

# Status of the ASTRID2 RF systems

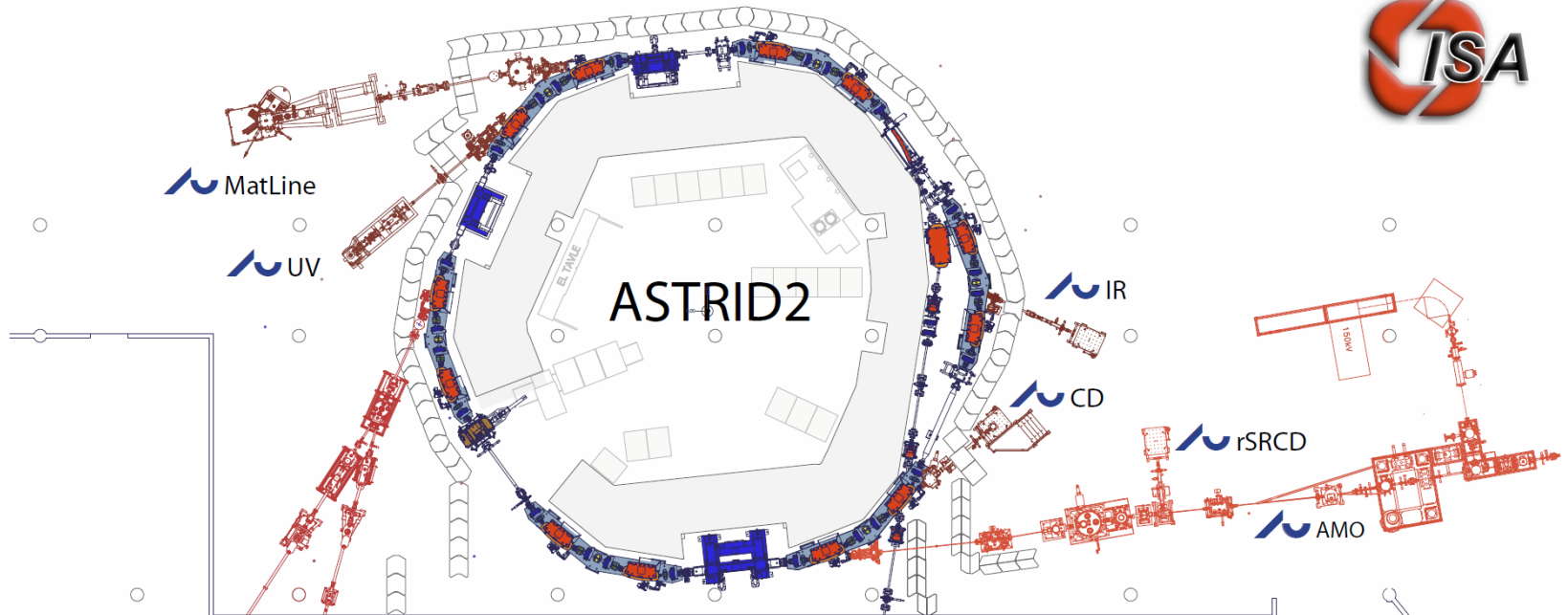
Jørgen S. Nielsen  
Center for Storage Ring Facilities (ISA)  
Aarhus University  
Denmark



