



JAGIELLONIAN UNIVERSITY  
IN KRAKOW



**SOLARIS**  
NATIONAL SYNCHROTRON  
RADIATION CENTRE

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# Status of SOLARIS

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**Paweł Borowiec**  
*On behalf of Solaris Team*

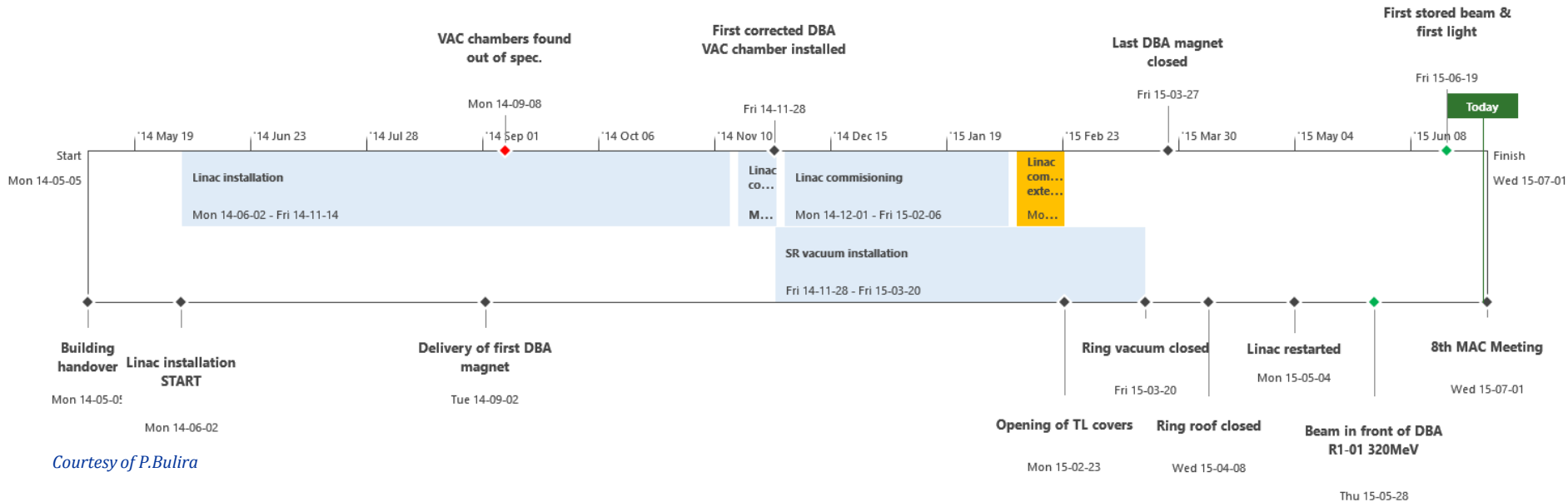
- 1. Timeline**
- 2. Injector**
- 3. Storage ring**



