JAGIELLONIAN UNIVERSITY IN KRAKOW

SOLARIS
NATIONAL SYNCHROTRON RADIATION CENTRE

Status of SOLARIS

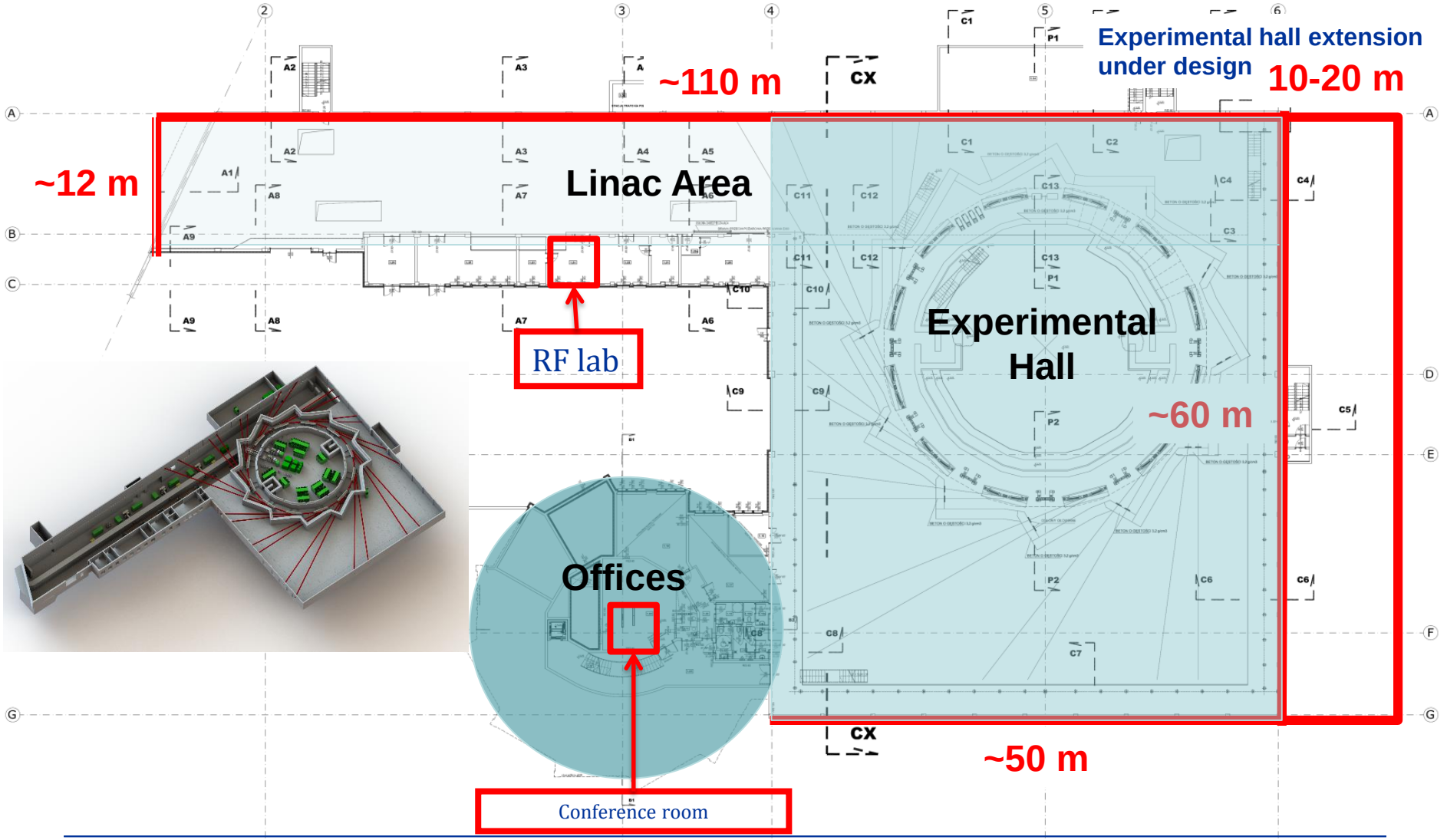
Paweł Borowiec
On behalf of Solaris Team

