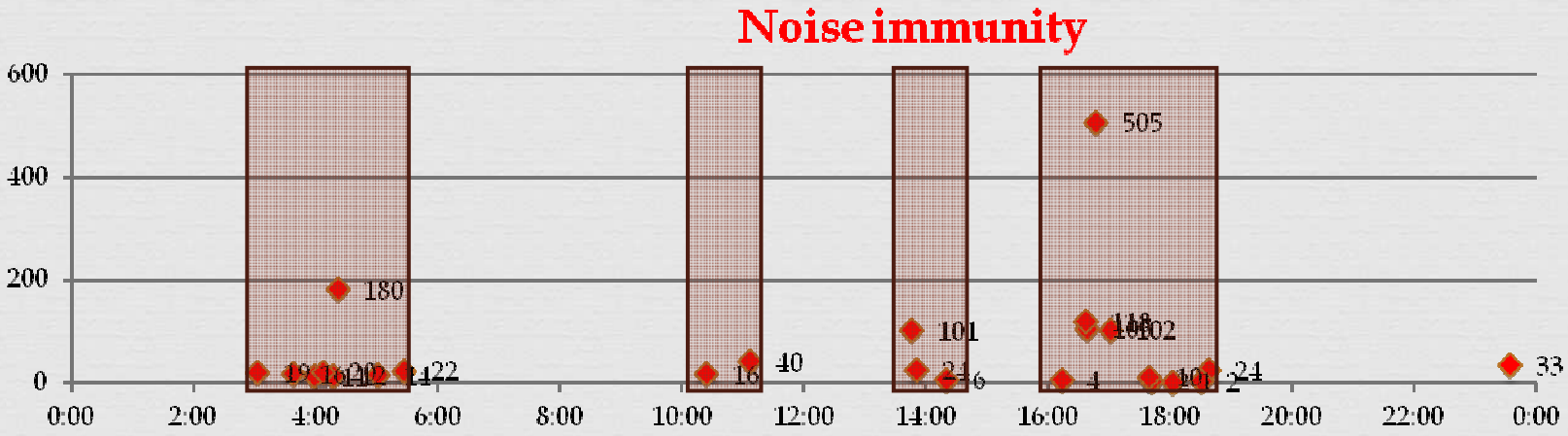






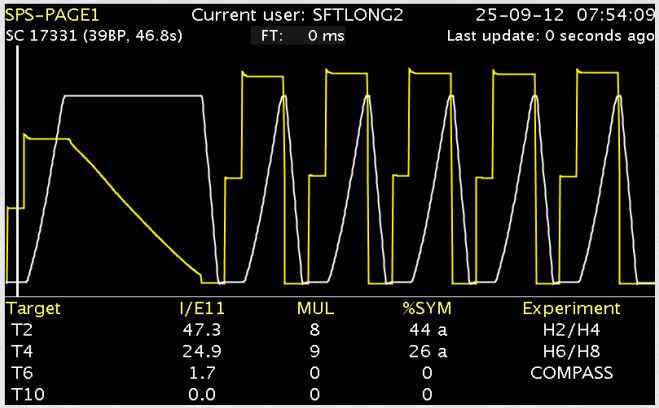
Noise sensitivity

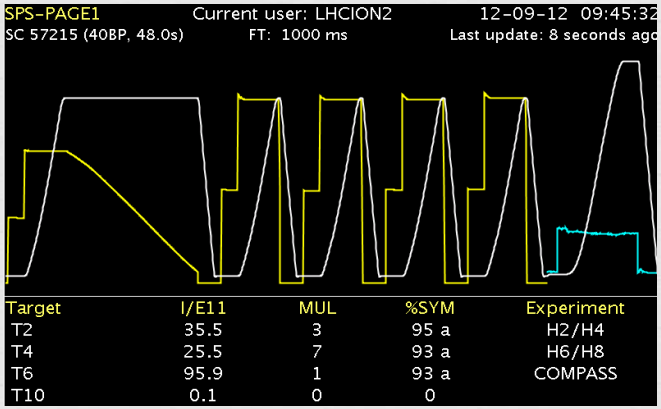
- What can be seen : Faults mainly occur always the same time windows
  - Cannot be the IOT tube itself (it has no internal clock to make our life hardier !)
  - Must be a lack of noise immunity in controls of the transmitter