Expected beginning of installation: **December 2013**

Building handover: **05.05.2014**

Postponed installation caused logistic problems



Courtesy of P.Bulira



**Accelerating structures – building of Solaris**

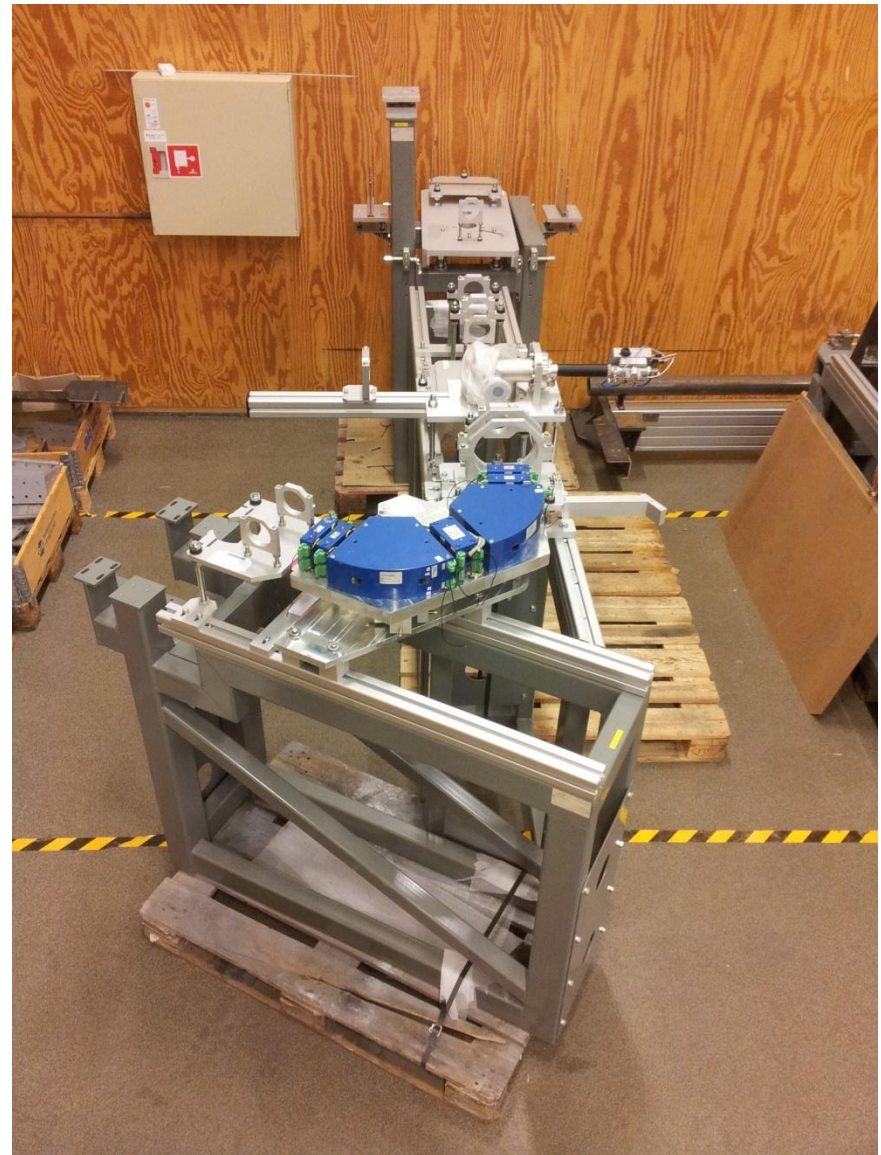
**Waveguides – storage place at UJ**

**Main cavities – Max Lab**

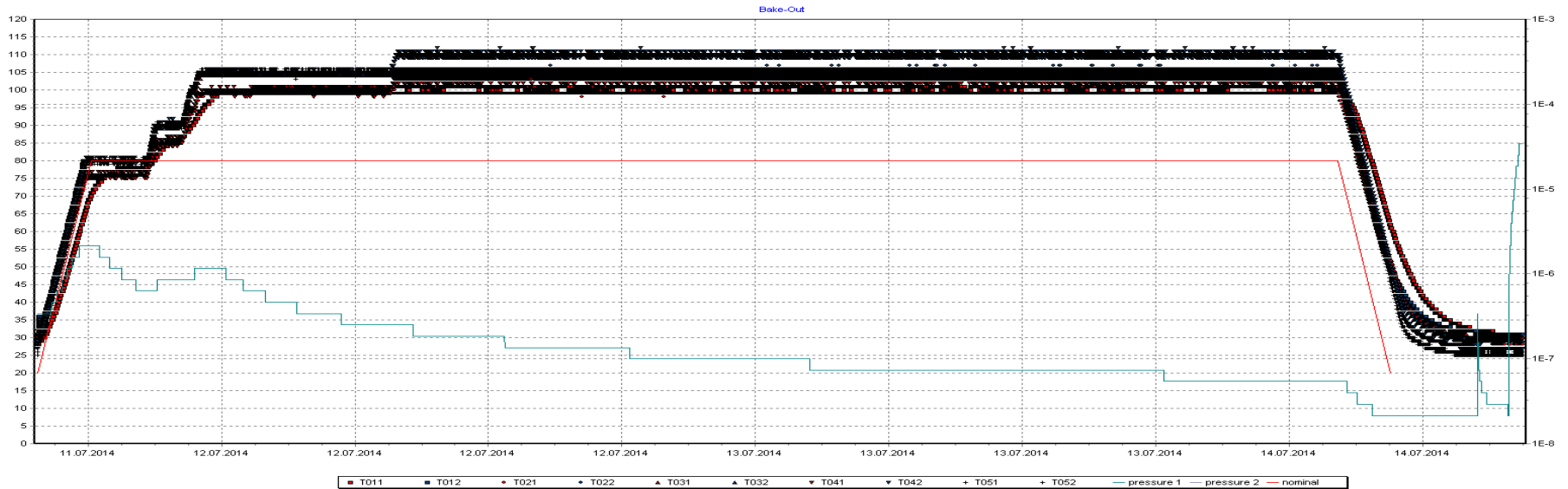
**Modulators + klystrons - Scandinova**

**March 2014 at Max LAB**

**Good training to avoid assembly mistakes**



**June -July 2014**  
**3 days cycle at 110 °C**

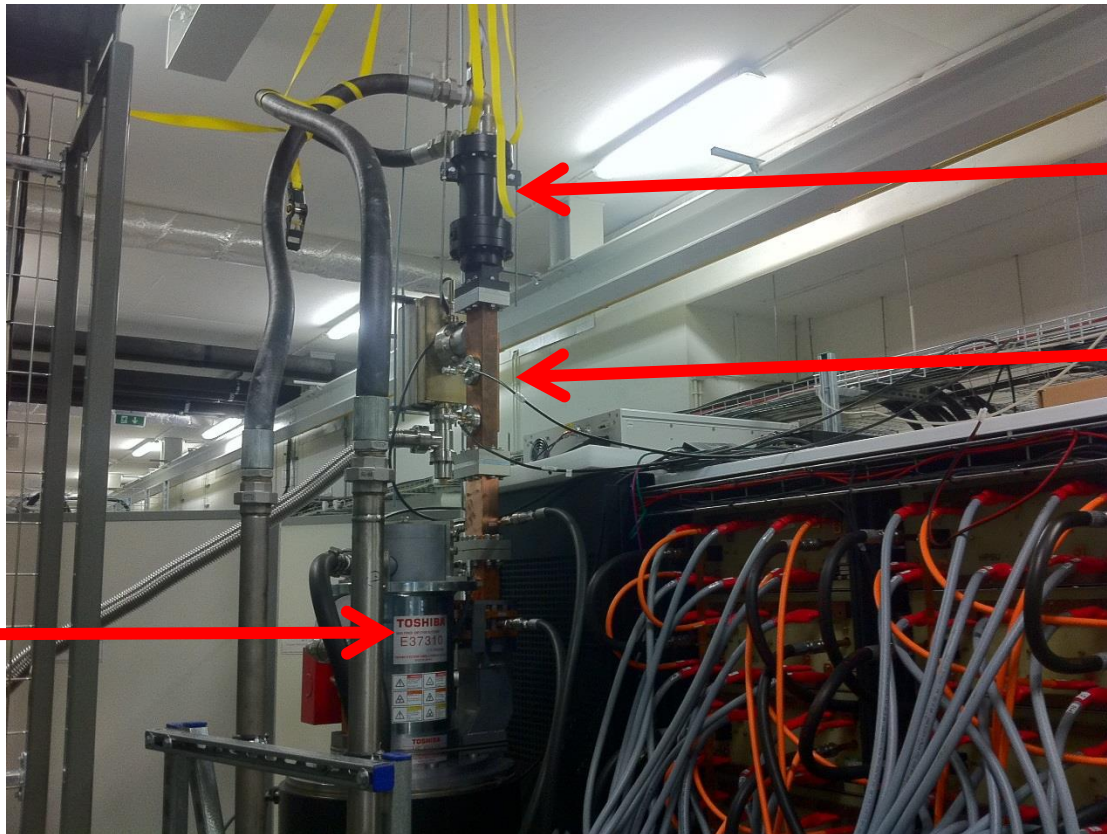


- 02.06.2014**      **Start of linac installation**
- 17.06.2014**      **Start of linac vacuum assembly**
- 08.2014**        **Linac under vacuum**
- 08-11.2014**    **Cabling and water installation**
- 09.2014**        **Gun system and transfer line under vacuum**
- 10.2014**        **SAT of modulators**
- 11.2014**        **Connecting of klystrons to waveguides**
- 11.2014**        **Conditioning of waveguides and accelerating structures**



## Start-up of high power RF

One K2 modulator driven up to 33MW on dummy load



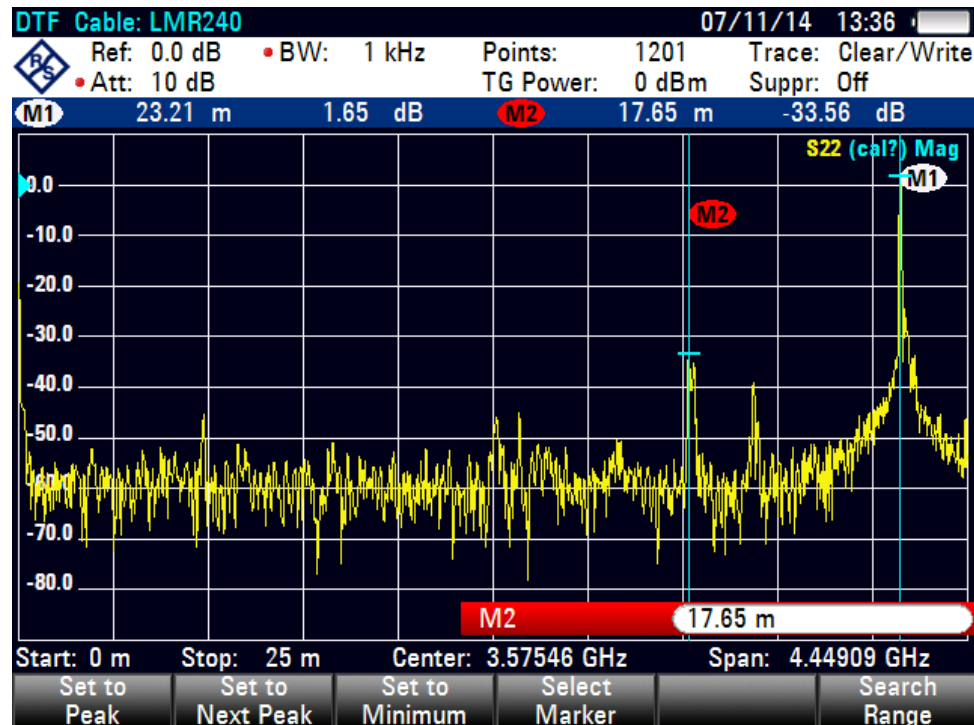
Water cooled waveguide  
dummy load

waveguide directional  
coupler

klystron



1. Education of sub-contractor about importance of work quality
2. Each RF cable examined before and after installation in terms of:
  - Attenuation at working frequency
  - Distance to fault
  - VSWR
3. Each RF cable has unique serial numer and „from-to” description
4. Around 5% of cables have to exchanged