e-mail: pawel.borowiec@uj.edu.pl

Outline

1. Introduction to Solaris
2. Injector RF
3. Storage ring RF
4. Activities
5. Spare parts

SOLARIS Building

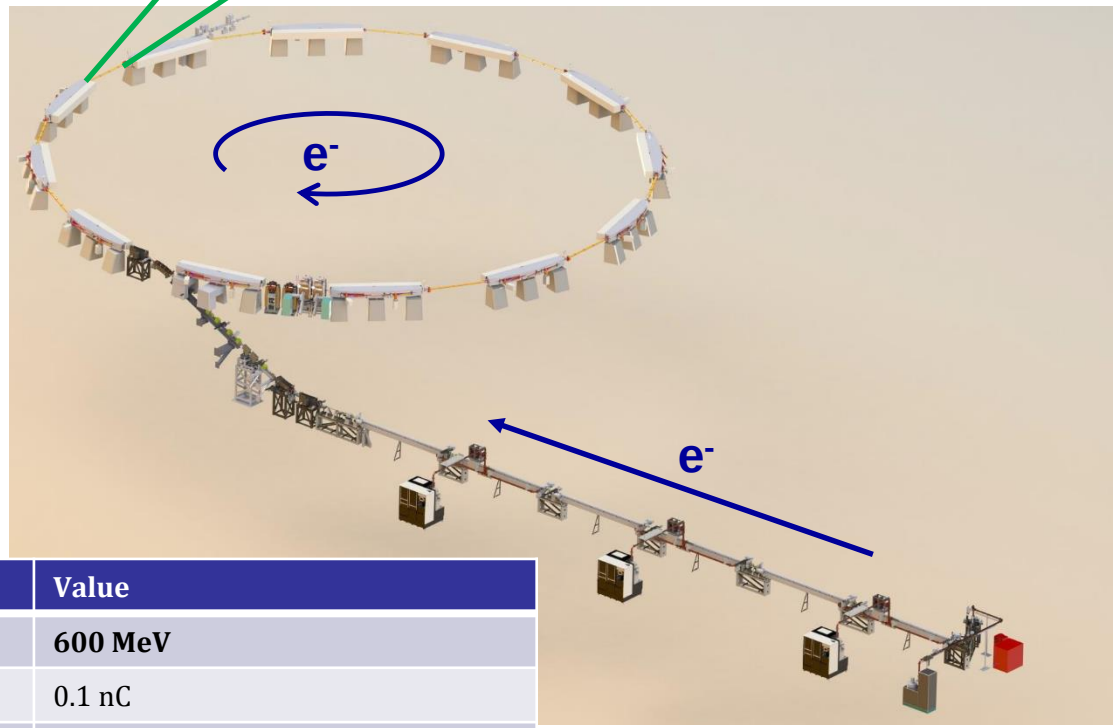


SOLARIS Machine

Storage Ring Parameters	Value
Energy	**1.5 GeV**
Current	500 mA
Circumference	96 m
Horizontal emittance (bare lattice)	5.982 nm rad
Coupling	1%
Tunes Q_x, Q_y	11.22, 3.15
Natural chromaticities ξ_x, ξ_y	-22.96, -17.14
Momentum compaction	3.055×10^{-3}
Momentum acceptance	4%
Overall Lifetime	13 hrs

2 beamlines under commissioning with synchrotron light

+ 2 beamlines founded



Injector Parameters	Value
Energy max	**600 MeV**
Bunch charge	0.1 nC
Emitance (geom, rms) x/y	3.1 / 2.0 nm rad
Energy spread (rms)	0.23%
Bunch length (rms)	3.68 ps
Injection repetition rate	Up to 10 Hz (linac up to 100Hz)

Linac

The injector is a *RF thermionic gun system* and linear accelerator which consisting of six S-band *travelling wave accelerating structures* combined in three accelerating units.

Pre-injector

Isolator
- Manufacturer: AFT, Backnang – Waldrems, Germany
- Forward peak power: 20 MW
- Forward average power: 5 kW
- Reverse power: 100% at any phase
- Filled with SF6

RF thermionic gun
- Manufacturer: Max IV, Lund, Sweden
- Cathode: BaO
- Energy of beam: 1.5-3 MeV
- Rep. Rate: 10Hz

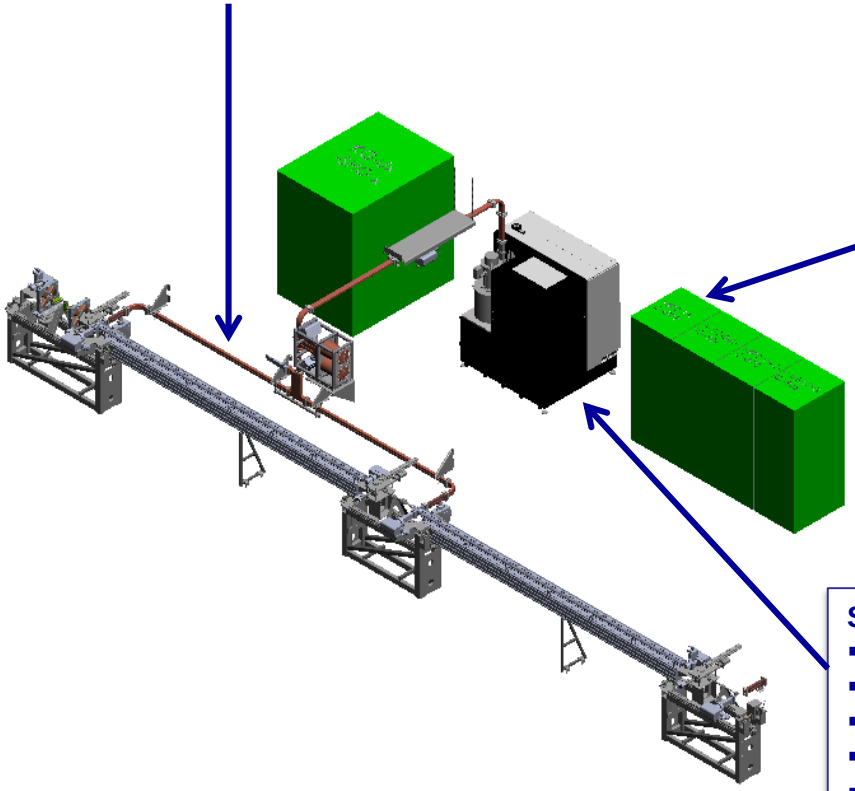
2 pieces of the Stripline chopper to fit bunches time structure to the 100 MHz bucket
- Manufacturer: Max IV, Lund, Sweden

RF window

S-band K1 RF Unit for RF thermionic gun
- Manufacturer: ScandiNova Systems AB, Uppsala, Sweden
- Solid-state modulator
- RF frequency: 2998,5 MHz
- RF peak power from Klystron: 8 MW
- Pulse length: 3 μs
- Repetition rate: 0 – 10 Hz
- Klystron: Thales TH2175A-1

Accelerating unit

Waveguides
- Manufacturer: IHEP, Beijing, China
- Size: WR284
- Flanges: LIL for UHV,