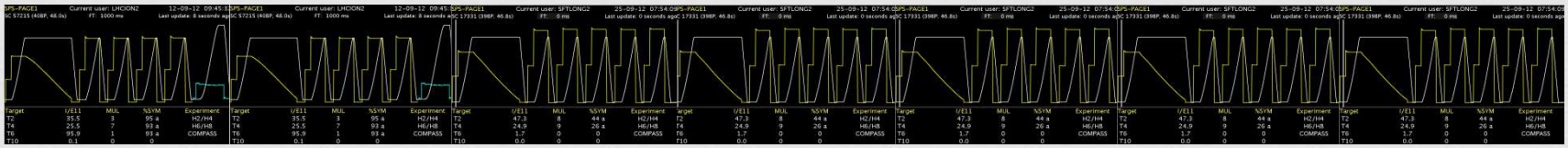
SPS supercycles

- SPS operates with Supercycles
- Supercycles are repeated every ~ 48 seconds
- We inject to LHC during 20 minutes every 4 hours
- During these 20 minutes we have one 8.5 seconds injection to LHC per Supercycle





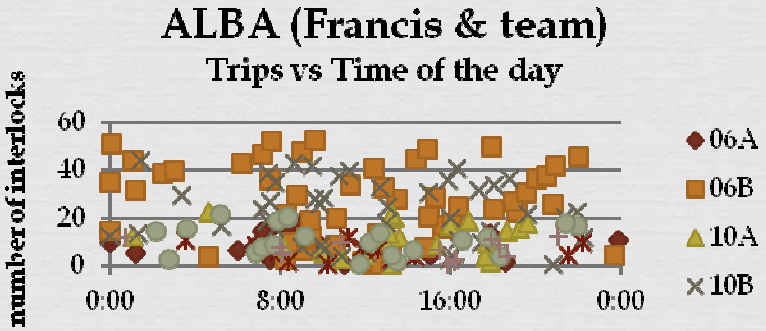
SPS supercycles

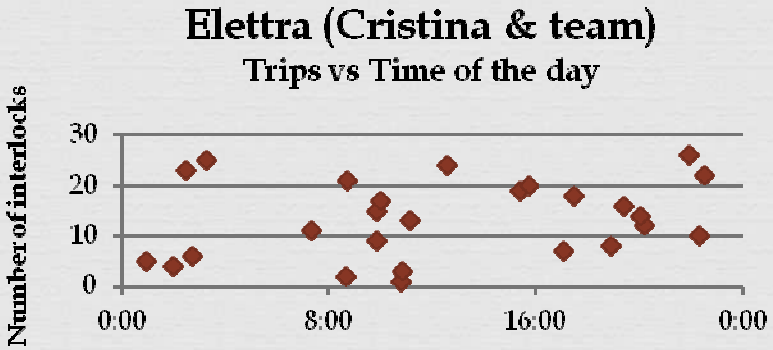
…  …

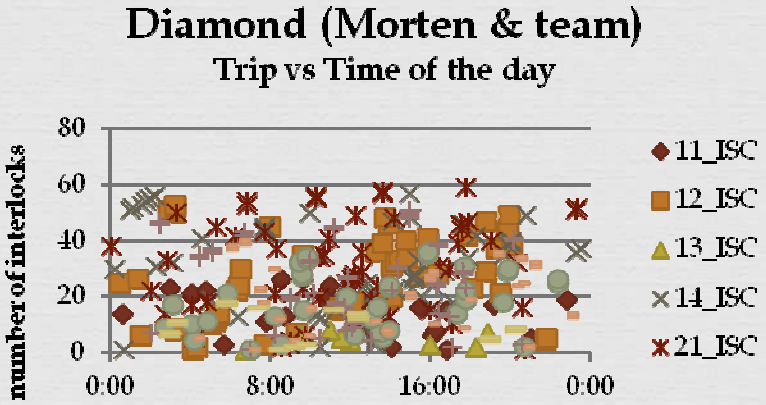
- We now have one trip per 48 hours with 1 x IOT
- Equipment self restarts within less than 120 seconds
- With 8 x IOTs in operation, statistically we will loose :
  - 3 x Supercycles every 6 hours
  - Worst case : 3 / 24 LHC Superscycles : really bad !
- Must be improved regarding SPS operation
  - with 100 tetrodes of our main accelerating system
  - We loose 2 / 1800 Supercyles