1. **Contamination of waveguides during venting after baking.**
  - **Viton sealings have broken, exchange to copper one for the next batches**
2. **Dimension of 3m long waveguides.**
  - **Manufacturing process – extrusion, not straight**
  - **Correct order of works to fit with flanges to accelerating structure**
3. **Water leak in connection on accelerating structure**
  - **Research Instruments has fixed in-situ**
4. **Accident with accelerating structure**
  - **Fortunately directional coupler took impact but it is destroyed**
  - **RF measurement, alignment check and leak test have shown good state of acc.struct.**
5. **Vacuum leak in waveguide, LIL flange brazing**
  - **New one has been manufactured by HERT Beijing, leaking one has been re-brazed**
6. **Vacuum leak in waveguide directional coupler**
  - **Exchange to new one**
7. **Wrong length of the CPR type waveguide, no possibility to connect gun's modulator**
  - **Mistake in 3D model.**
  - **New waveguide has been manufactured by MaxLab in one week!**
8. **Re-arrangement of water manifold around gun body**
  - **Collisions with support plate**
9. **Water leak in modulator during SAT**

1. **Short RF pulse without SLED phase inversion at 1Hz**
  - Increasing of klystron's high voltage, then elongation of RF pulse and start from lower voltage
  - Since conditioning of waveguides after power divider were not efficient, SLED have been used
2. **Short RF pulse with SLED phase inversion at 1Hz**
  - Increasing of klystron's high voltage, then elongation of RF pulse and start from lower voltage
  - When reasonable high voltage has been achieved, increasing of repetition rate to 5Hz, 10Hz, 50Hz and 100Hz with start from lower voltage (it depends on vacuum activation)
3. **Nominal RF pulse length at 100Hz,**

**Baking out of waveguides before installation helped in conditioning process**

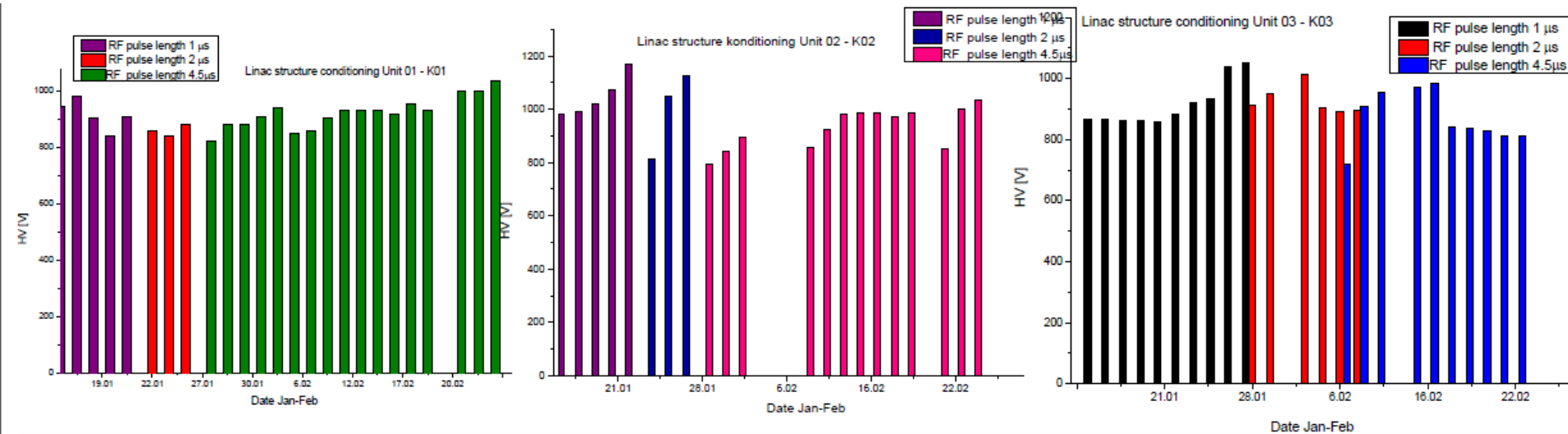
**but**

**Baking out of whole linac is necessary**

**Shifts organisation for linac conditioning (January- February & May-June):**

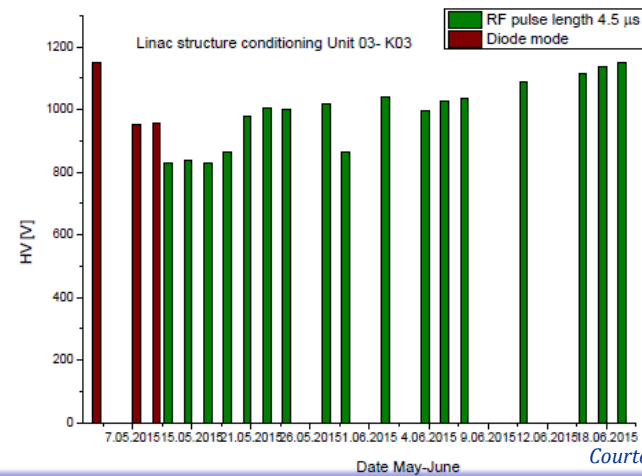
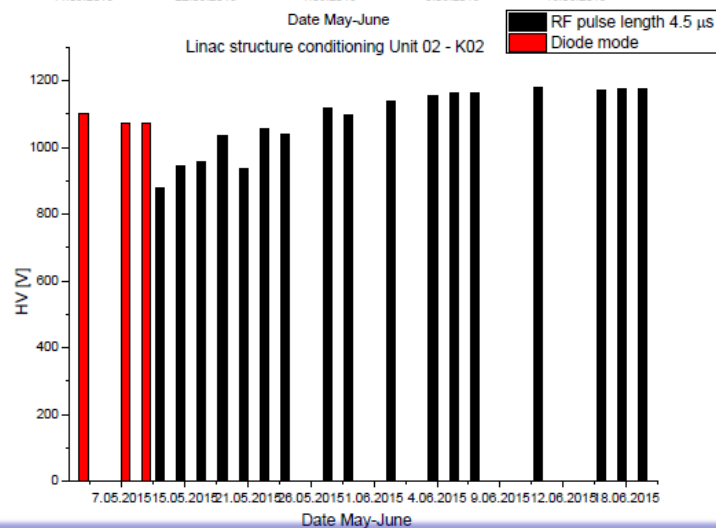
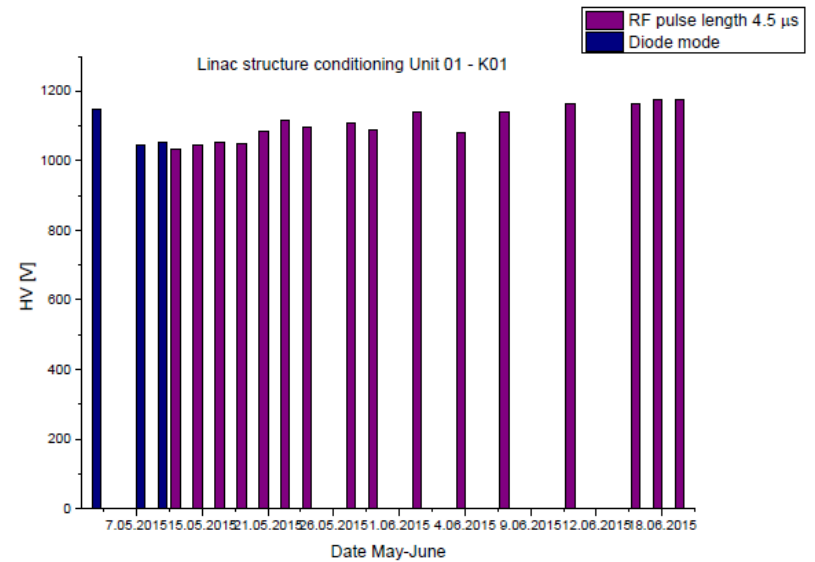
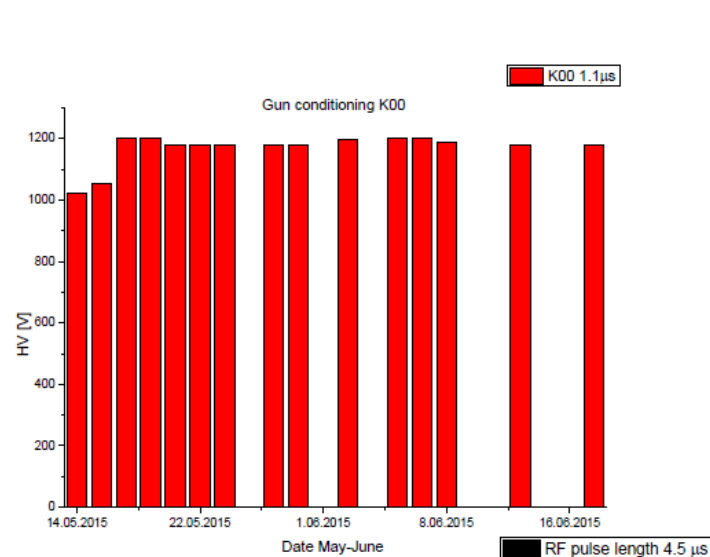
**Monday -Friday; 7 a.m. – 9 p.m.**