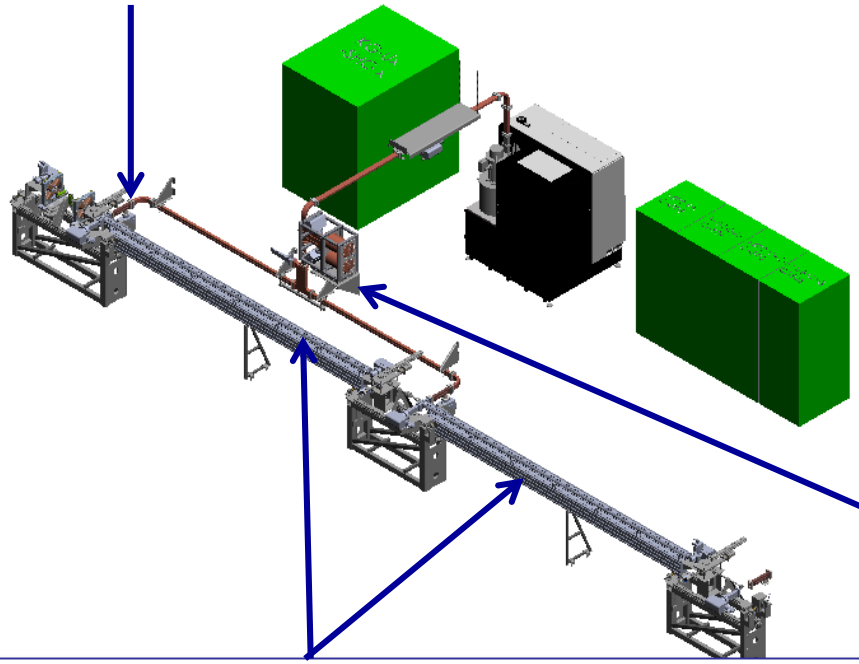


„LLRF" for each RF Unit in the Linac
- Manufacturer: Max IV, Lund, Sweden
- Pulse shaping
- Phase adjustment
- 180º phase swap for SLED
- Open loop, no feedback

S-band K2 RF Unit for accelerating sections
- Manufacturer: ScandiNova Systems AB, Uppsala, Sweden
- Solid-state modulator
- RF frequency: 2998,5 MHz
- RF peak power from Klystron: 37 MW
- Pulse length: 4,5 μs
- Repetition rate: 0 - 100Hz
- Klystron: Toshiba E37310

Accelerating unit

Waveguide directional couplers
- Manufacturer: Max IV, Lund, Sweden
- Flanges: LIL
- Coupling: 50 dB
- Some have CF40 port for ion pump connection



SLED cavity with 3dB hybrid coupler
- Manufacturer: Research Instruments GmbH, Bergisch Gladbach, Germany
- Resonant mode: TE015
- Q, unloaded: 98000

Room temperature S-band travelling wave accelerating structure
- Manufacturer: Research Instruments GmbH, Bergisch Gladbach, Germany
- Resonant mode: 2π/3
- Accelerating gradient : 20MV/m
- Length: 5m

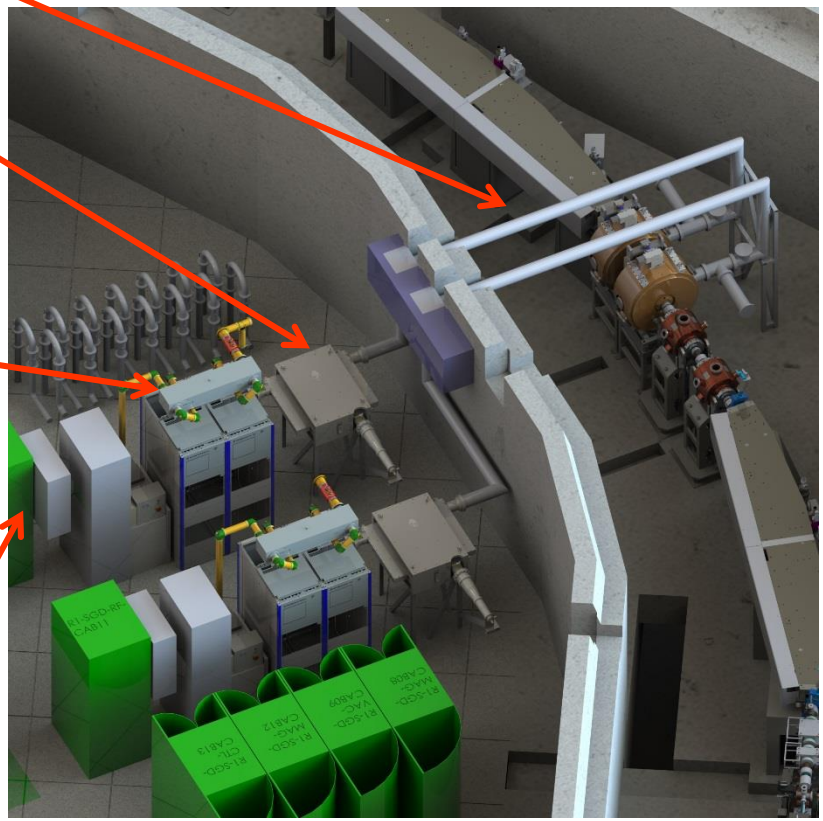
Storage Ring RF

6 1/8" EIA rigid coax line and directional couplers
- Manufacturer: Exir Broadcasting AB, Hörby, Sweden

Isolator
- Manufacturer: AFT, Backnang – Waldrems, Germany
- Forward peak power: 120 kW CW
- Reverse power: 100% at any phase

100MHz RF Transmitter THR9
- Manufacturer: Rohde & Schwarz GmbH, Germany
- Technology: Solid state
- RF frequency: 99,93 MHz
- RF peak power: 60 kW CW
- Modifications for Light Source Operation:
  - Constant gain mode
  - Relay contacts for interlock

