SRF developments for ion acceleration

Guillaume OLRY - IPN Orsay
I- Upgrade of existing facilities

Under construction: ISAC-II phase 2 (Triumf), ATLAS upgrade (ANL), PIAVE-ALPI upgrade (INFN-Legnaro), HI Booster (IUAC)

Cavity design & prototyping: Re-Accelerator (MSU), HIE-ISOLDE (CERN)

II- New facilities

Under construction: SARAF (Soreq), SPIRAL2 (GANIL)

Cavity design & prototyping: HINS (Fermilab), EURISOL (IPN Orsay & INFN-Legnaro), EUROTRANS (IPN Orsay & Frankfurt)
Addition of 20 QWRs, beta=0.11, 141 MHz, housed in 3 modules → + 20 MV to the ISAC-II ions

- Fabrication with a local company, PAVAC
- Two copper models to test fabrication, assembly sequence and frequency tuning procedure
- Inner conductor modified → lower Epk/Ea & Bpk/Ea

2 bulk Niobium prototypes produced (freq. within 10 kHz of goal)
- BCP etching and HPWR done at TRIUMF
- Vertical tests: both cavities meet the specs.
- First 6 QWRs at the end of October 2008
- Increase the total voltage by 14 MV max by adding of 7 cavities housed in one module (replacing existing one)
  - Separate cavity and cryomodule vacua
  - Focusing: one SC solenoid
  - 7 QWRs (beta 0.14, 109 MHz)
  - Design gradient: 8 MV/m
  - Electropolishing & HPWR done at ANL

- Clean assembly of the cryomodule → Dec. 2008
- Moved into the ATLAS tunnel in January 2009 for installation and test

THP025 M.P. Kelly

Linac08 conference, Victoria, BC, Canada / September 29 - October 3, 2008
• Upgrade of the existing 5 cryostats (housing 4 QWRs each) & addition of a new cryomodule (with 4 new QWRs)
→ Double the total voltage from 10 to 20 MV
  ▪ Common vacuum & warm QP
  ▪ New RF amplifiers and couplers to achieve the new design gradient: 5 MV/m (formerly, 3 MV/m for the 20 “old” QWRs)
  ▪ 4 QWRs, beta 0.047, 80 MHz with also a new tuning system (modified ISAC-II tuner)

• Cavity #1 meet the specs
• Cavity #2 under test
• Cavities #3 & #4 are ready
• Validation of the new cryomodule: end of 2008
• Upgrade of the “old” cryostats (one by one) till the end of 2009
• Successful acceleration of ion beams through 1st module housing 8 QWRs, beta 0.08, 97 MHz (ANL collab.) end of 2007
  - $<\text{E}_a> \sim 3 \text{ MV/m}$
• Next upgrade: 2 more modules (housing 8 QWRs + 1 SC solenoid each).
  - Local production and in-house EB welding, Electropolishing, HPWR and heat treatment
  - Modifications: helium jacket top plate, power coupler, mechanical tuner, damping of vibrational modes (with SS balls)

• Final assembly and installation by the end of 2008
Outline

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- Re-accelerate exotic ions up to 3 MeV/u
- 2 bulk Niobium QWRs (INFN-Legnaro collab.):
  - beta 0.041, 80.5 MHz
  - beta 0.085, 80.5 MHz
- In-house etching (BCP) and HPWR
- Vertical test of beta 0.041 cavity
  - $E_{pk} \sim 70$ MV/m & $B_{pk} \sim 120$ mT $\rightarrow$ 1.9 MV
- Prototype cryomodule test with QWR & HWR
- **Stage 1**: final energy up to 5.5 MeV/u with 10 QWRs, beta 0.12, 101 MHz
- **Stage 2**: final energy up to 10 MeV/u with 10 QWRs, beta 0.075, 101 MHz & 5 more QWRs, beta 0.12, 101 MHz
- 5 cavities & 1 SC solenoid/cryomodule (common vacuum)
- Nb/Cu sputtering technology
- 1 copper model of the ‘high’ beta 0.12 ready by the end of October 2008
  - Drift tubes faces modified for steering compensation

Lindeco conference, Victoria, BC, Canada - September 29 – October 3, 2008
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Soreq

- **Phase 1:** p 4MeV & d 5.2 MeV at the PSM exit
  - 6 HWR, beta 0.09, 176 MHz
  - Focusing: 3 SC solenoids
- **Specs:** $P<10\; W/cavity$ @ $E_{peak}=25\; MV/m$ ($E_a=5\; MV/m$)
- **Cold tests @ Soreq since sept 2007**
  - $<E_a>\approx 6\; MV/m$
  - Low Q-value on 3 cavities
  - Ponderomotive oscillations ($>E_{peak}=16\; MV/m$) → should be fixed with piezo tuner
  - No major perturbations from microphonics

