LHC Beam Dumping System

Experience from reliability run and Re-commissioning procedures

MPP 31.10.2014

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OUTLINE

- Summary of MKD HV Generator problems and renovations during LS1
- Summary of Electrical distribution renovations during LS1
- Summary of TSDS problems and renovations during LS1

- Summary of Second Dry Run Results

- Requirements for Commissioning without Beam (Cold Checkout)
- Requirements for Commissioning with Beam

- Conclusion

MKD HV GENERATORS RENOVATION

MKD HV generator GTO stack renovation

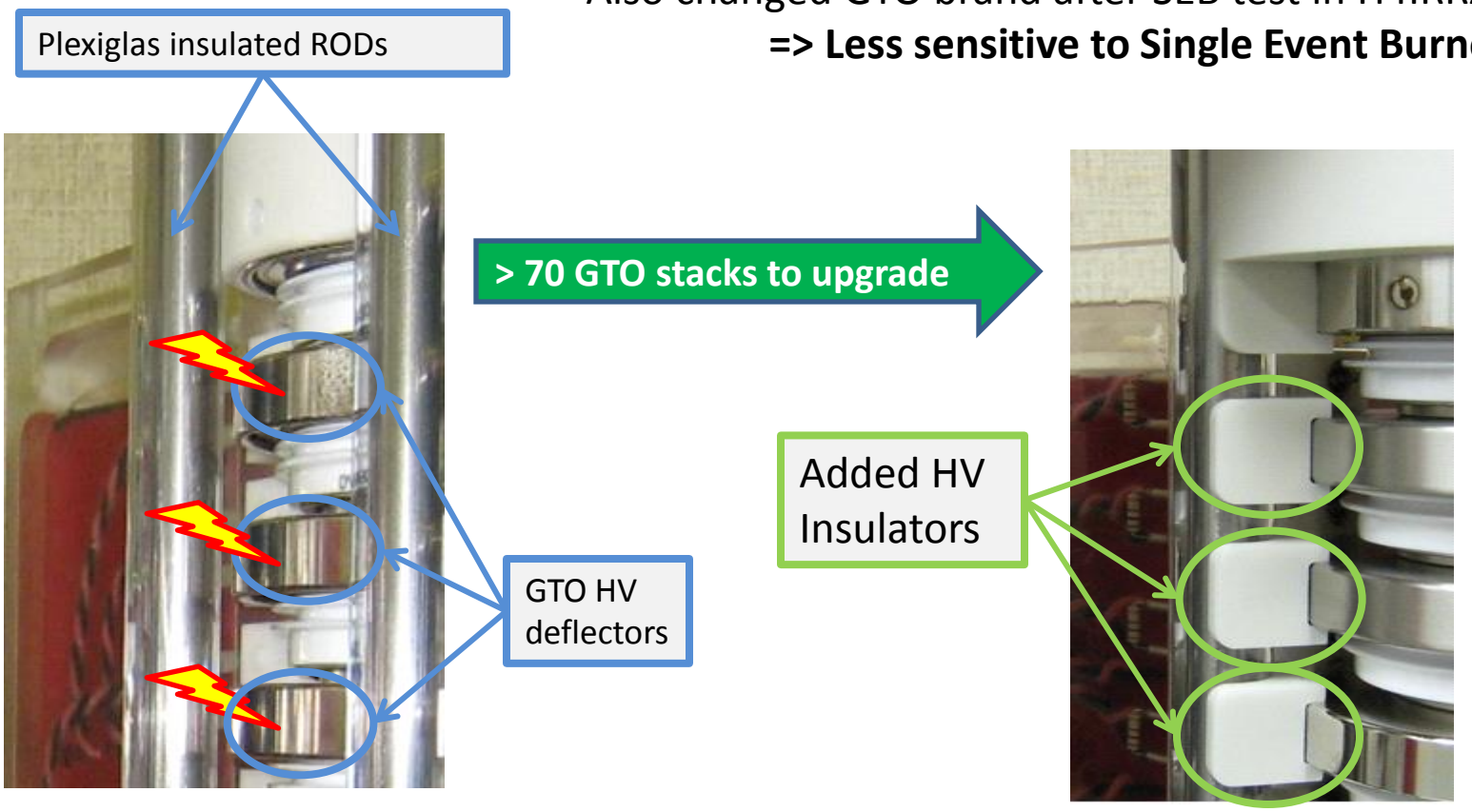
LHC Run I operation limited to 5 TeV due to electrostatic discharge on GTO stack

=> Spontaneous triggers

⇒ **Added insulator between Plexiglas insulated ground ROD and GTO HV deflectors.**

Also changed GTO brand after SEB test in H4IRRAD

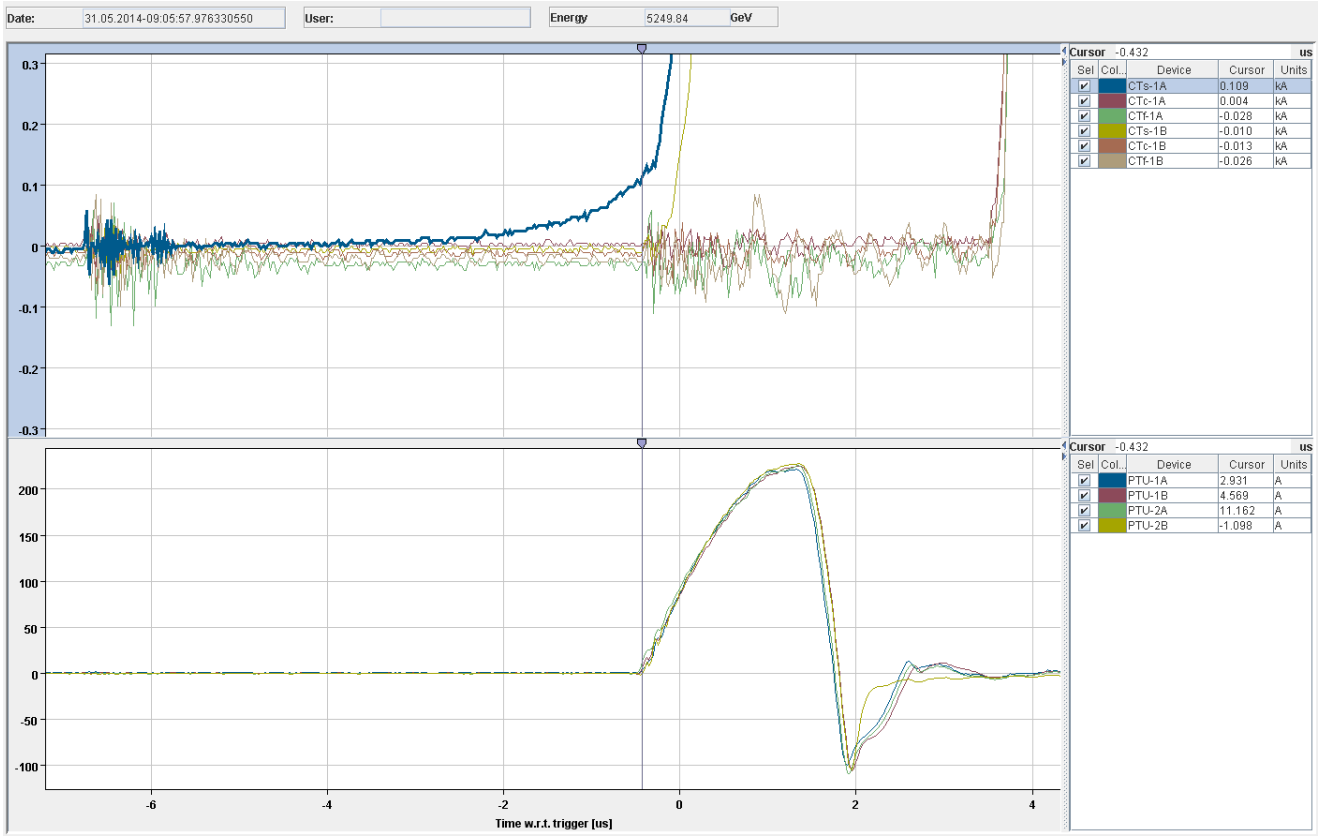
=> Less sensitive to Single Event Burnout



Spontaneous Triggering of MKD HV Generators

Stay at 7 TeV for long periods, trigger every 8h (?):

- Started tests with MKD Beam1 (08.2013): => 2 Gen. doing spontaneous triggers.
- Started tests with MKD Beam2 (11.2013): => 6 Gen. doing spontaneous triggers.