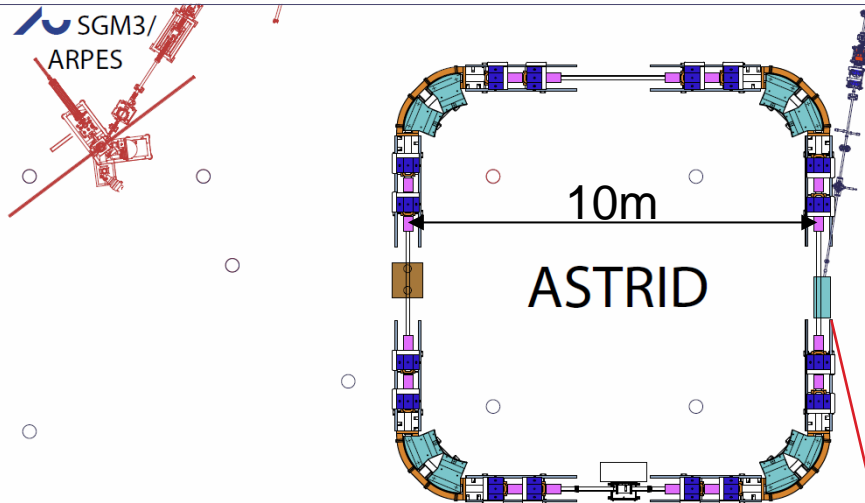
# ASTRID2

- ▶ ASTRID2 is the new synchrotron light source in Aarhus, Denmark, since 2013
- ▶ ASTRID2 main parameters
  - Electron energy: 580 MeV
  - Emittance: 12 nm
  - Beam Current: 200 mA
  - Circumference: 45.7 m
  - 6-fold symmetry
    - lattice: DBA with 12 combined function dipole magnets
      - Integrated quadrupole gradient
  - 4 straight sections for insertion devices
  - Using ASTRID as booster (full energy injection)
    - Allows top-up operation

# The ASTRID 2 facility



SGM3/  
ARPES



## ASTRID2 main parameters

|                             |         |
|-----------------------------|---------|
| Circumference               | 45.71m  |
| Energy                      | 580MeV  |
| Current                     | 200mA   |
| Characteristic energy       | 257eV   |
| RF frequency                | 105MHz  |
| Harmonic                    | 16      |
| Horiz. emittance            | 12nmrad |
| #Straight sections          | 6       |
| Length of straight sections | 2.82m   |
| #ID's                       | 3       |

Microtron (100MeV)



# ASTRID2 RF

- ▶ 105 MHz (like ASTRID)
- ▶ Main RF parameters
  - Harmonic: 16
  - RF voltage: 50–150 kV
  - Synchrotron frequency: 10–20 kHz
  - Synchrotron radiation power: ~1.4 kW
  - Cavity power: 0.5–7 kW
- ▶ 8 kW solid state amplifier from Tomco Technologies (Australia)



# Problems, problems, ...

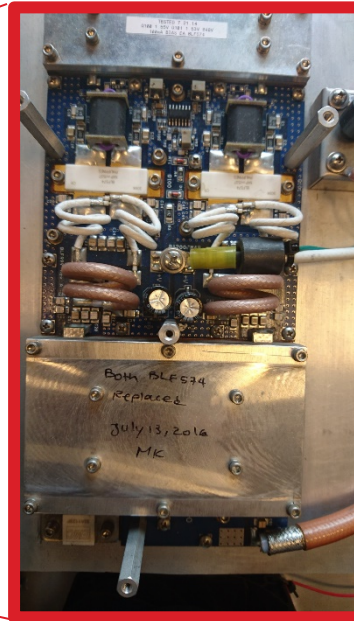
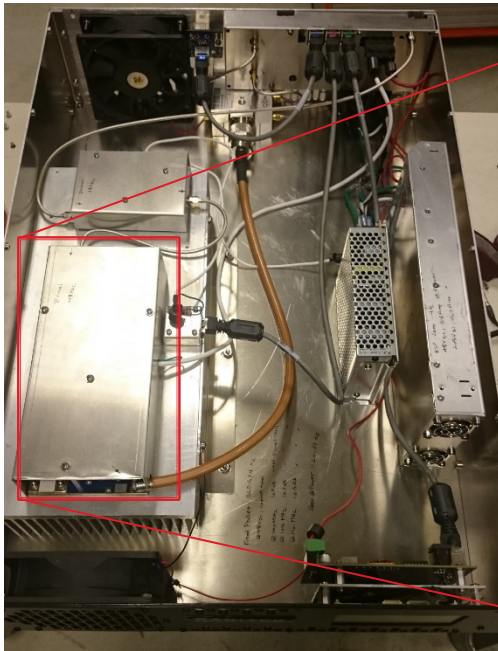
- ▶ **ASTRID: Raditek 1 kW solid-state amp:**
  - Twice burned the transistors (unknown reason)
    - Commercial FM broadcast amplifier from Raditek Inc.
- ▶ **ASTRID2: Tomco 8 kW solid-state amp:**
  - **Burned two 1 kW sub amplifier modules**
    - 1: Burned one amplifier submodule
    - 2: Burned one circulator