## January - February 2015



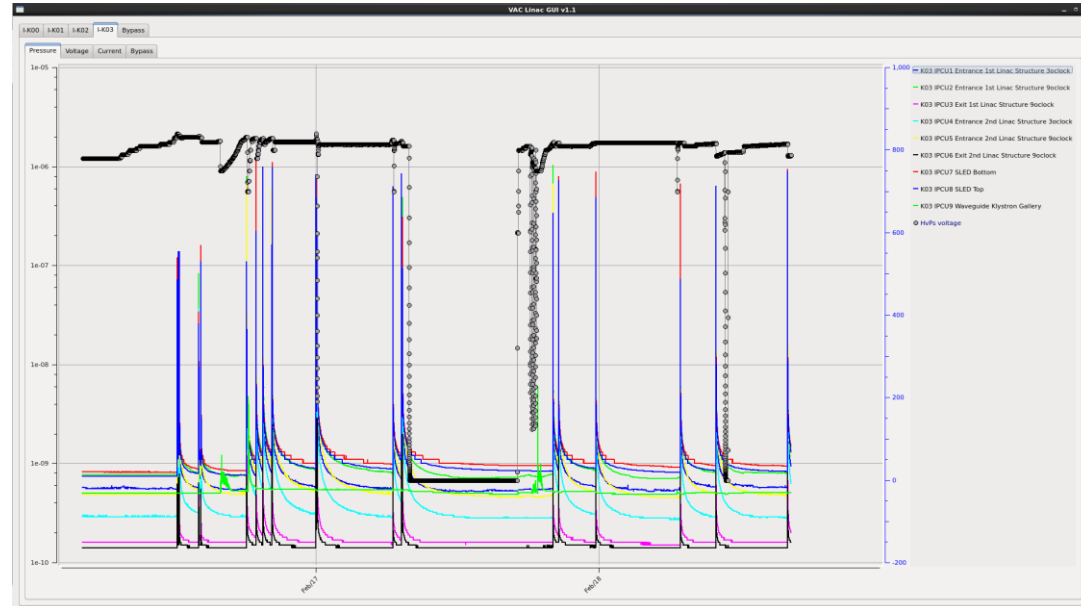
Courtesy of A.Wawrzyniak

## May - June 2015



Courtesy of A.Wawrzyniak

### Arcing in waveguides



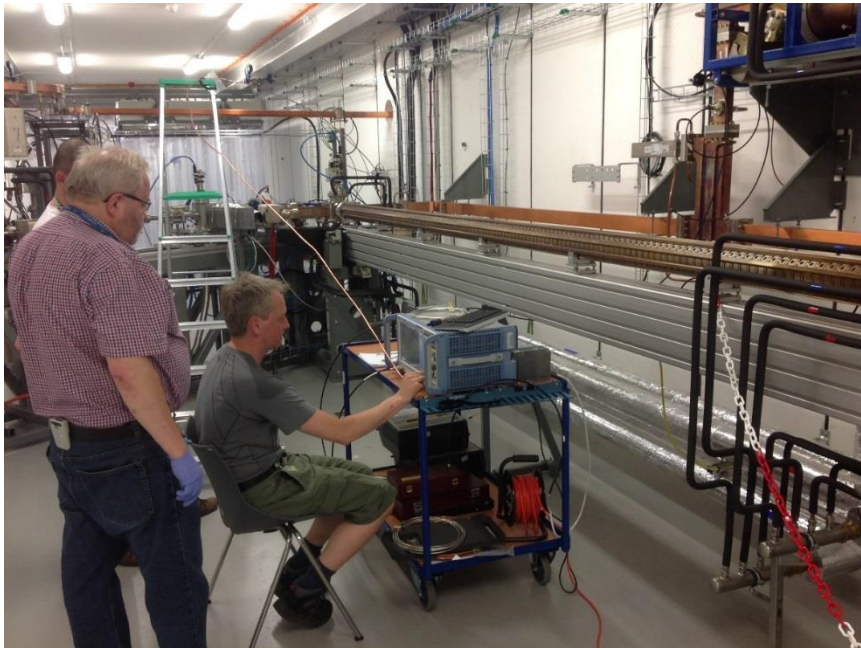
- Broken 9 pieces of 20dB attenuators and 2 RF sensor diodes
- Still many vacuum activation at high power

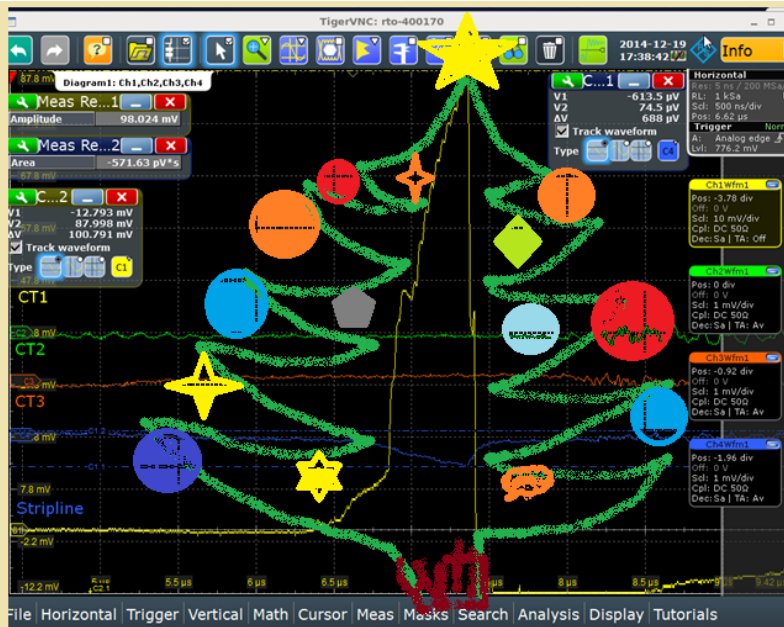
Significant pressure increase in gun's vacuum waveguide system, not possible to pump down.

- Vented with nitrogen, leak check, leak tight, pumped down, problem solved but what was a reason?