Problem is still due to small electrostatic discharges inside HV generator that provoke the triggering of the GTO stacks.

Understanding the Problem

After months of investigations:

1) **We found a workaround**:
   Adding resistance in parallel with G-C of GTO to reduce mutual coupling (via trigger transformers) => electrostatic discharges do not trigger the GTO stack anymore.
   => Resistances installed on all GTO trigger transformers.

2) **We identified one source of the problem**:
   An insulator tube gets charged slowly due to its geometry and surface properties, and eventually discharges through the top GTO A-G capacitance.
   - New tube series production launched.
   - 20 % of series will be tested in the laboratory.

   => New tubes installed in all HV generators.

3) **We found a lot of dust inside the HV generators:**
   After proper cleaning of all the generators, no significant electrostatic discharges occurred anymore.

Sand blasted Bakelite tube after sparking

MKD HV Generators - SECOND RELIABILITY RUN RESULTS

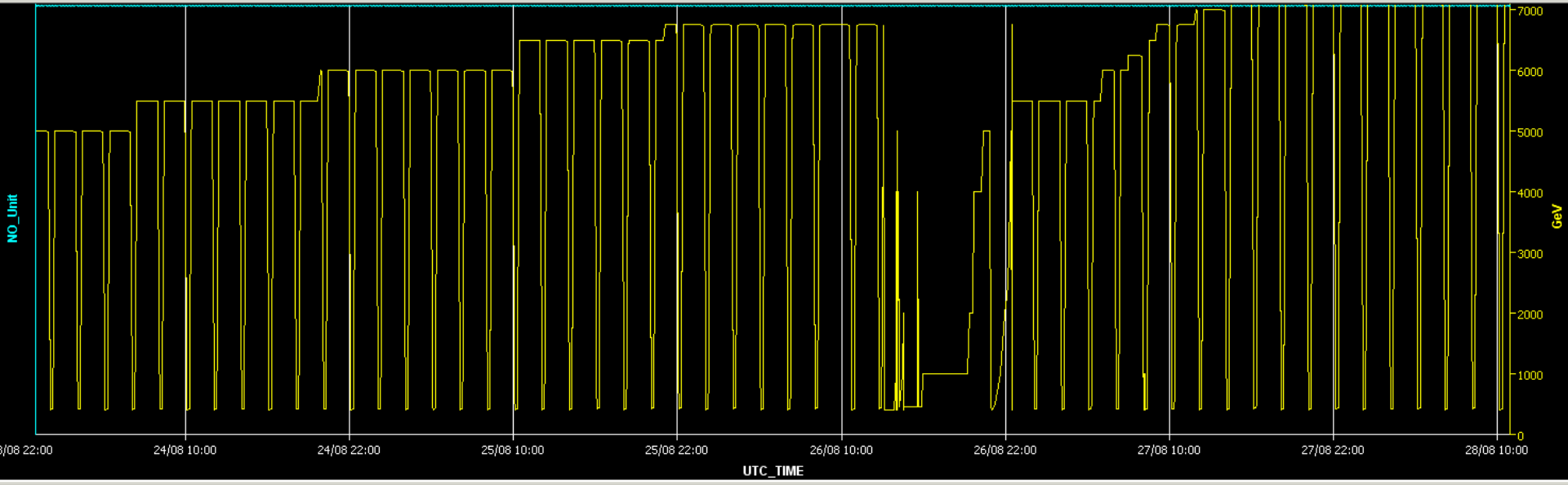
No more problems with HV Generators

LOCAL Reliability Run:

- Progressive increase of voltage and flat-top duration
- Flat-top up to 7.1TeV / 6h
- **=> No problem found !**

=> HV Generators OK, tests continue during Dry Runs…

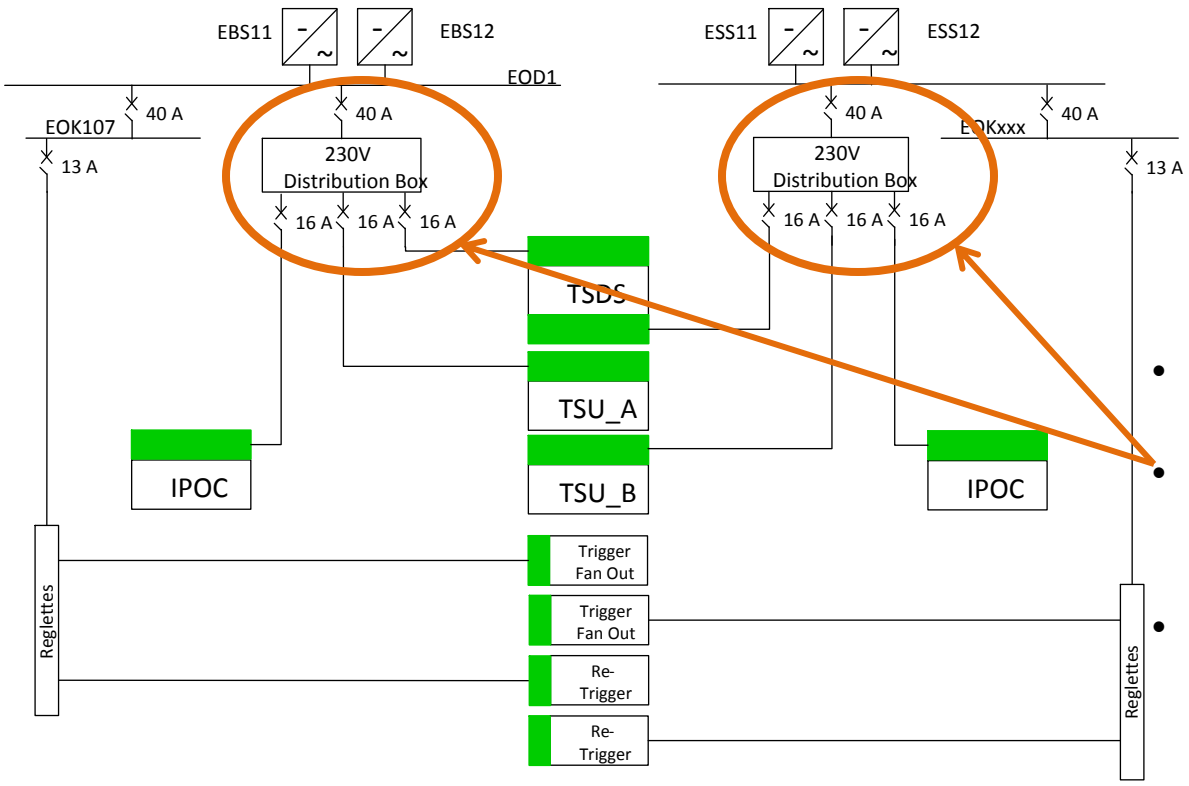
BUT: Still some worries about DUST in UA (in generators due to HV)

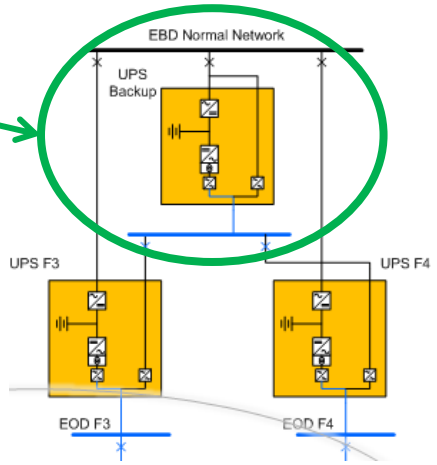


ELECTRICAL DISTRIBUTION RENOVATION

Improvement of Power Distribution Architecture

- Third UPS (backup) added everywhere





- Second UPS installed for LBDS (US65)
- Distribution Boxes with Separate circuit breaker for every crate PSU.
- Software monitoring of crate redundant PSU (DIAMON)
  => SIS request a dump in case of failure of redundant PSU.
- ‘Secondary’ PSU surveillance inside TFO and all general purpose crates.