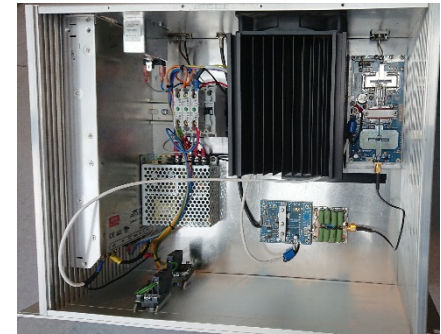


# ASTRID Problems

- ▶ ASTRID: Raditek 1 kW solid-state amp:
  - Twice burned the transistors (unknown reason)
    - Commercial FM broadcast amplifier from Raditek Inc.
      - Power module: Commercial 1 kW FM broadcast module (BLF574)

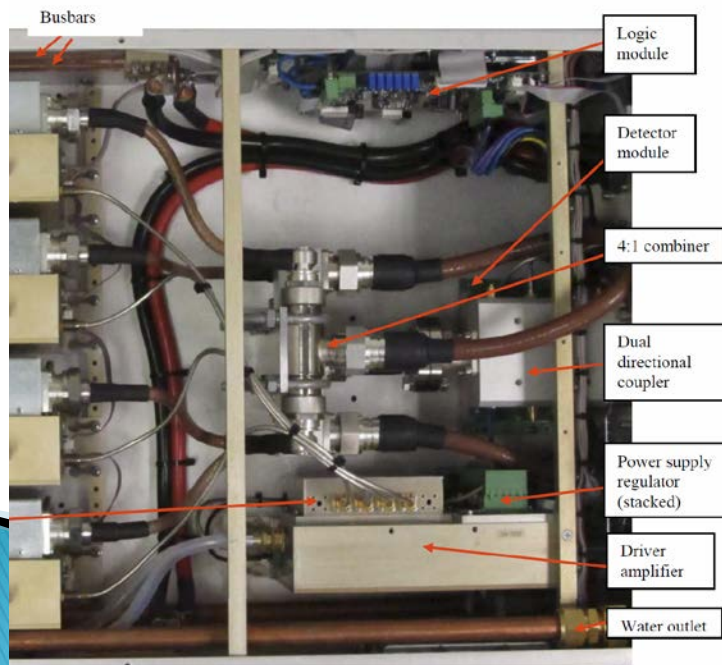


Backup:  
Homemade 600 W  
amplifier based on  
commercial FM  
broadcast amplifier  
module