## Phase matching of waveguides within accelerating unit

Unit	Phase difference [ ° ]	Phase difference after matching [ ° ]
1	-20,78	2,39
2	-16,70	3,03
3	-12,04	-1,83





19.12.2014

**First electrons from  
SOLARIS RF GUN**

**RF Power Forward to the  
gun= 0.86MW**

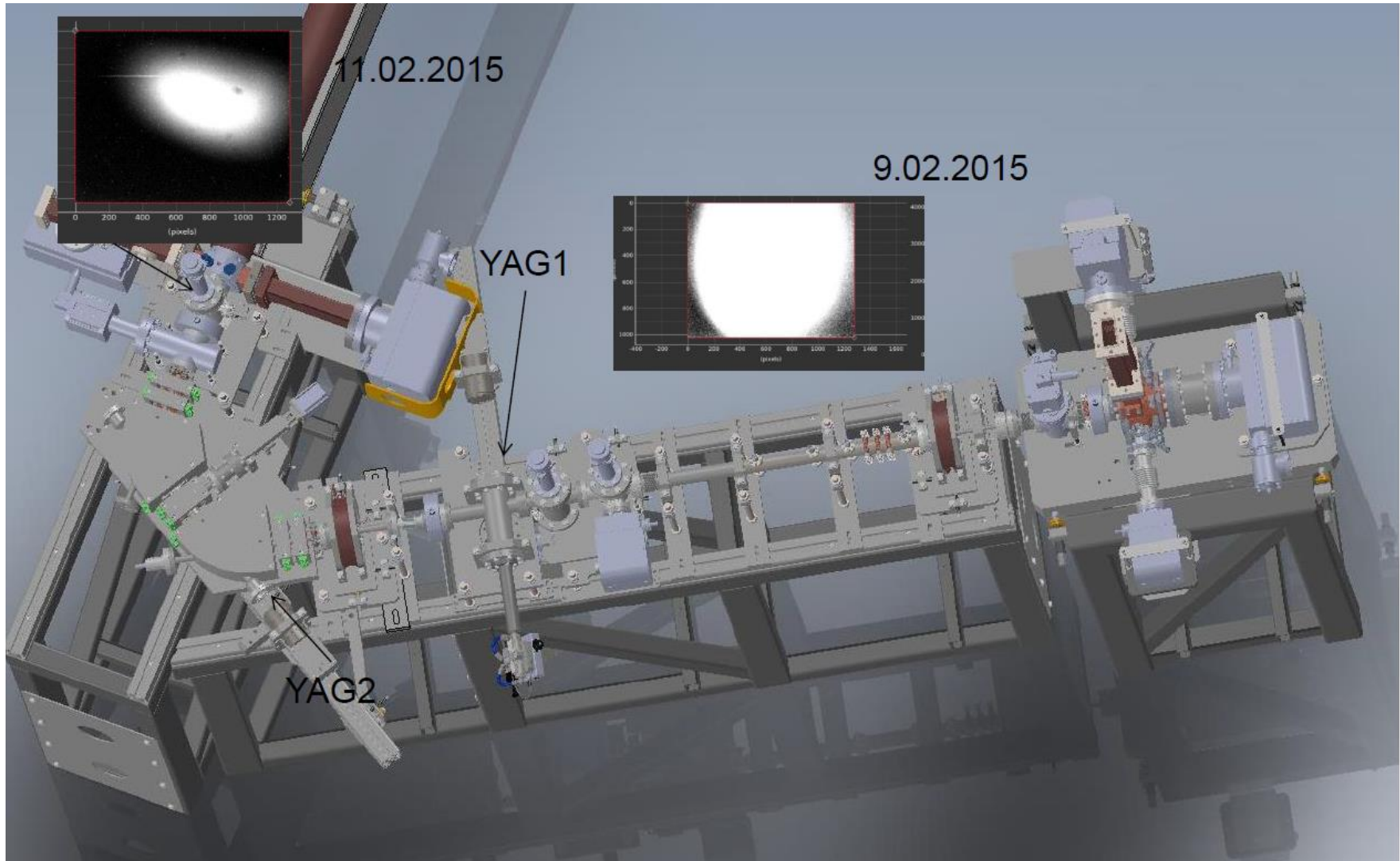
**Electron current = 100mA**

*Merry Christmas  
and a Happy New Year*

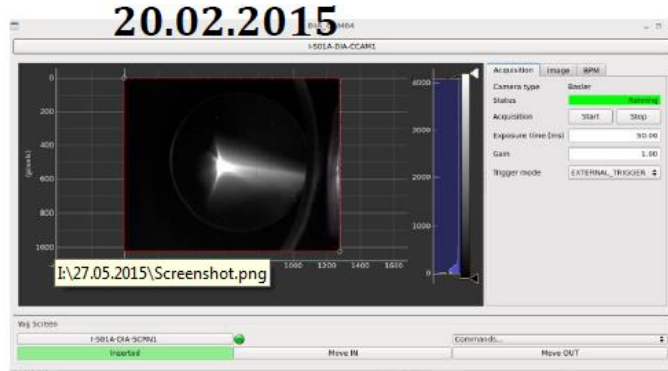
**SOLARIS TEAM**





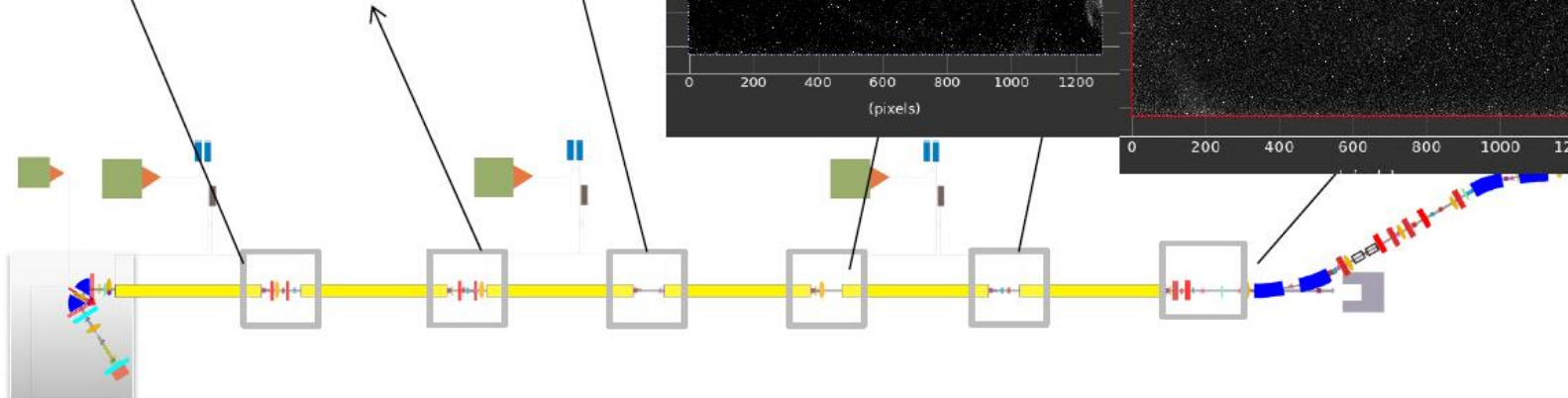
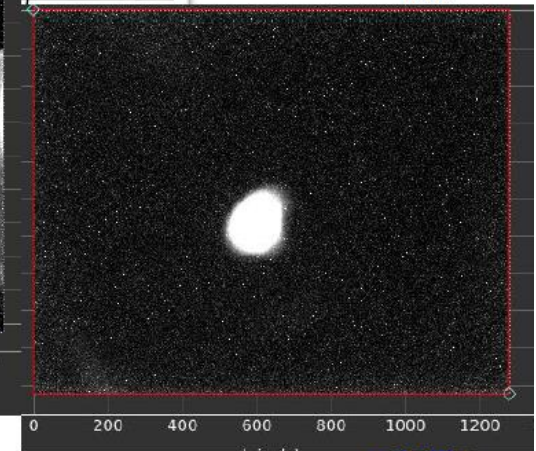
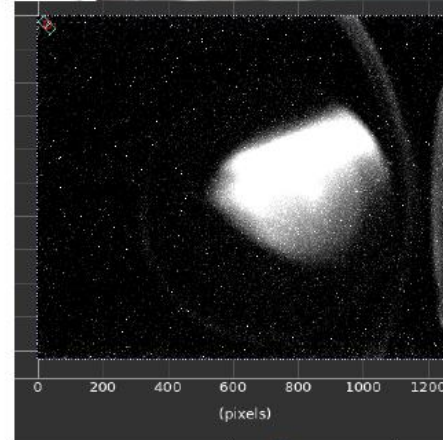
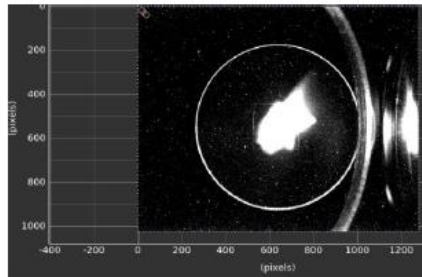