Planned Actions: Consolidation of UPS Electrical Distribution

What	Who	When
Install redundant UPS powering from UPS in US65 to LBDS general purpose racks (MYDGPxx to MYDGPyy) in UA63 and UA67.	EN/EL	09/2013
Implement correct redundant UPS power distribution system for LBDS general purpose racks.	EN/EL	09/2013
Define specifications and implement power distribution boxes inside racks housing VME & cPCI crates.	BE/CO EN/EL	09/2013
Calculate correct selectivity of UPS distribution system.	EN/EL	09/2013
Check correct selectivity of UPS distribution system.	EN/EL	09/2013
Remove temporary LBDS UPS connection to F4 line (QPS) in UA63 & UA67.	EN/EL	09/2013

Planned Actions: Test of UPS Electrical Distribution

What	Who	When
Full simultaneous test of power cut of two UPS in UA67 US65 And MAIN. **=> Resulted in a synchronous dump as expected.** No diagnosis, so first TSU client not identified.	EN/EL TE/ABT	03/2013
Individual test of UPS power cut in UA67 and US65. $\Rightarrow$ **Resulted in a synchronous dump as expected.** ***Nonetheless, Non conformity identified and corrected.*** TSU IPOC diagnosis not available, because **redundant PSU not yet installed in KISS FEC**.	EN/EL TE/ABT	10/2014

Planned Actions: Implementation of 'Secondary' voltages surveillance

What	Who	When
Develop (and produce) secondary voltages surveillance modules for G64, VME and TFO crates.	TE/ABT	12/2012
Connect G64, VME and TFO secondary voltages surveillance modules to LBDS ASIbus. Integrate surveillance within safety part of LBDS master PLC. Generate synchronous internal dump request in case of failure.	TE/ABT	09/2013
Implement REMOTE surveillance of VME and cPCI crates. Connect REMOTE surveillance to LHC SIS (INJECTION PERMIT or BEAM PERMIT).	BE/CO	06/2014
Hardware and software surveillance of crate PSU not yet tested.	TE/ABT	??/????

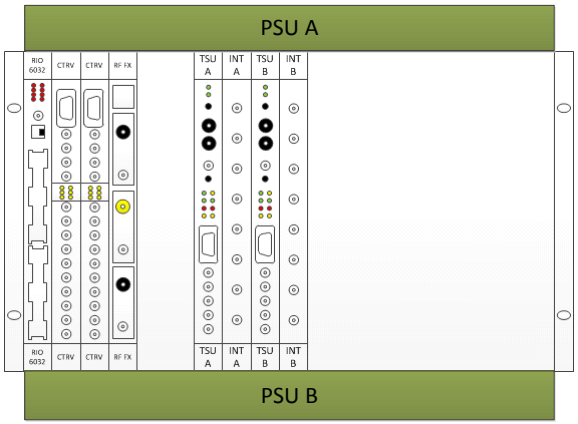
TSDS RENOVATION

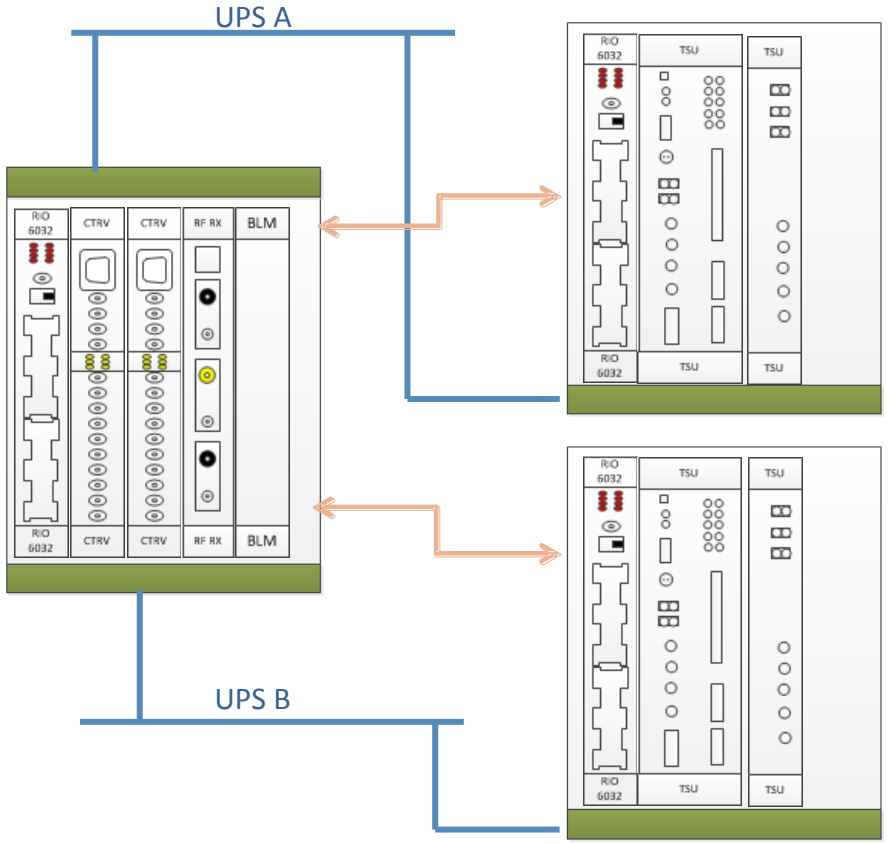
New TSU Deployment

Change deployment from 1 VME crate to 3 VME crates.

Motivation:

- Internal review of LBDS Powering (2012)
- VME crate +12V problem (2012)





Installation in LHC done.

TSU v3 Development

Motivation for new TSU v3 design:

- External review of TSU v2 cards (2010)
- CIBU powering filter problems (2011)
- Improvement of surveillance & diagnosis
- Deployment over 3 VME crates

Project status:

- Hardware prototypes **validated**.
- Production of 12 cards **done**.
- Firmware development **still in progress…**

Planning:

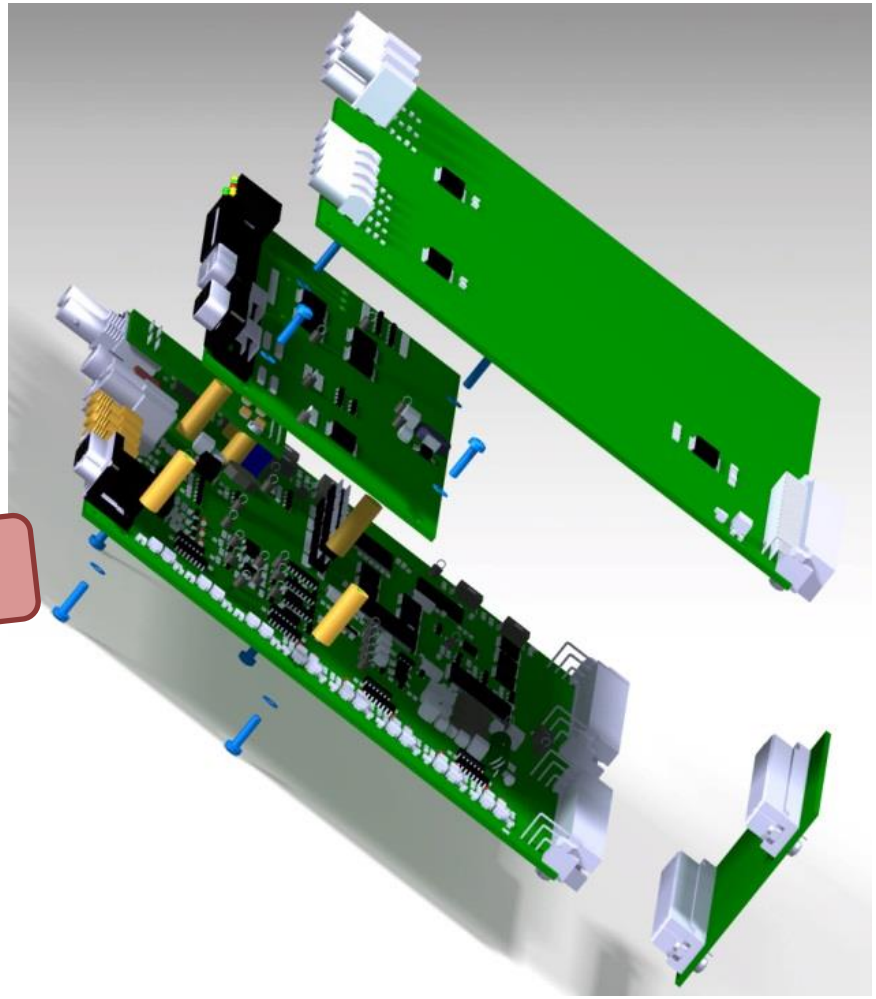
- 1st step:
  TSU v3 hardware with TSU v2 firmware
  ⇒ **DONE**