Digital LLRF for Storage Ring
- Manufacturer: ALBA, Barcelona, Spain
- Commercial µTCA board
- Control of amplitude and phase cavity voltage and resonance frequency control (Tuning)
- Safety Interlock and Diagnostic
- Fast data logger
- I/Q demodulation technique



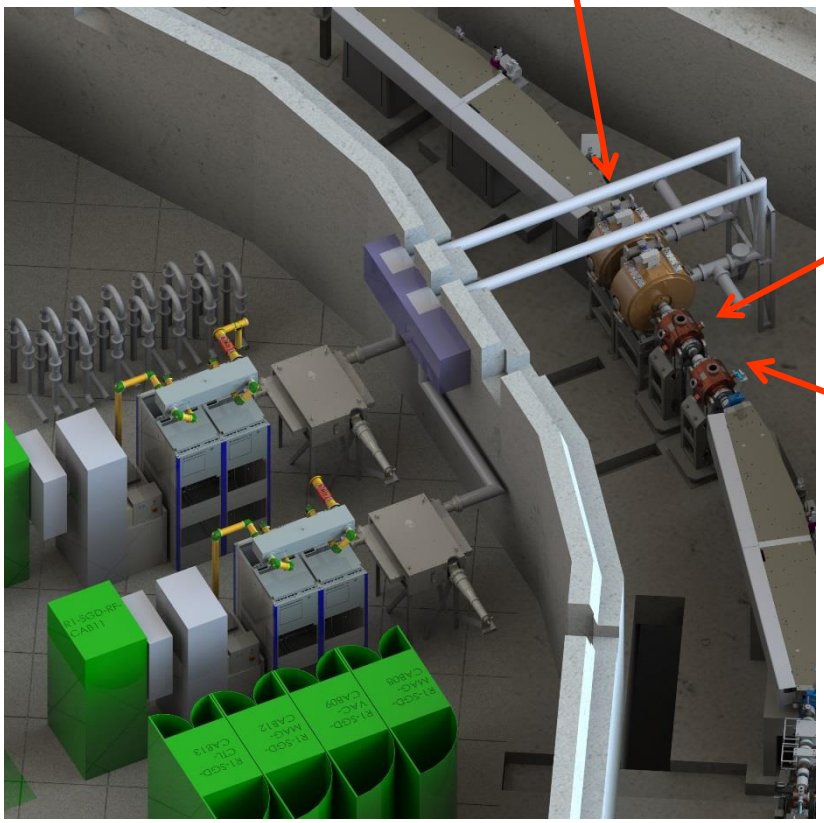
Storage Ring RF

100MHz Main Cavity

- Manufacturer: Research Instruments GmbH, Bergisch Gladbach, Germany
- Upgraded MAX-Lab cavity
- Resonant frequency: 99,93 MHz
- Tuning range: ±540 kHz
- Gap voltage: 300 kV

300MHz Landau Cavity

- Manufacturer: Research Instruments GmbH, Bergisch Gladbach, Germany
- Tuning range: ±550 kHz
- Total voltage: 487 kV
- Whole range tuning time: 45 minutes



Plunger for fast detuning of Landau Cavity during injection and ramping

- Manufacturer: Measline Krakow, Poland
- Detuning range: 500 kHz
- Whole range tuning time: 4 minutes

Injector Activities

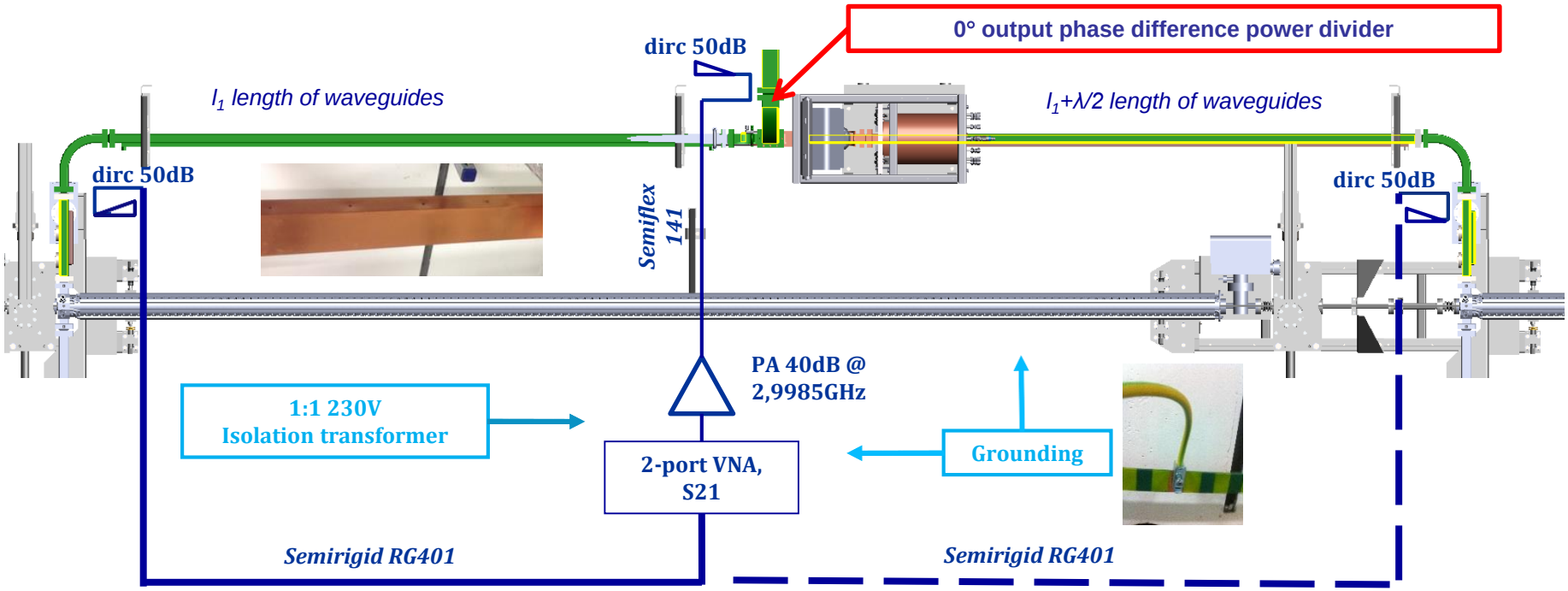
Looking for nominal energy of the injector (600MeV)