*Courtesy of A.Wawrzyniak*

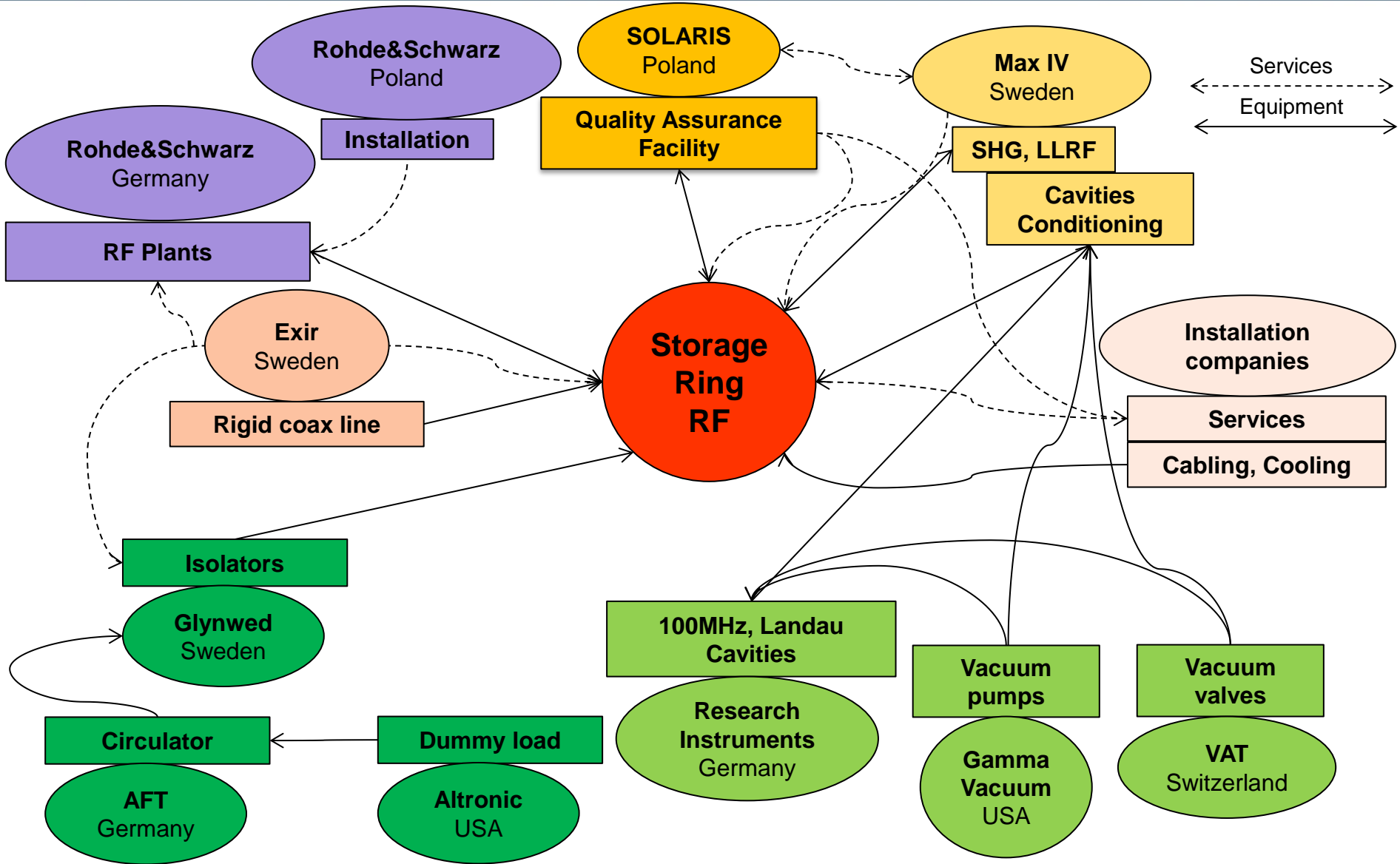


22.02.2015

YAG



Courtesy of A.Wawrzyniak



1. **Modification of raised floor, electrical grid in service galery 02.2015**
2. **Signature of contract with Rhode&Schwarz, Sweden in December due to formal reason with delivery date 10.03.2015**
  - **SAT of transmitters 23 - 27.03.2015**
  - **First THR9 system and highest installed RF power in Band II in Poland**
3. **Signature of contract with Rhode&Schwarz Poland for installation of transmitters and assistance during SAT**
  - **16 - 20.03.2015**
4. **Signature of contract with Exir, Sweden for installation of rigid line and assistance during SAT of circulators**
  - **Connection of transmitters to circulators with rigid line 07.04.2015**
  - **Connection of circulators to cavities with rigid line 15-17.04.2015**
5. **SAT of circulators 08 - 10.04.2015. AFT required to fix SAT date 8 weeks in advance**



**High power SR RF installed and tested within 5 weeks  
10.03.2015 to 17.04.2015**



### 1. Delivery and installation

- Among of 24 delivered packages one with water connectors was missing, it has been shipped in 2 days
- Change of water hoses routing, additional bleeders have been purchased. Lower flow losses, longer pumps lifetime, bleeders at the highest point.
- Mistake of R&S during installation of glycol hoses (inlets to outlets)
- Some glycol leaks on clamp connection
- Installation time not correctly estimated, finishing during SAT of 1st system

### 2. SAT of transmitters on dummy load

- PLC interlocks not ready (Solaris), local wired interlock loop
- Both systems achieved 60kW RF output

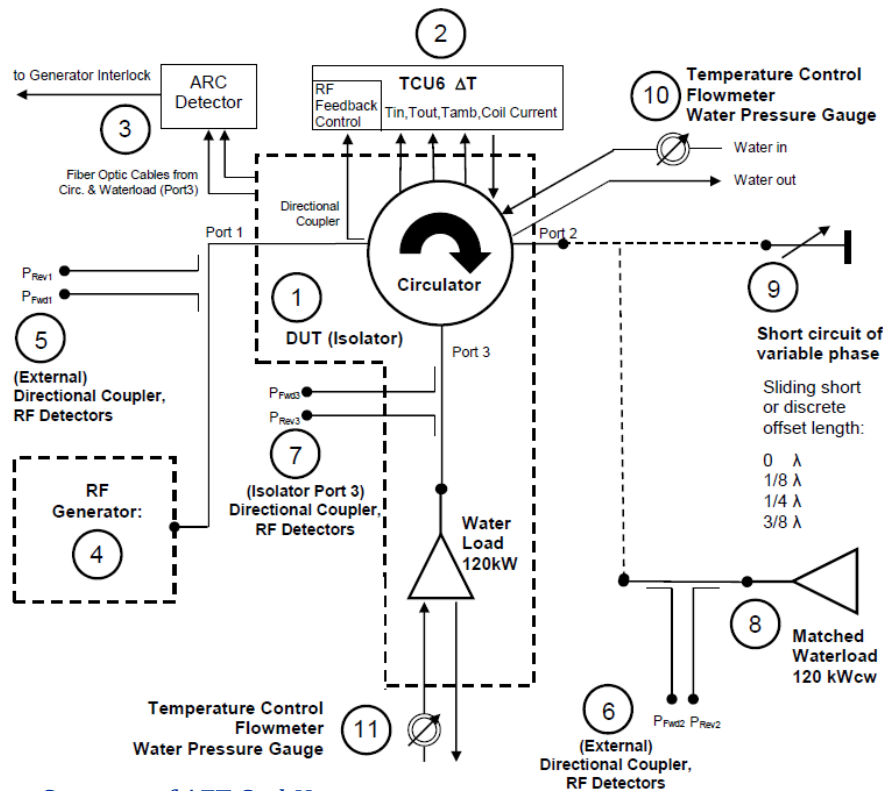


## Delivery and installation

- New 2-ports arc detector electronics

## SAT

- Test at dummy load and  $0\lambda$ ,  $1/8\lambda$ ,  $1/4\lambda$ ,  $3/8\lambda$  terminations