TSU v3 installed in the LHC !!!

- 2nd step:
  TSU v3 firmware with new features
  => ONGOING

⇒ Firmware development is **ongoing by small steps**

⇒ **Revalidation of each changes** before next step using the **TSU Test Bench**



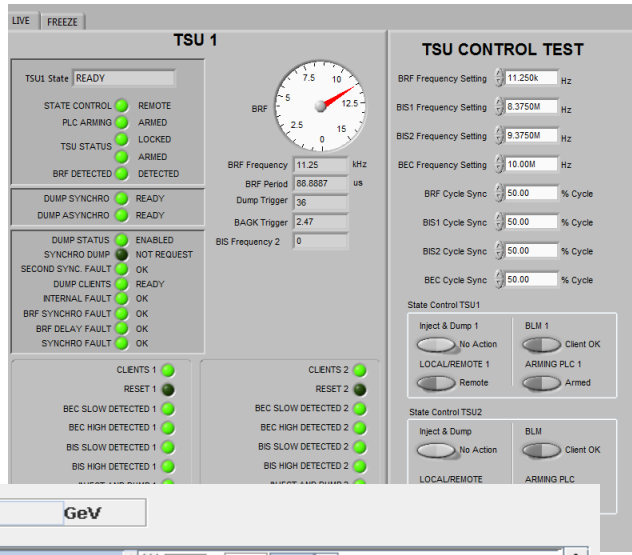
TSU Test Bench

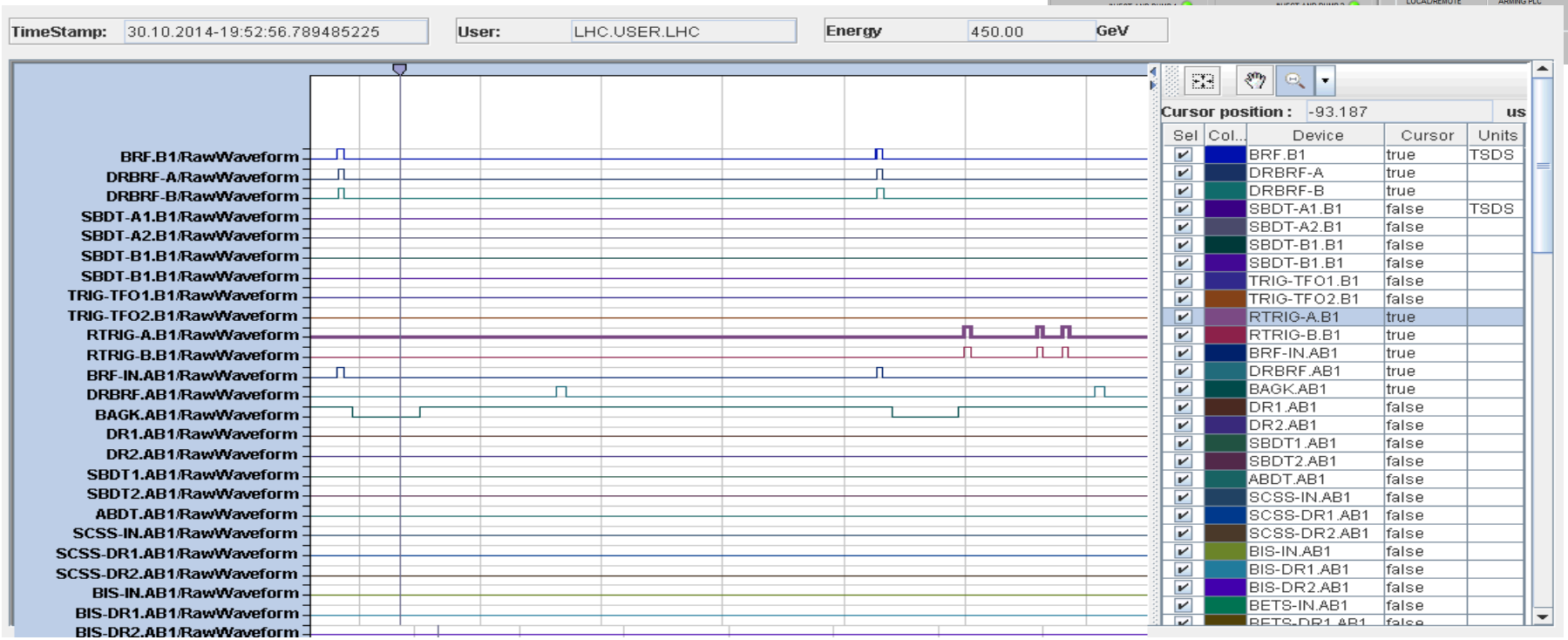
Motivation:

Careful validation of new firmware before use in operation.

Based on a National Instruments PXI system to:

- Generate all TSU input signals.
- Check all TSU output signals.
- Check IPOC analysis results.
- Various dump scenario (>100) executed in loop 24h/7d.





Planned Actions: Study of WIENER Power Supplies Replacement

What	Who	When
Study the option to **replace the actual single FEC** housing the two redundant TSUs **by separate and fully redundant FECs.**	TE/ABT	11/2012
Add diode in the +5V and +12V powering circuit at the input of the TSU & increase capacitance level at the cathode side of the diodes **in order to increase hold-on duration in case of global powering failure**.	TE/ABT	11/2012
Add internal surveillance of +12V and +5V within the TSU. Generate an INTERAL_FAULT condition in case of detection of one voltage out of tolerance (typ. -10%) and request a DUMP_TRIGGER through the redundant TSU.	TE/ABT	11/2012
Study the impact (reliability, powering, failure mode…) of **replacing the WIENER FECs with new ELMA FECs**.	BE/CO TE/EPC PH/ESE	12/2012
Install ELMA FECs in LBDS (1 redundant and 2 simples).	BE/CO	09/2013