Other Laboratories

- With data for both e2V and TED tubes, all other laboratories have better statistics than we have







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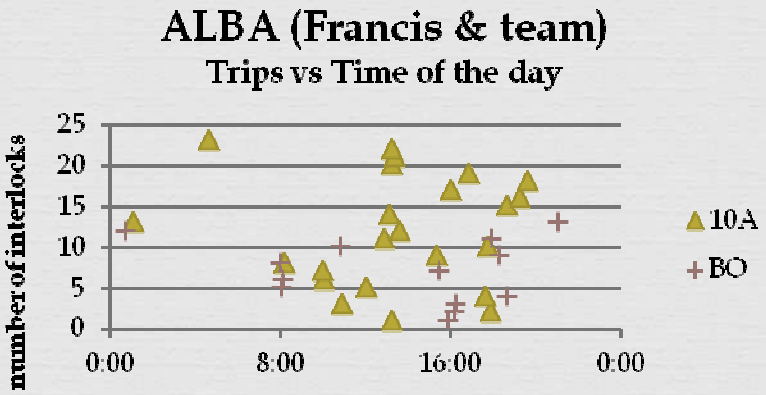

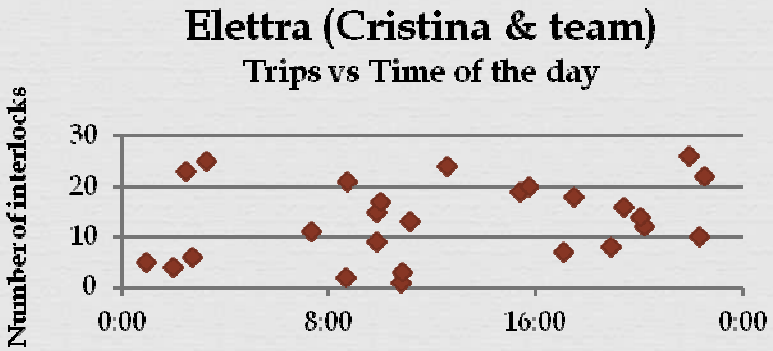

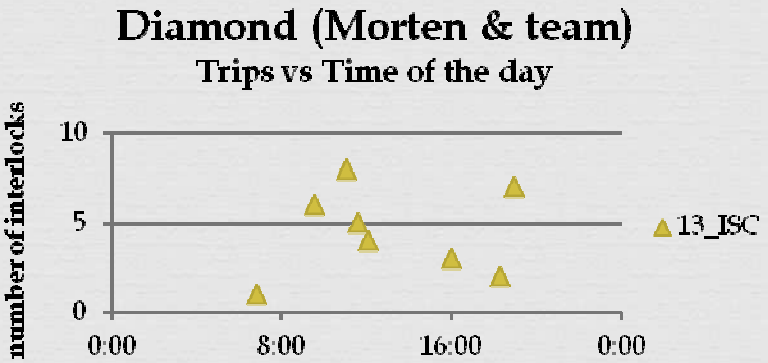

Conclusion 1/3

- Improve Controls immunity to noise
  - 'In house' controls, in order to minimize EMC sensitivity (or to be able to measure it…)

- Operation of our first IOT - **TH793** (#640963) :
  - 10'150 hours with HV applied
  - We already have 2 new **TH795** (#724074 - #725776)
  - How destructive have been HVPMPS, EMC and CERN maintenance and unwanted trips ?
  - Should we have to replace our IOT to be stable again ?

Conclusion 2/3

- Series delivery is scheduled for the last amplifier at CERN by end of September 2013 the latest
- We expect to have 8 transmitters in operation by October 2013, and to accumulate data until June 2014 before SPS restarts after our Long Shut-Down

Conclusion 3/3

- many thanks to ALBA, Diamond, Elettra, for their statistics
- These results from other labs using IOTs are very encouraging as having better statistics then us
- How and which data to collect to be of interest for all IOTs community ?

Thank you very much for your attention