# ASTRID2: Tomco 8 kW SSA

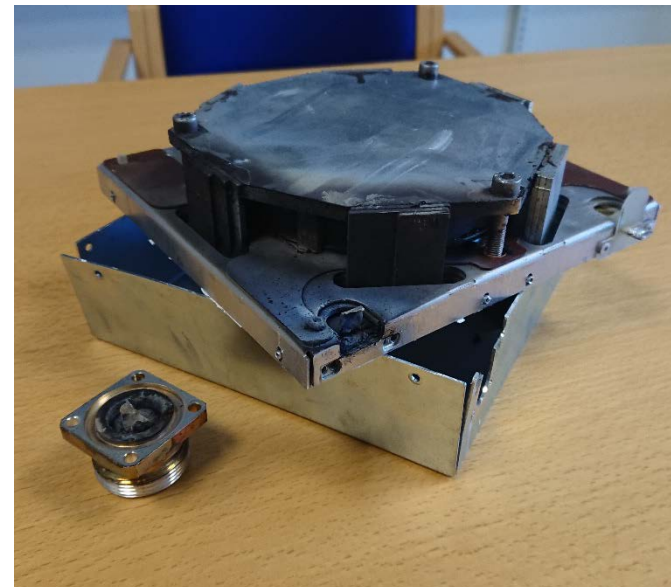
- ▶ Consist of eight 1 kW amplifier modules
  - Combined 2 and 2 and then to 4 kW
  - The two 4 kW boxes are then combined to the full 8 kW
    - Simple in-phase radial type
- ▶ Specified to withstand full reflection at any angle
  - Individual 1 kW circulators on each of the 1 kW amplifier modules





# Tomco 8 kW SSA failures

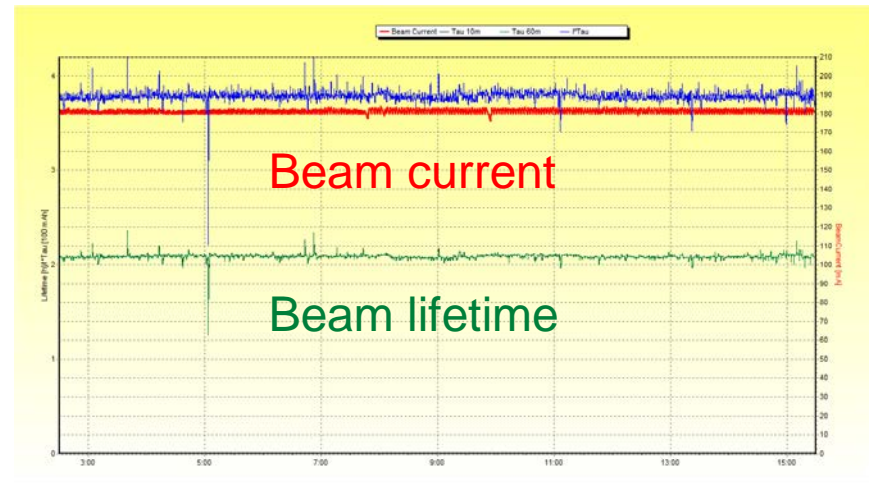
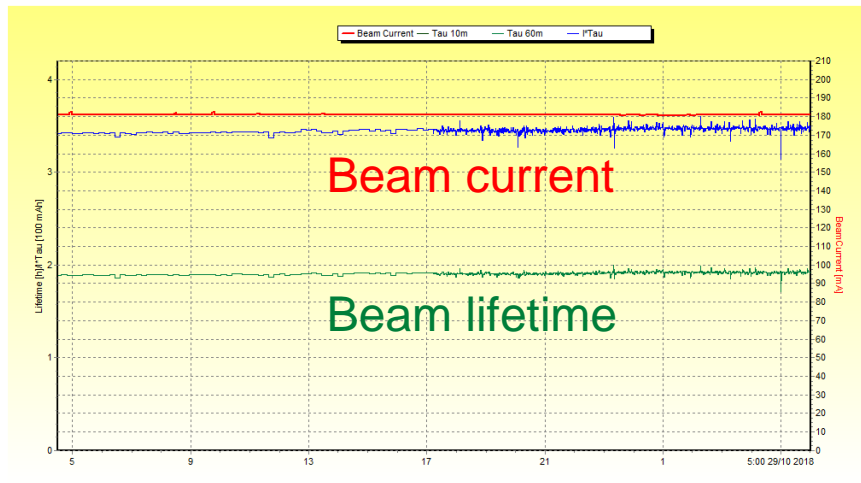
- ▶ **Amplifier submodule:**
  - Exploded when turning on the amplifier at relative high power, probably with cavity not correctly tuned
  - Tomco repaired the module free of charge (courtesy)
- ▶ **Circulator:**
  - Failed during deliberate test with high reflected power (detuned cavity)
    - Using one box: 4 kW forward power, ~2.5 kW reflected power