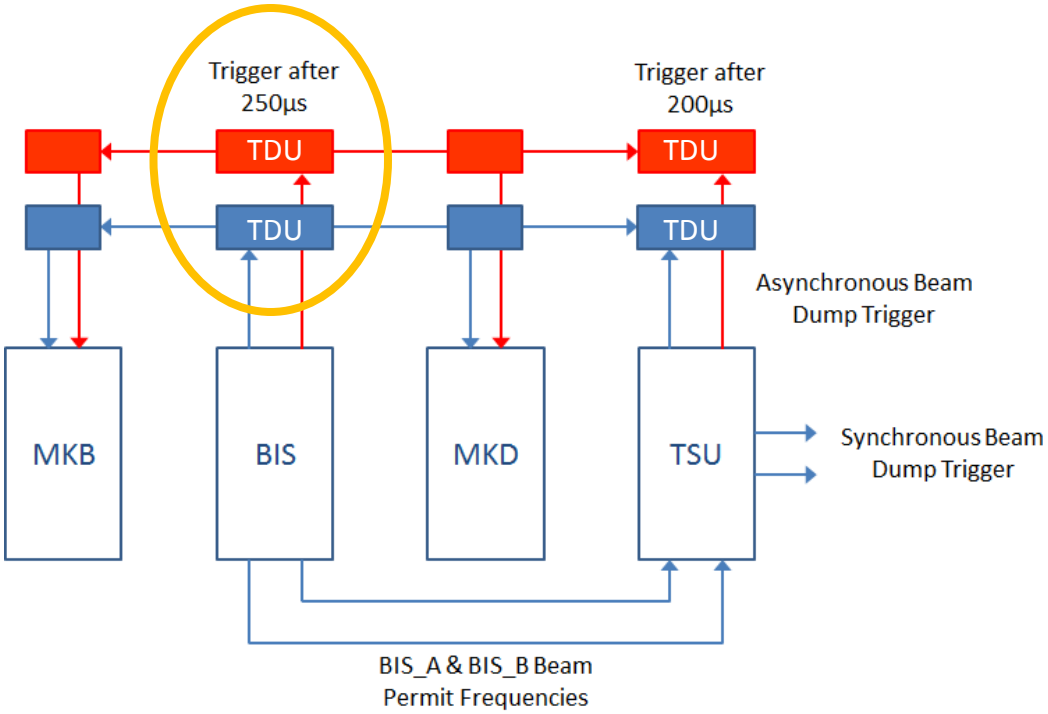
Direct connection from BIS to LBDS Retrigger-lines

In the case the TSU cards do not send triggers at all (unknown/new failure mode) ?

=> BIS generates retrigger pulses after 250 us

MPE designed a new **CIBDS** card, inserted between BIS and Re-Trigger delay boxes.

CIBDS and TDU250 are installed in UA63 and UA67



Direct Connection from BIS to LBDS Retrigger-Lines

- Asynchronous dump triggered by BIS has been tested.
- Presence of pulses from CIBDS and TDU250 will be checked by IPOC.

BIS retrigger pulse quite low after 15 MKDs.

- Enough to trigger LBDS

NOT Enough to be detected by IPOC

Planned Actions: Direct Connection from BIS to LBDS Retrigger-Lines

What	Who	When
Study possible implementation and integration of redundant asynchronous triggering of the LBDS directly from the BIS.	TE/ABT TE/MPE	10/2012
Produce re-trigger crates with 250us delay (4 + 2 crates).	TE/ABT	03/2013
Modify cables routing of re-trigger lines at the level of the BIS racks in UA63 & UA67 in order to include BIS dump request in the chain.	EN/EL	09/2013
Install cables between BIS and LBDS racks for monitoring of re-trigger crates within BIS.	EN/EL	09/2013
Generate "trigger pulse" from BIS to re-trigger crates for TRUE to FALSE transitions of the BIS frequencies.	TE/MPE	TBD
Add channels in LBDS master PLC surveillance for additional re-trigger crates.	TE/ABT	09/2013
Modify TSU-IPOC analysis for detection of re-trigger pulses coming from BIS 250us after dump request.	TE/ABT	03/2014