Courtesy of AFT GmbH

- **Vibroisolators damage in cooling fan support, replaced for new, safe type**
- **Foreign object in cooling circuit, removed**
- **Damage of ceramic insulator in ion HV connector. Exchange of ion pump, additional venting was necessary**
- **False alarms from arc detectors in circulators. After long investigation found that ground connection between arc detector and PLC works like antenna. Optocouplers has been installed.**
- **Overlooked  $\beta$  tuning (from 1 to 2) during installation for beam operation, additional venting was necessary. Phase matching of pick-ups at the same time.**
- **Not sufficient flow in water cooling of main cavities, additional pump installed**

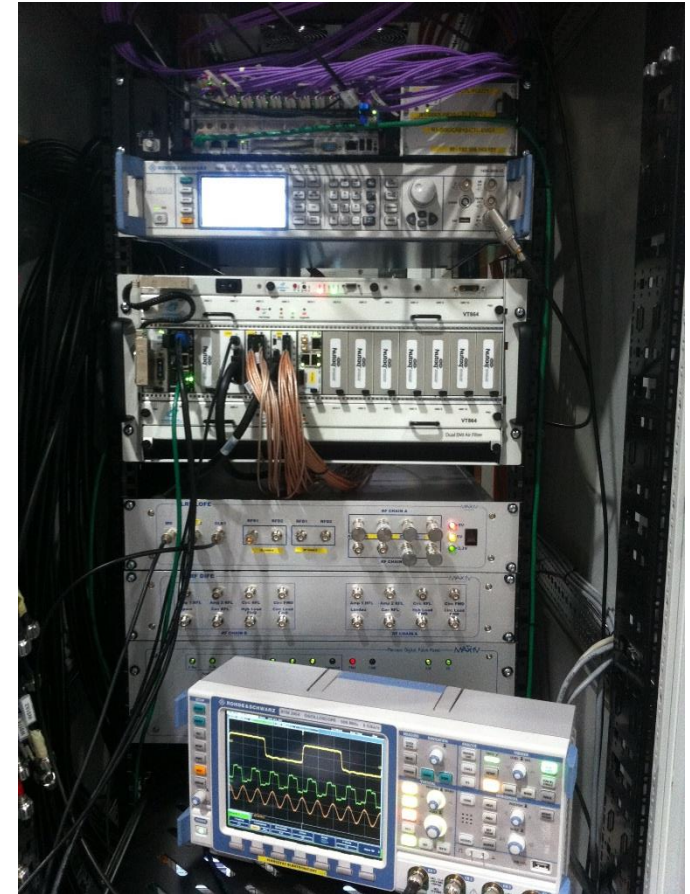
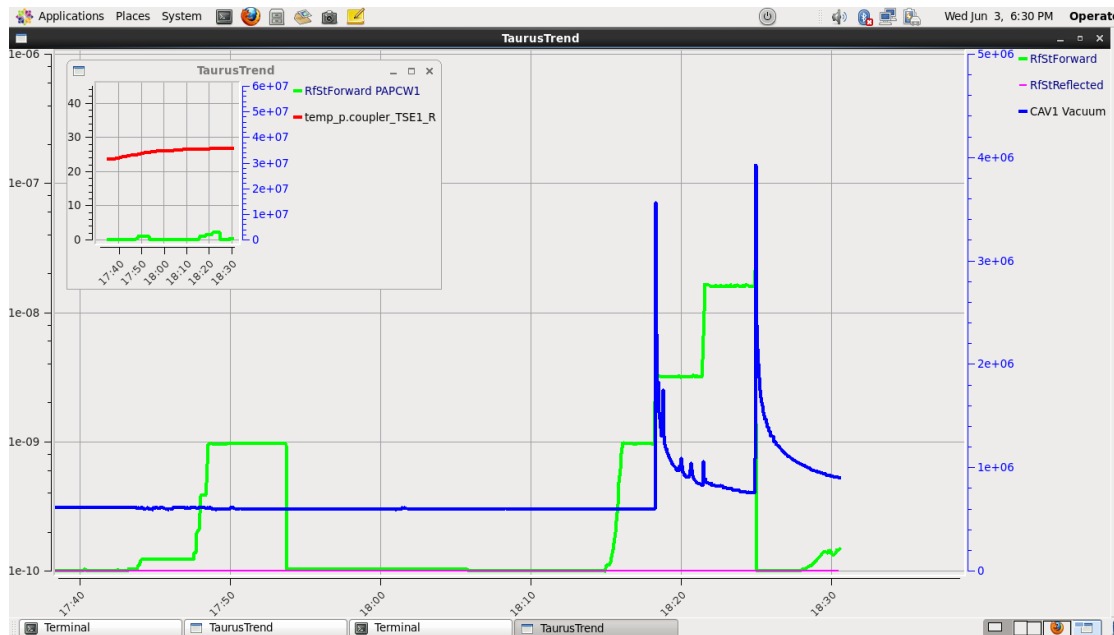




**Delivered on 18.05.2015**

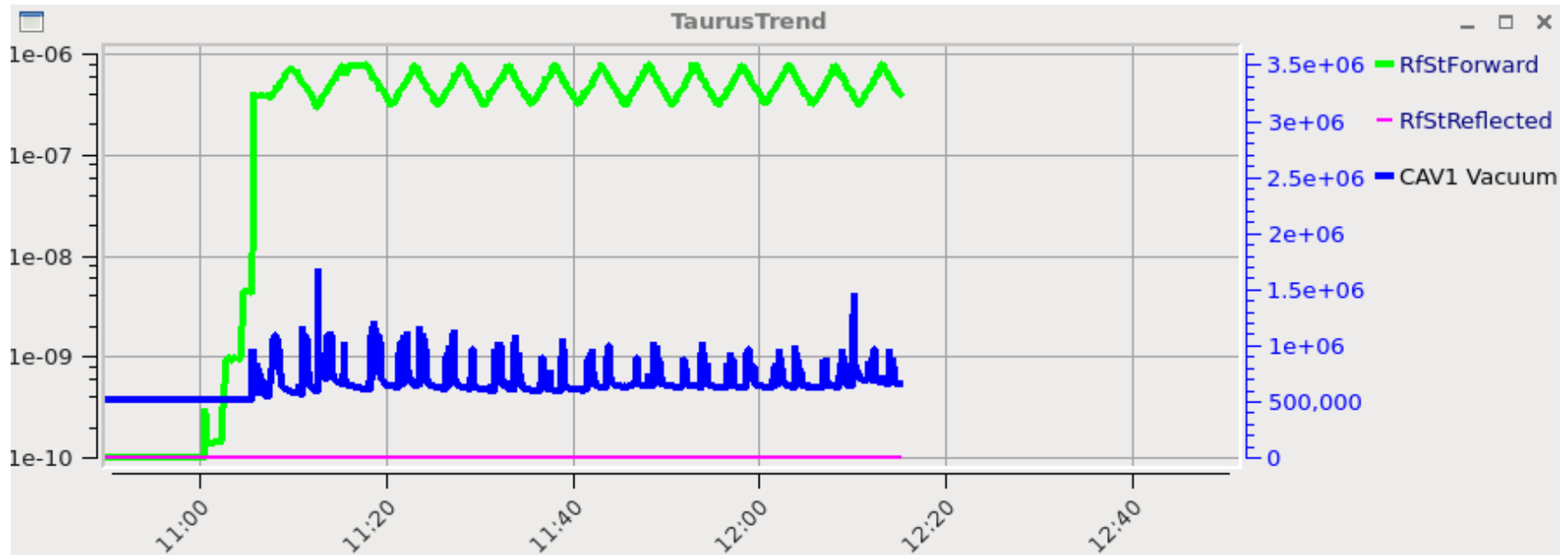
**Commissioning with presence A.Salom (Alba synchrotron).**