SLED tuning crosscheck with standard RF approach:

- **Observation of SLED pulse envelope shape, 2 units better, 1 worse in terms of energy gain**

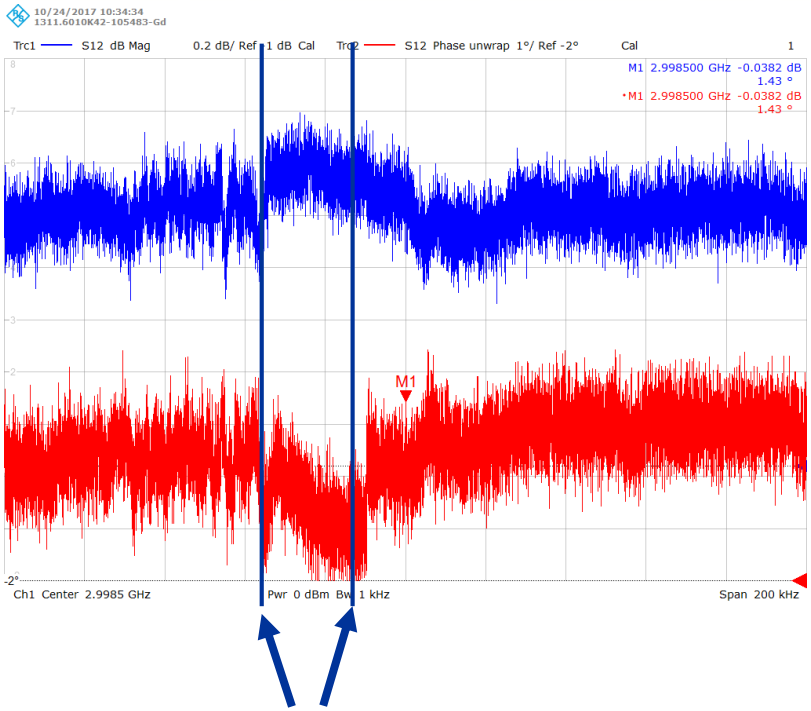
New idea: SLED tuning with beam present in the injector: +9 MeV more achieved, 545MeV now

But still some energy missing → crossheck of accelerating structures phasing in units