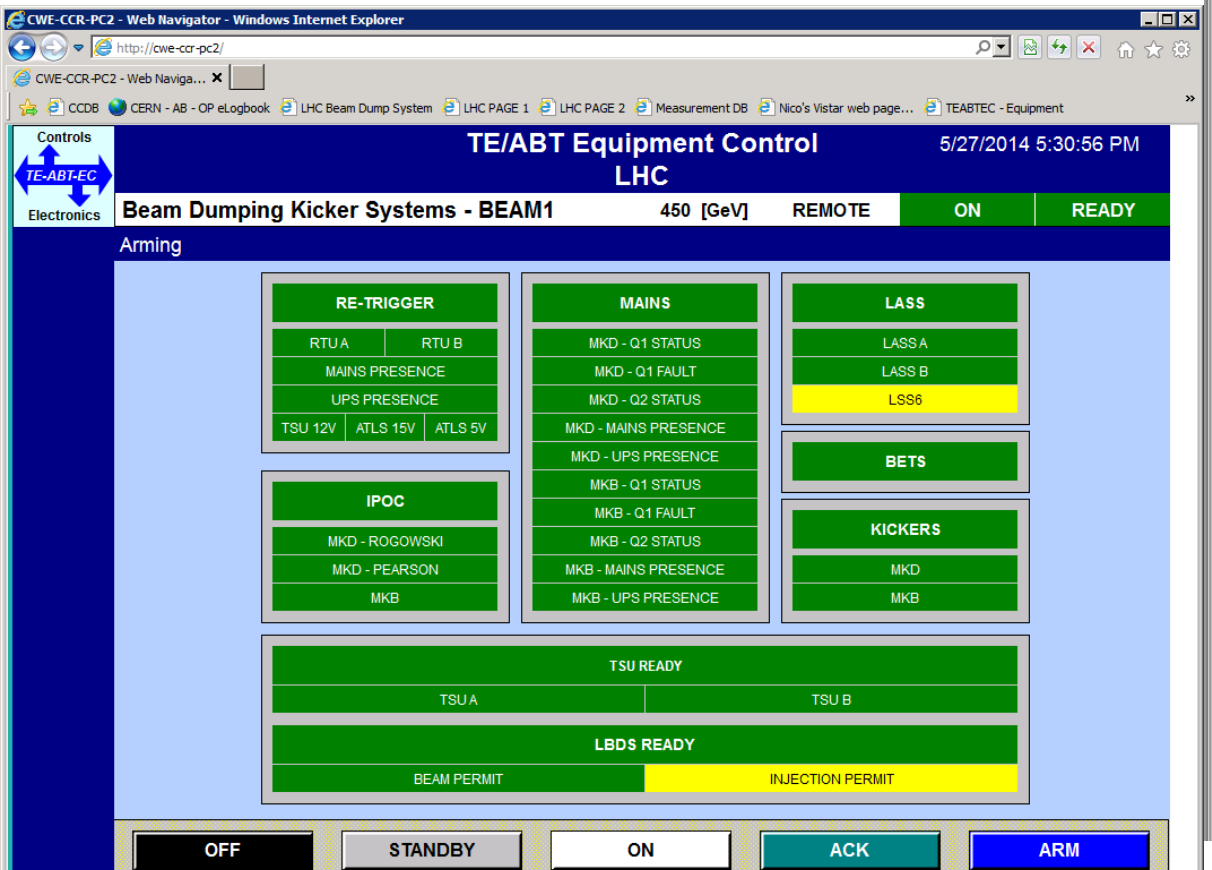
SECONDARY DRY RUN

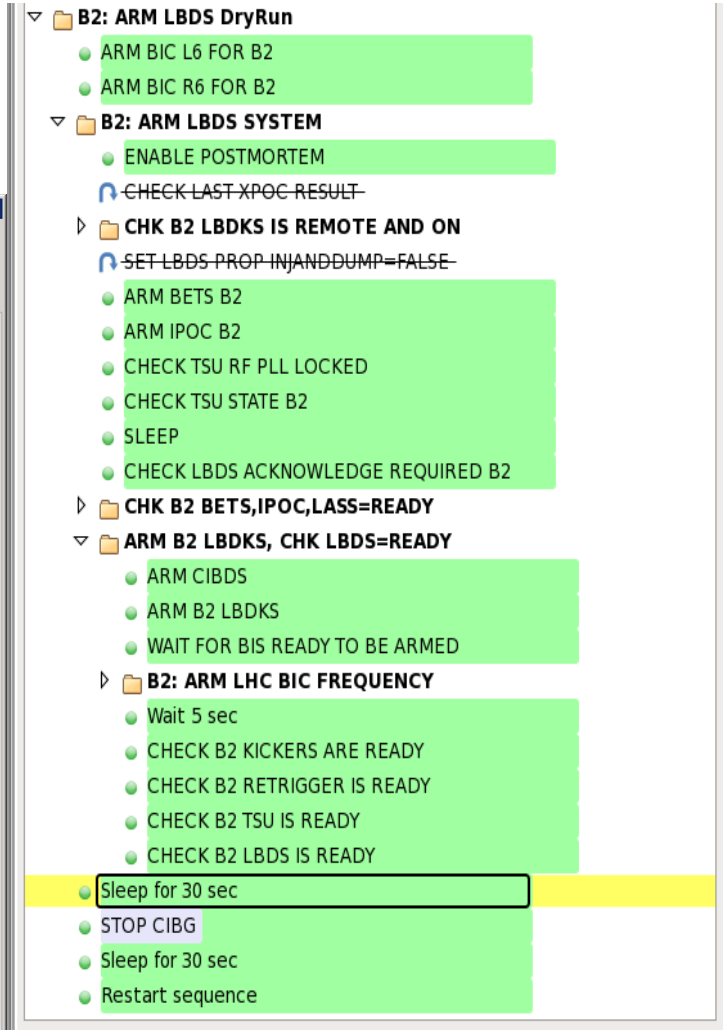
SECOND DRY RUN RESULTS

LBDS Looping Arm - Ramp - Dump in REMOTE

- GLOBAL BIS loop closed
- Signal Generator connected to BETS
- BRF coming from RF.
- **New TSU v3 cards Armed !!!**

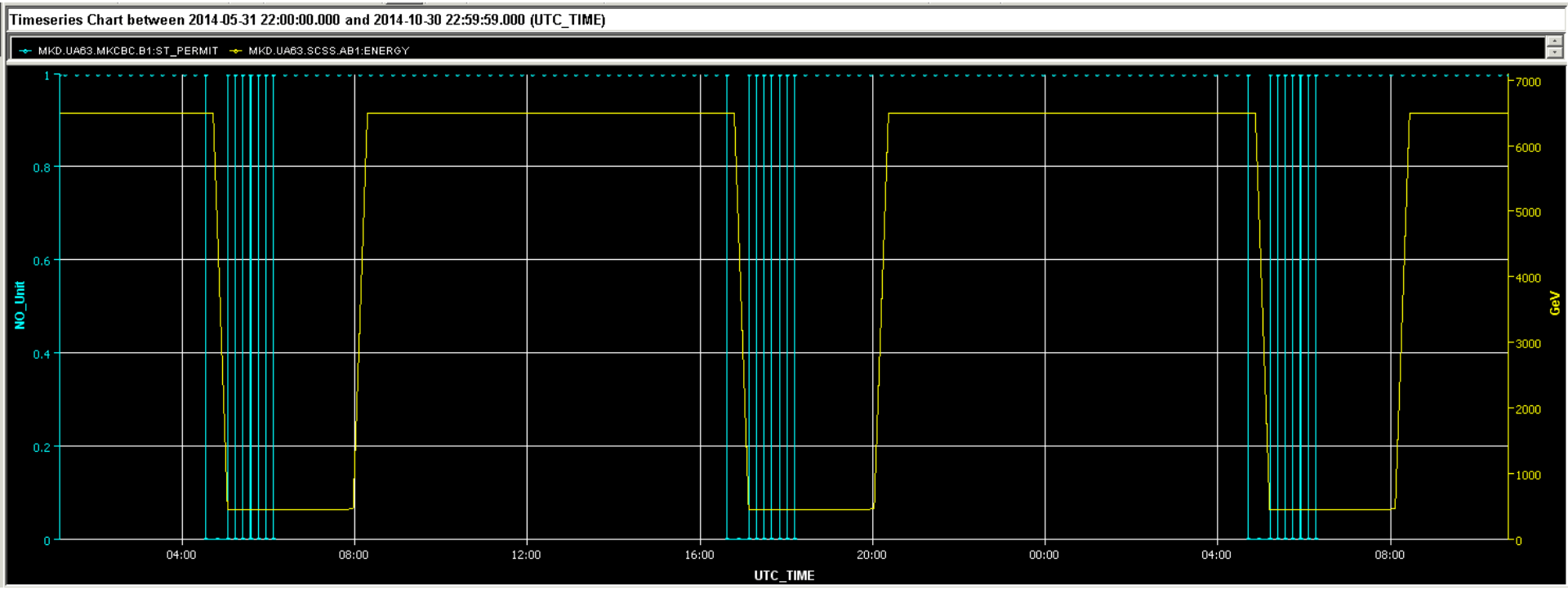
⇒ Looping Arm-Ramp-Dump using LHC Sequencer





SECOND DRY RUN RESULTS

LBDS Looping using BETS-Simulator



12h Cycles - Looping using Sequencer:

- 1 pulse every 10min at 450 during 1h
- ~1h cool down at 450 GeV
- 20min Ramp-Up to 6.5 TeV
- >8h Flat-Top at 6.5 TeV
- 20 min Ramp-Down to 450 GeV

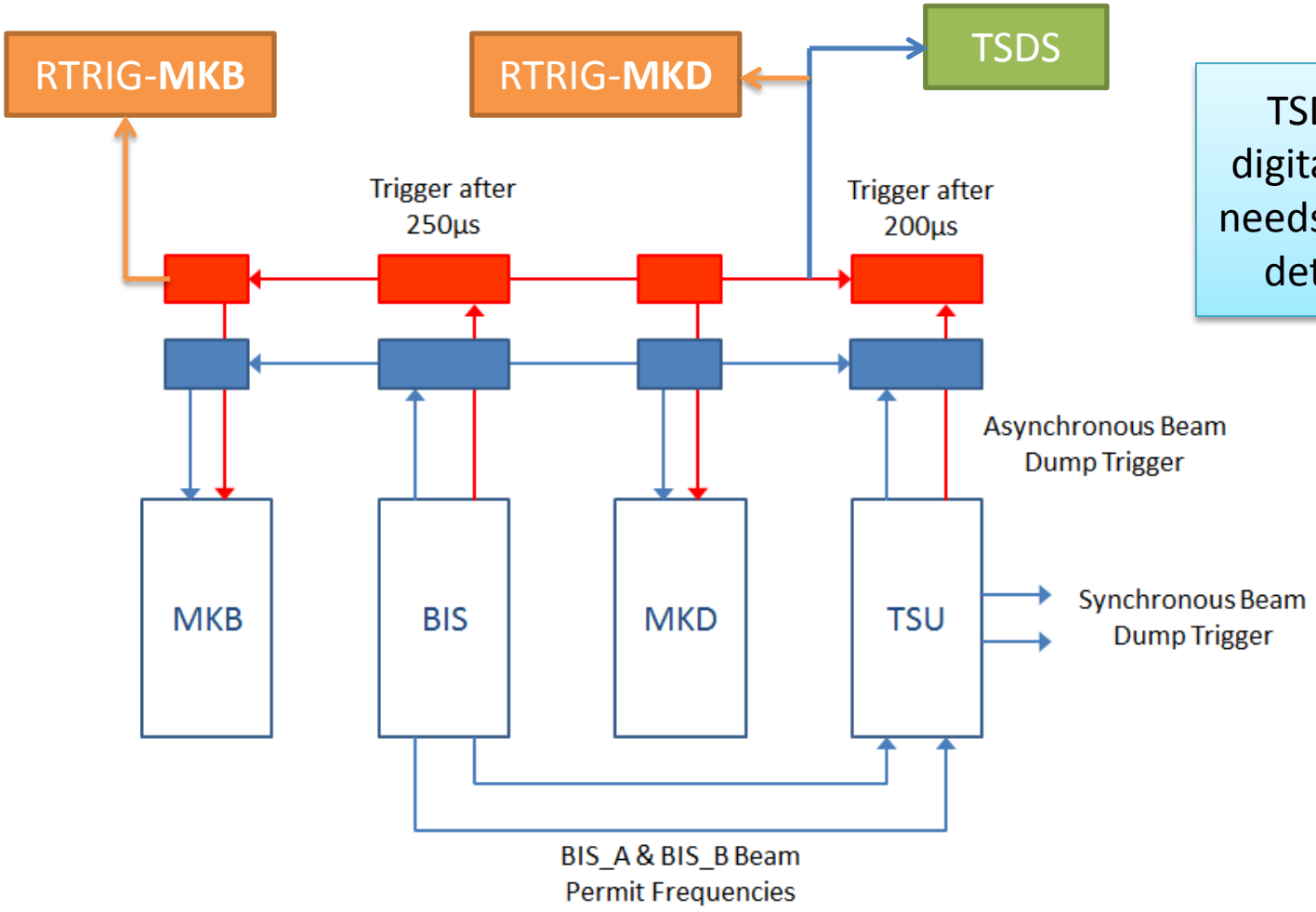
- No problem seen with **HV generators**
- No problems **arming the CIBDS cards**
- No problems **arming the new TSU cards**