# Consequences

- ▶ For four months we had to use only one PA box (4 kW)
  - Reduced cavity voltage => reduced beam lifetime (only 1.9 h and not 2.1 h)



Blue curve: Beam lifetime \* Beam current [Ah]

# Long term solution

- ▶ **Ordered a 8 kW circulator**
  - Only allow 2 kW reflected power in steady state
  - To be installed in December
- ▶ **More monitoring and interlock of reflected power**
- ▶ **Should allow us to run higher cavity amplitudes hopefully giving higher beam lifetime**
  
- ▶ **Question:**
  - **Can a power combiner split reflected power unequally?**
    - Both failures were with no beam

Thank you for your attention

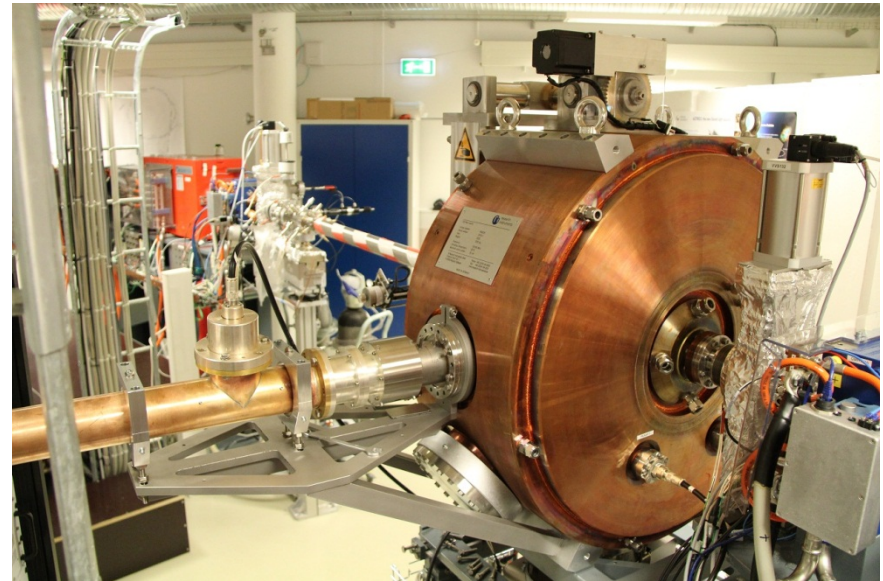
Thank you for your attention





# ASTRID2 Cavity

- ▶ Basically the same as MAX IV cavities
  - Built by RI (RF design by MaxLab)
- ▶ Has been conditioned to  $\sim 150$  kV ( $\sim 4.5$  kW)
  - No problems seen, but there is outgassing
- ▶ Usual operate at 120 kV ( $\sim 3$  kW)
  
- ▶ Have a 315 MHz Landau cavity (also from RI and based on MaxLab design).
  - ▶ Installed March 2015



# New ASTRID RF power amp.

- ▶ 1 kW Solid State from Raditek Inc.
  - Replaces the ~25 year old 8 kW tetrode amplifier
- ▶ Saves electrical power
  - Idle power consumption:
    - Tetrode: ~7 kW
    - Raditek: ~150 W