Injector Activities

Measurement setup

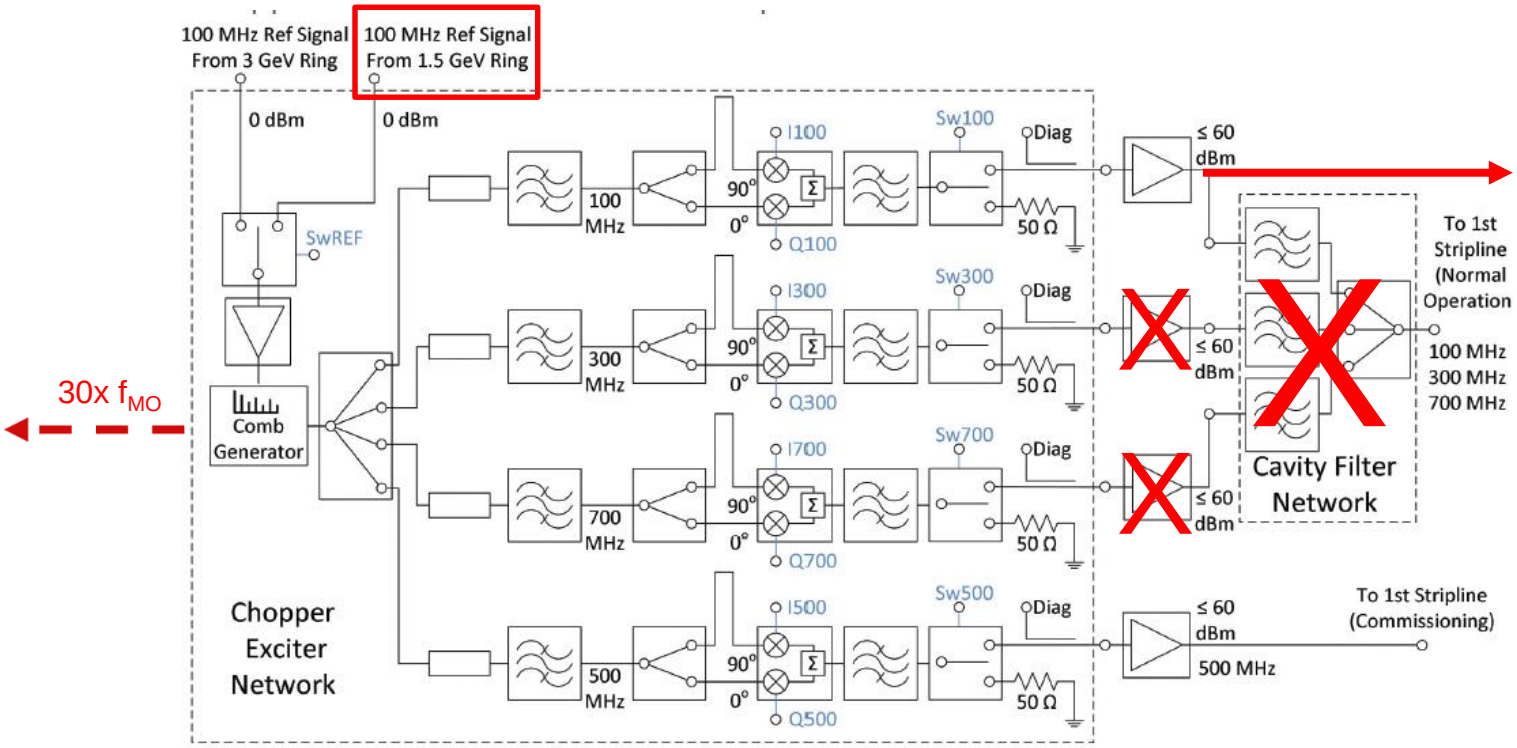


Man movement next to the measurement setup

Unit	Initial phase difference after installation in 2014 [°]	Phase difference after matching in 2014 [°]	Phase difference measurement in 2017 [°]	uncertainty in 2017 [°]
1	-20,78	-2,39	**-6,5**	**± 1,5**
2	-16,70	-3,03	-3,56	± 0,2
3	-12,04	1,83	-1,17	± 0,2

Again new idea: Waveguide matching based on observation of the beam energy, to be done…

Injector
Chopper - exciter

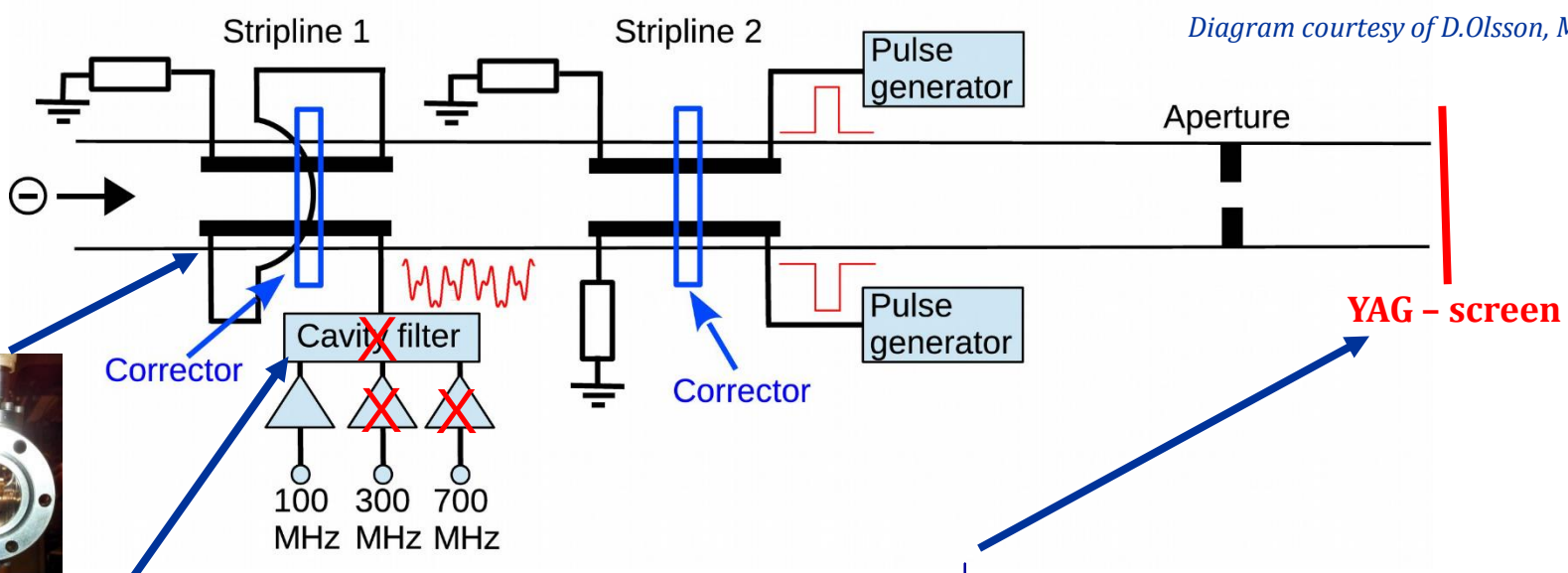


*Constructed by Sven-Olof Heed and Robert Lindvall

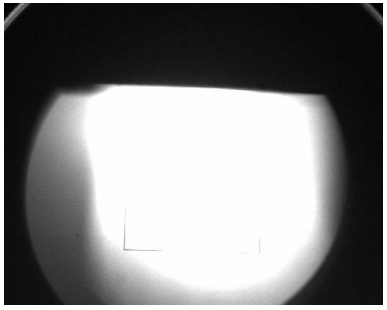
Chopper in-phase with storage ring frequency. Locked via 100MHz master oscillator signal. Linac phase locked with storage ring via 10MHz.

Chopper setup in Solaris

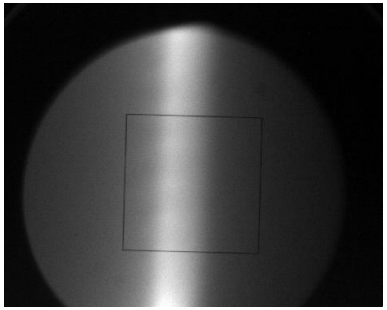
Diagram courtesy of D.Olsson, Max IV



Results from Solaris



Beam not chopped



Beam chopped,
Aperture retracted

Beam chopped,
2mm aperture inserted

Injector Klystrons

Klystrons working time after 3 years of operation:

	Standby Time [h]	HV Time [h]	Trigger Time [h]	Trigger to Cathode time [%]
I-K00 gun	1618	1683	1375	**29,4**
I-K01	1477	655	10088	82,6
I-K02	1495	461	10921	84,8
I-K03	1668	929	9877	79,2