=> All dumps performed properly

Direct Connection from BIS to LBDS Retrigger-Lines

New IPOC systems at both ends of Re-Trigger lines

Presence of pulses from CIBDS and TDU250 will be checked by IPOC.

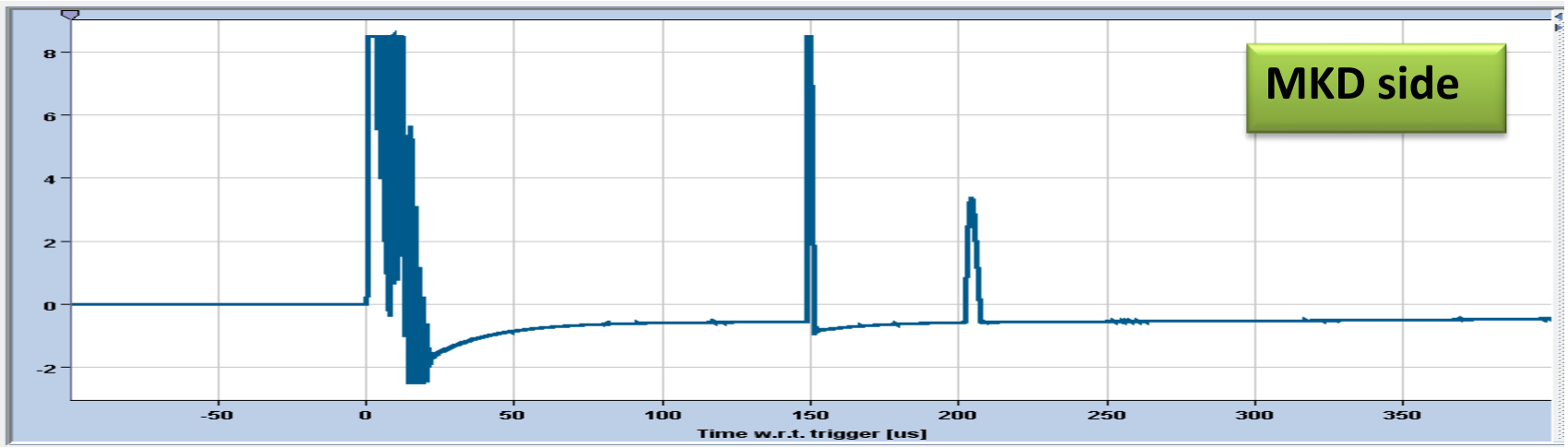


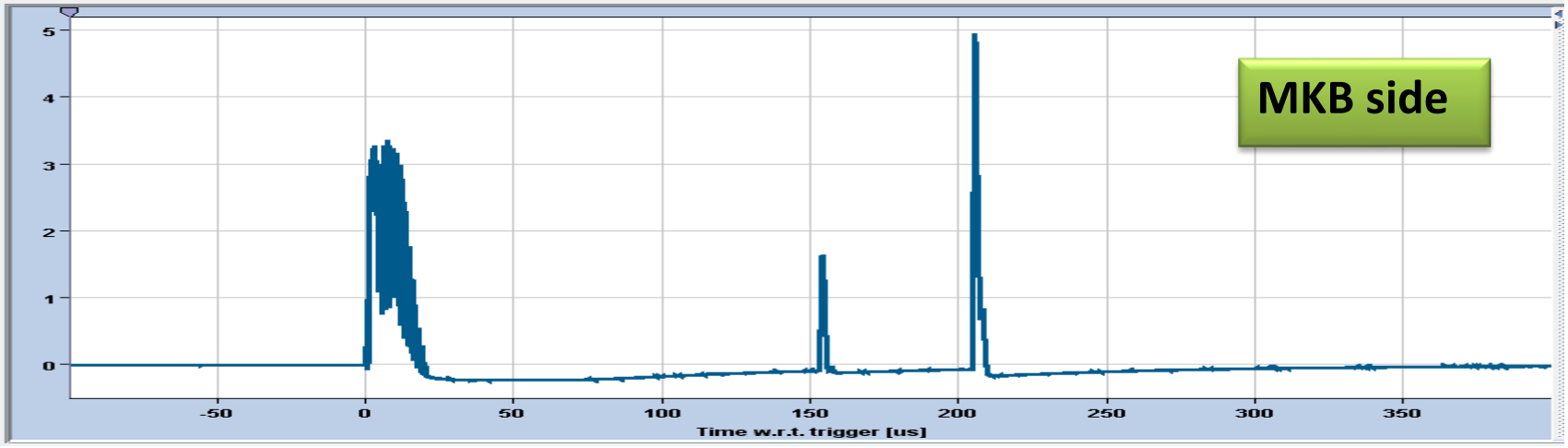
TSDS IPOC has digital inputs, so it needs at least 2V to detect a pulse.