**03.06.2015 first RF in one cavity from LLRF**



## Automatic cavity conditioning:

- Disabling RF transmitter at  $1,3e-07$ mbar, manual reset is required
- High vacuum level at  $5,0e-08$ mbar
- Low vacuum level at  $1,0e-08$ mbar
- Controlling of RF power to keep vacuum between low and high
- Additional code for sweep of RF power especially around multipacting area
- Both cavities conditioned up to 30kW



**Delivered to Solaris but not installed in first stage of commissioning.**

**07.2015 Baked out**

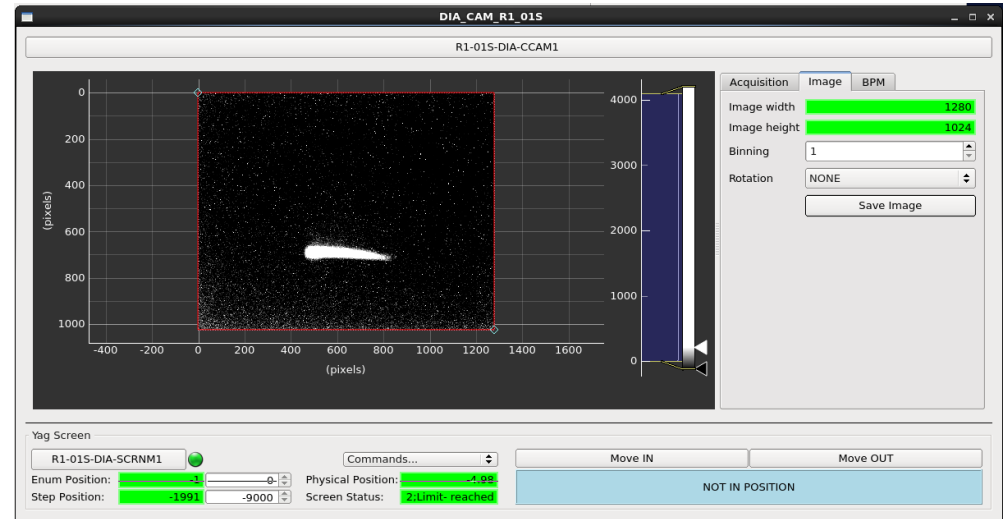
**Manufacturing of plunger for detuning**

**Installation in December 2015**

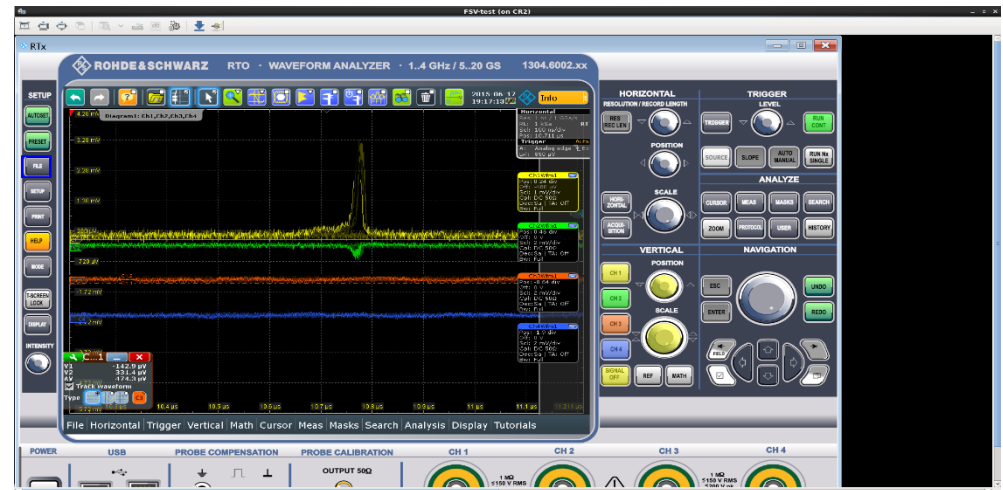


04.05.2015 restart of linac after storage ring installation

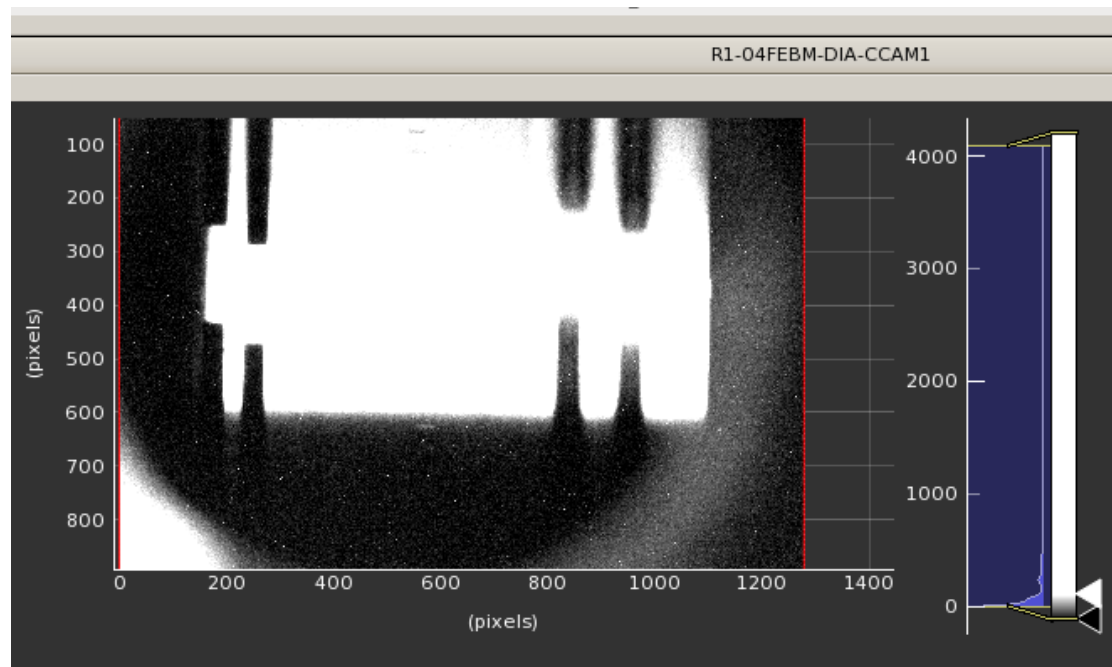
27.05.2015 first beam in storage ring,  
Energy 320 MeV  
Charge 1.5 nC  
Rep. rate 10Hz



11.06.2015 first turn in storage ring  
stripline kicker connected  
to scope



**31.07.2015 Max. accumulated current 13,5 mA**



**Photon beam @ BL04 front end YAG screen**

I WOULD LIKE TO EXPRESS SPECIAL THANKS TO

**MAX IV TEAM** for sharing their knowledge and time

**ELETTRA TEAM** for the assistance and consultancy in various areas of the project

**ANGELA SALOM** for support with LLRF

**ALEKS BOGUSZ** for help during start-up of linac



**21.09.2015 Opening ceremony**



**Thank you for your attention**