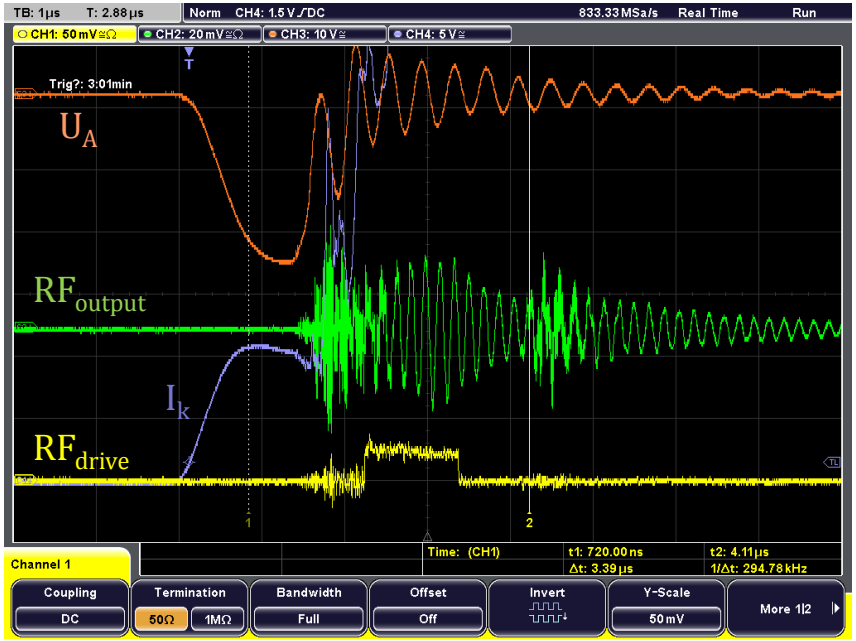
Not so efficient use of gun's klystron: 2 injection per day but cathode heater kept at 100% of the current

→ Massive arcing in the klystron in 05'2017, whole day conditioning from 30% to 100% of U_A

High demand on availability of the klystron

←→ cathode's heating

Modulator control system allows only for cathode's ON/OFF operation.



Injector Modulators

After 3 years of operation the transformer oil in modulators has degraded in terms of breakdown voltage below 50kV/2.5mm according to PN-EN 60156.

No degradation in terms of dissolved gases.

Oil dehydration:

Oil treatment for 8 hours at 70°C, 10mbar

71kV/2.5mm achieved

Final result 61kV/2.5mm in transformer tank

- Residual oil
- Refillling from 1000l tanks

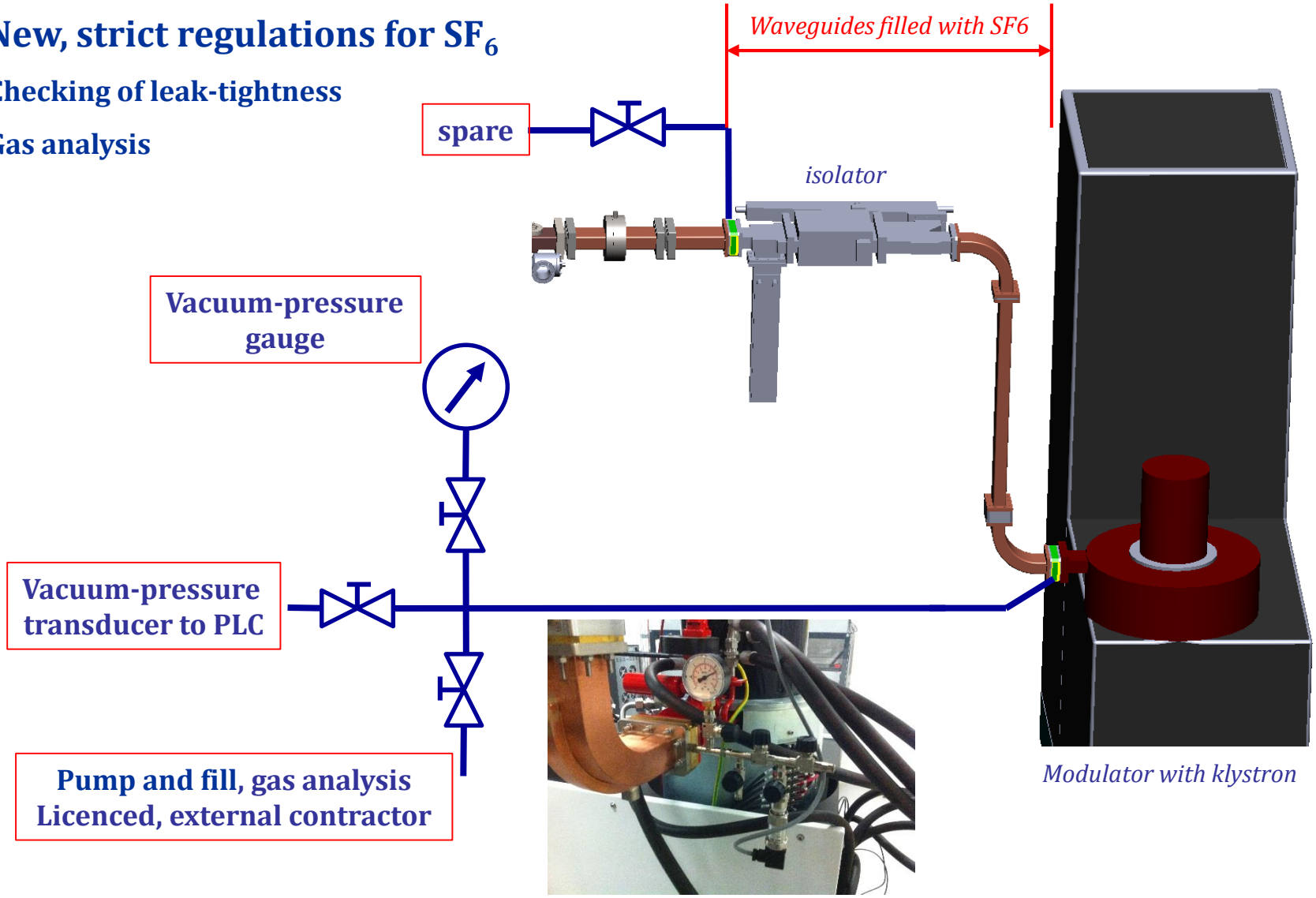
New possibility available from this year: compact dehydration unit connected to the transformer even during operation, some plumbing needed