SECOND DRY RUN RESULTS

Direct Connection from BIS to LBDS Retrigger-Lines

Pulse at **450 GeV**

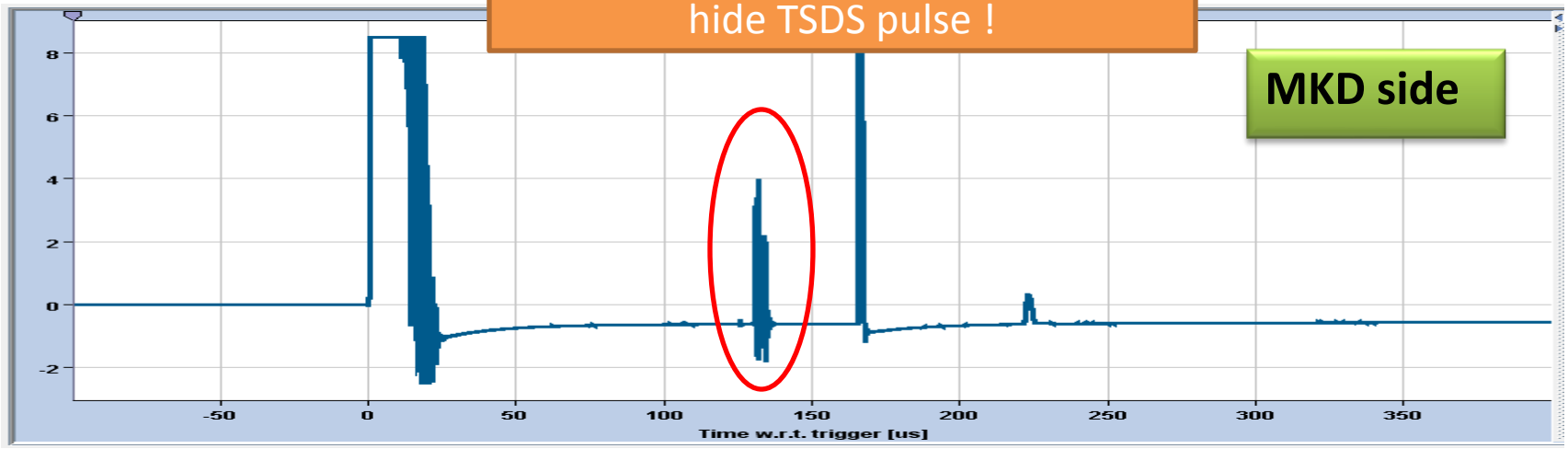


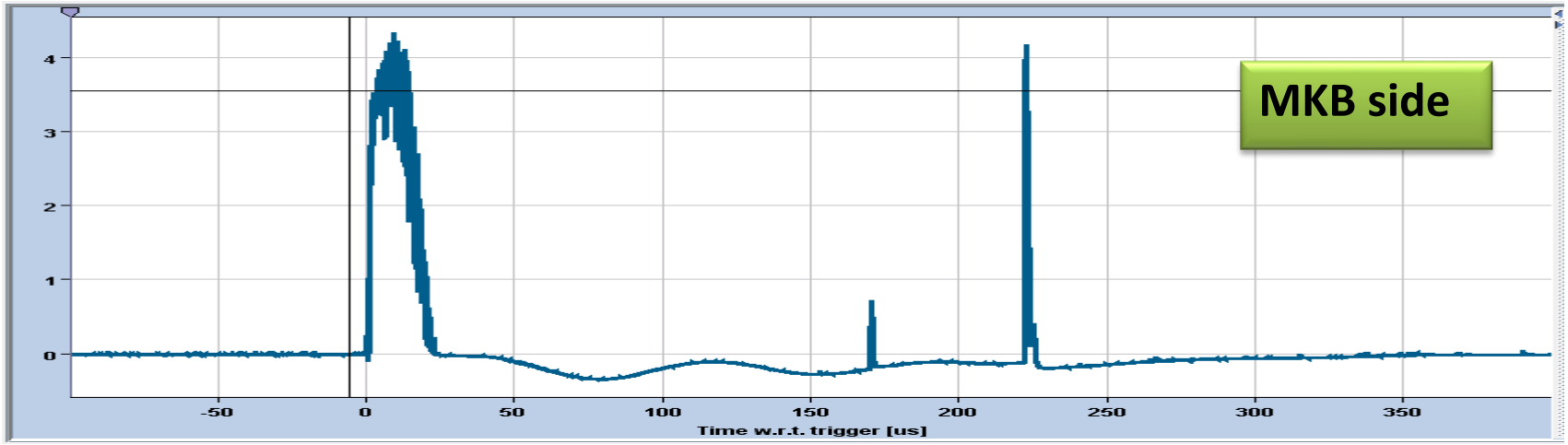


Direct Connection from BIS to LBDS Retrigger-Lines

Pulse at **6500 GeV:**

Free-Wheel Re-Trigger pulse could hide TSDS pulse !





Direct Connection from BIS to LBDS Retrigger-Lines

Problem:

Free-Wheel Re-Trigger pulse could hide TSDS pulse !

(Measured up to **150us** after trigger)

=> Can we increase the TDU delays ?

- TSDS = **250us** (instead of 200us)
- CIBDS = **270us** (instead of 250us)

We need to perform studies on the re-trigger line:

- A model for full simulation of Re-Trigger line is needed.

UPDATED PLANNING

Dates	Duration	Control	Activity
=> End of 2014		REMOTE	**Dry Run:** - Global BIS Loops / BETS Simulator - Validate TSU firmware(s) - Validate BIS-Retrigger (IPOC) - Validate LBDS settings (SCSS / IPOC / XPOC) - Ramp, Flat-Top 8h, Dump
End November	1 week-end	REMOTE	**LBDS must be ready for Transfer Lines Tests:** - **Validate Inject&Dump**
Date TBD by OP and MPE…		LOCAL	**LOCAL Reliability Run:** - Remove BETS Simulator - Test HV holding for long periods - Regular Ramps & Energy-Scans

We would like to keep LBDS in REMOTE with the LOCAL BIS loops as long as possible !

COMMISSIONING WITHOUT BEAM

We request 2 days in REMOTE with BIS closed to:

- Re-validate **hardware**
  (HV Generators, TSU, BETS, IPOC, TCDQ, Etc…)

- Re-validate of all **software** layers
  (SCSS, IPOC, XPOC, BETS, TSU, Etc…)

- Re-validate Arming sequences
- Re-validate Inject & Dump sequence
- Re-validate Beam Injection Permit

PLUS:

- **Updated** Machine Protection Procedures for LBDS (EDMS **896392**)

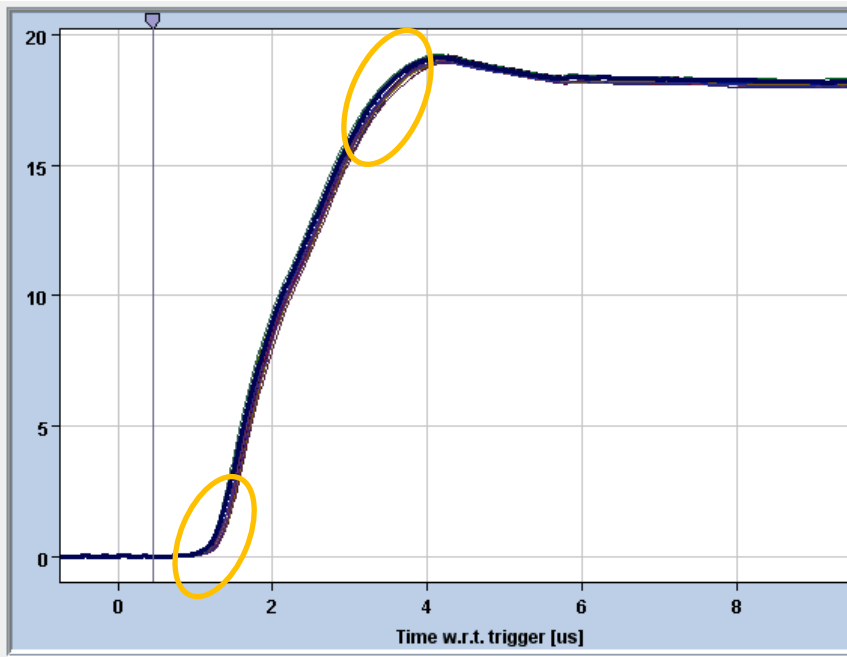
COMMISSIONING WITH BEAM

- Re-synchronise MKD rising edge with dump of pilot bunch 1
  => Adjust TSU Trigger delay

- Re-synchronise BAGK with injection of pilot bunch 1
  => Adjust TSU BAGK delay

- Scan of MKD rising edge
  - Never done…
    => Procedure to be approved !
  - 1 complete shift required ?

- Test of BLMDD TSU client
  - Never tested with beam…
    => Procedure to be approved !



PLUS:

- **Updated** Machine Protection Procedures for LBDS (EDMS **896392**)
- **Updated** procedure in case of non-working dump trigger (EDMS **1166480)**

Planned Actions: OTHER

What	Who	When
Review **integration of BLMDD within TSDS**. Check possible failure scenarios.	TE/ABT BE/BI	03/2013
Study impact of new TSDS configuration on reliability & availability of LBDS after modification.	TE/ABT	06/2013
Perform a study which predicts the consequences of different type of powering failures (MAINS, UPS and individual secondary voltages).	TE/ABT	06/2013
Define test procedure for a full re-commissioning of the LBDS powering (NORMAL and UPS) after LS1 and after major maintenance activities.	TE/ABT EN/EL	12/2013

CONCLUSION

1) Unforeseen complicated problems of spontaneous triggering of MKD HV generators: After months of investigations we identified various source to the problem.
   => Successful Reliability Run II (BUT problems with dust foreseen)

2) Electrical distribution improved
   =>successfully tested.

1) TSDS renovation: CIBDS and TSU v3 installed in LHC
   => Tests ongoing during Dry Run.

- Dry Runs in REMOTE started.
  => No major problems found.

- LBDS is ready for Transfer Line Test, end November.

Thank you for your attention.

Spares slides / Removed…