Amplifier

Circulator

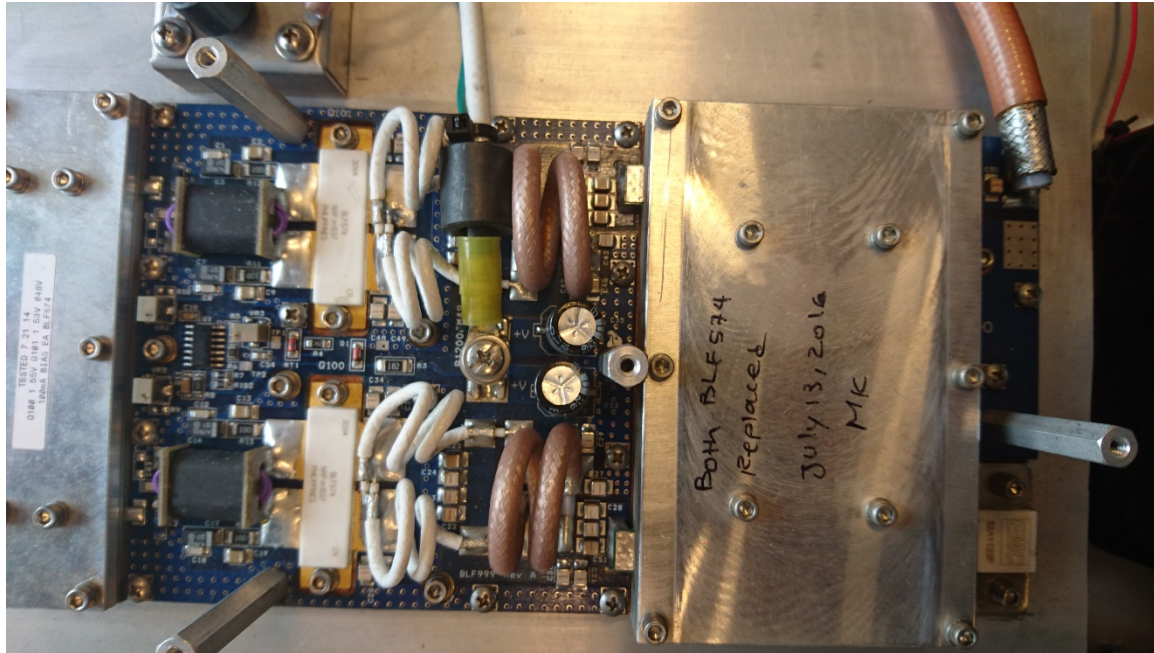


Old amplifier



# New ASTRID RF power amp.

- ▶ 1 kW power module:



- ▶ Commercial FM module

Amplifier

Circulator





# ASTRID2 Layout

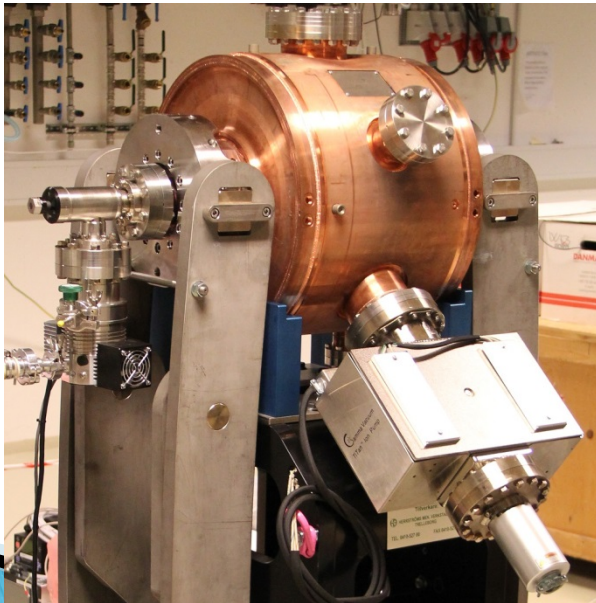


# ASTRIDx LLRF

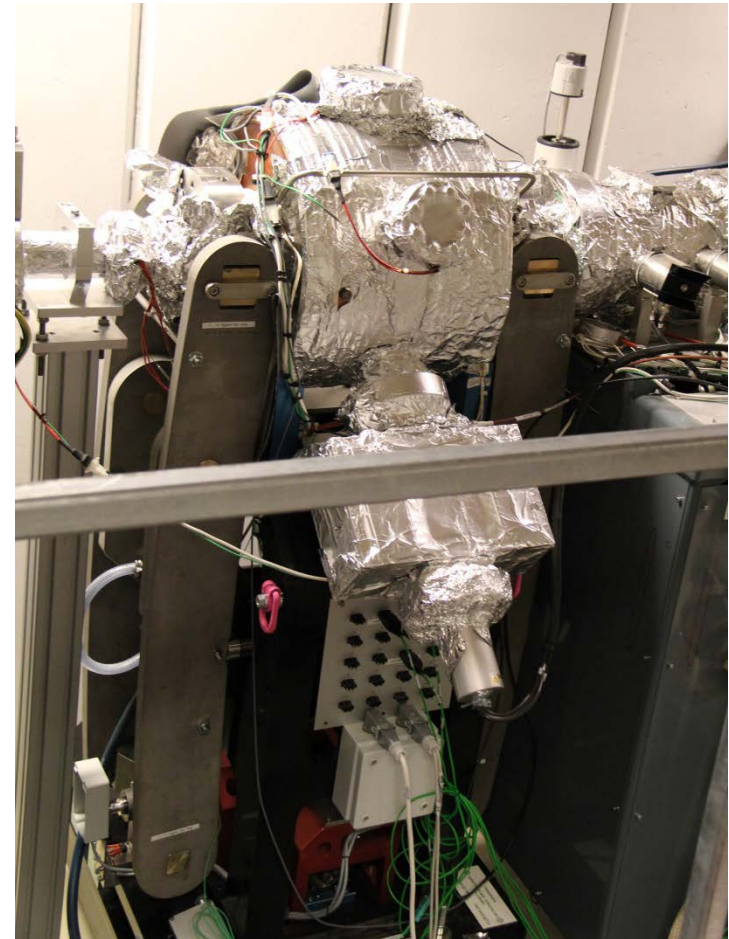
- ▶ **Since January 2011: New LLRF in operation at ASTRID**
  - Same system for ASTRID and ASTRID2 (except for different tuning control)
- ▶ **Digital control of baseband signals**
  - A computer (PC) running LabVIEW Real-Time with FPGA equipped multifunction card to measure and control the baseband signals
    - NI PCIe-7852R:
      - Virtex 5 FPGA, 8 AI, 750 kS/s/ch, 8 AO, 1 MS/s/ch, 16 bit
    - **Detection:** IQ demodulators with low pass filter
      - $\pm 180^\circ$  phase detection
    - **Control:** Amplitude and Phase (voltage controlled)
- ▶ **FPGA (Amplitude Loop): No problems at all**
- ▶ **Real-time (Tuning Loop and Phase Loop): A few restarts have been necessary** (data acquisition loop stops)
- ▶ **Very happy with the systems**

# Landau cavity

- ▶ Installed March 2015
- ▶ Prebaked ( $130^{\circ}\text{C}$ )
- ▶ Preconditioned with 100 W ( $\sim 20$  kV)
  - Multipactoring around 10 W (200 V)



Installed in the ring





# Landau cavity

## ▶ Better lifetime

- Before: 1.4 h @ 80 mA and 1.0 h @ 120 mA
- Now: 2.0 h @ 80 mA and 1.85 h @ 120 mA

## ▶ More stable beam

- Moved instabilities to frequencies in the (many) MHz range
- SR diagnostic camera (in control room) now shows a stable beam (and happy users)

## ▶ Good tuning range is limited

- Pt. use a detuning of +400 kHz (tuning range is  $\pm 500$  kHz).
  - “Theoretical optimum” (flat potential) is +160 kHz
- Drop in cavity voltage and outgassing 250–300 kHz
  - Needs more conditioning ?

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