Electron Gun System SF_6

New, strict regulations for SF_6

Checking of leak-tightness

Gas analysis



Failures of the equipment

Modulators:

- First broken IGBT in the high voltage switch unit. Equipment after warranty.

100MHz cavities

- Leakage up to 1.0e-7 mbar*l/s at ceramic of pick-ups (already 4 pieces).

New designed pick-up's without ceramics have been delivered under warranty.

Rhode & Schwarz signal generator SMA100A (Master Oscillator for linac)

- Synchronization error on 10MHz reference, repaired under warranty -> OCXO oven problem

Overheating of 50W 20dB RF attenuators from Landau cavities pick-up

- Not detectable by LLRF because of 450MHz low pass filter in series
- Expected few watts, value from 100MHz - 3GHz spectrum measurements during commissioning at certain Landau tuning position
- Investigation on-going, >150mA beam current needed

Lifetime investigation, *special thanks to Ake for support*

- Resonable Landau cavities conditioning allowed to perform some research

Lifetime limitations in Solaris with 200 mA of stored beam with Landau cavities **detuned**.[1]

Component	Quantity
Elastic scattering	22.24 h
Inelastic scattering	37.45 h
Touschek lifetime	**21.13 h**
Total lifetime	8.41 h

Lifetime limitations in Solaris with 200 mA of stored beam with Landau cavities **tuned**.[1]

Component	Quantity
Elastic scattering	23.66 h
Inelastic scattering	43.57 h
Touschek lifetime	**68.81 h**
Total lifetime	12.54 h

[1] M. B. Jaglarz *et al.*, "Electron beam lifetime in Solaris storage ring", WEPAB067, IPAC17, Copenhagen, Denmark, May, 2017.

Field stabilization to maintain constant Main to Landau cavity voltage ratio

- Longer lifetime during beam decay
- Algorithm in LLRF, tested with Landau cavity but requires to add detuning limits to avoid reaching resonance and beam loss → beam current information transfered to LLRF
- New LLRF firmware uploaded
- DCCT voltage signal converter to RF level modulation due to AC coupled ADC → in production, design by M.Kopeć, Solaris

RF
Spare parts stock

High demand on reliability. Transition to user's time.

Components at Solaris

Main cavity:

- Elements of tuning mechanism with stepper motor, stepper motor driver
- Power coupler

Isolator:

- 120kW dummy load

LLRF:

- Digital patch panel

100MHz transmitter:

- PHR901 5kW amplifier module

Modulators:

- HV power supply, High Power Switch Unit (in reparation)

Waveguides:

- LIL flange RF window

RF accessories:

- Attenuators, Dummy loads
- Splitters, Adapters, Cables

RF
Spare parts - orders

Modulators:

- Gun's klystron Thales TH2175A-1
- Linac's klystron Toshiba E37310

LLRF (critical, because one hardware handles all cavities)**:**

- Complete μTCA crate including host computer
- FPGA + ADC/DAC cards

100MHz transmitter:

- Extension of warranty for next 2 years **– waiting for order in 2018** (current warranty till 25.03.2018)

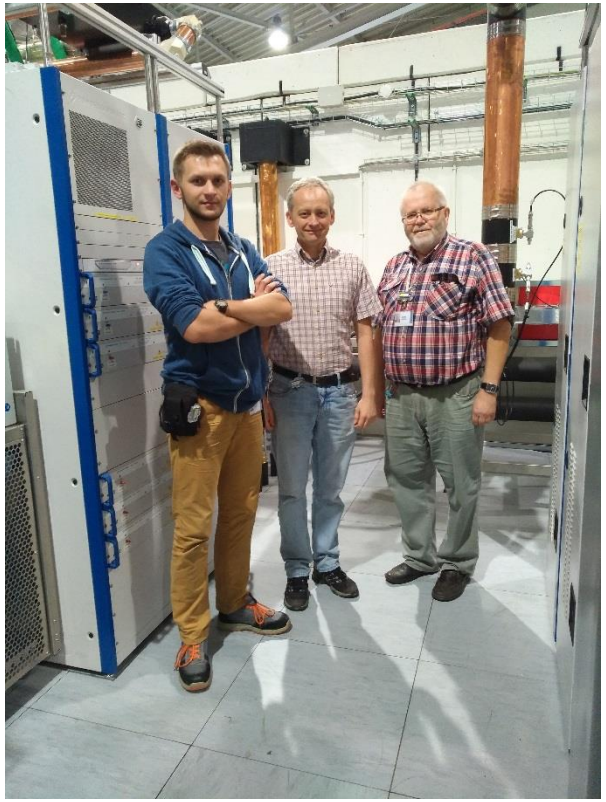
Parts not considered for order due to the cost:

- Main and Landau cavities
- Isolators for SR and linac

Parts not considered for order due to low risk of damage:

- Coax rigid line components (inspection last shutdown, slight oxidation on silver coated parts visible)

Marcin, new RF team member



Thank you for your attention