<table>
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<th>Cavity</th>
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<th>10/2007 PSM Test</th>
<th>03/2008 PSM Test</th>
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• The module is now on-line, “almost” ready for beam tests
• Specs: P<10 W/cav @ Epk=32 MV/m (Ea=6.5MV/m)
• QWR “A” series: fab. just started → 2 first cavities in march 2009
  ▪ Opening bottom plate, tuning by deformation
  ▪ Vertical test: Ea=11 MV/m (low Qo for 2nd cavity)
  ▪ Cryomodule test: November 2008
• QWR “B” series: fab. under progress, 3/16 delivered, 1 tested (maybe two) → last cavity in March 2010
  ▪ Welded bottom plate, tuning by plunger
  ▪ Vertical test 1st series cavity: Ea max=9.3 MV/m
  ▪ Cryomodule test: Ea max=8.5 MV/m @ 10 kW (over-coupling), tuning system OK.

QWR “A” beta 0.07

QWR “B” beta 0.12

SC plunger for tuning
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• SC H- linac with Single-Spoke Resonator from 10 MeV to 60 MeV (beta 0.22 & beta 0.4, 325 MHz)
• 4 beta 0.22, SSR prototyped:
  ▪ Two first cavities delivered (1 tested)
  ▪ SSR1-03 & 04 are produced by IUAC
• Vertical test (4.4 K): Epk~70 MV/m, Bpk~115 mT
• MP barriers between 2 and 11 MV/m (confirmed by simulations)
EURISOL

INFN-Legnaro

- HWR, beta 0.15, 176 MHz
- Design gradient: 5.5 MV/m
- RF design finished
- Frequency tuning by cup deformation

Courtesy of A. Facco

IPN-Orsay

- Triple Spoke, beta 0.30, 352 MHz, bulk Niobium
- Design gradient: 8 MV/m
- RF design finished: $E_{pk}/E_a=4.12$, $B_{pk}/E_a=9.05\text{mT}/(\text{MV/m})$
- Frequency tuning with a SC plunger (SPIRAL2-type)

Linac08 conference, Victoria, BC, Canada / September 29 - October 3, 2008
• CH-type cavity: 19-gap, beta 0.1, 360 MHz
• Vertical test: 7 MV/m (design 4 MV/m)
• Horizontal test: Nov. 2008 with its tuning system
• Design of a new 7-gap cavity

New 7-gap cavity

• 2-gap, beta 0.20, 352 MHz
• Tested in horizontal cryostat with its tuning system equipped with piezo actuators

100 Hz/µm

piezo displacement
frequency detuning
### Spoke all-around-the-world

#### Tests results @ 4K

*\( L_{acc} = \frac{\text{number of gaps} \times \text{optimal beta} \times \lambda}{2} \)*

<table>
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<tr>
<th>Lab</th>
<th>Type</th>
<th>Frequency [MHz]</th>
<th>Optimal beta</th>
<th>( E_a^* ) [MV/m]</th>
<th>( E_{pk} ) [MV/m]</th>
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Mean values for ~350 MHz spoke cavities: 8.0 41 97
HIPPI/FZJuelich

- Triple Spoke cavity, beta 0.48, 352 MHz
- EB welding at FZJuelich
- Optimized for pulsed operation
- First test in vertical cryostat
Thank you

TRIUMF: B. Laxdal
Fermilab: L. Ristori
ANL: M. Kelly
MSU: W. Hartung, M. Doleans
FZ-Juelich: R. Toelle, E. Zaplatin
INFN-Legnaro: A. Facco
Soreq: I. Mardor, D. Berkovits, J. Rodnizki
Frankfurt: H. Podlech
CERN: M. Pasini
IUAC: A. Roy
IPN Orsay: H. Saugnac
CEA Saclay: P. Bosland
# Spoke all-around-the-world

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*Lacc = spoke cavity owner’s definition*

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ISAC-II: Phase 1

- Boosts ion energy by 20 MV to provide stable and RIB’s > Coulomb Barrier

- 20 “medium beta” QWRs housed in five cryomodules (INFN-Legnaro collab.):
  - Common vacuum
  - Focusing: one SC solenoid
  - Bulk niobium, 106 MHz
  - 8 beta 0.057 & 12 beta 0.071
  - $<E_{acc}> \sim 7.2$ MV/m (design $6$ MV/m)

- ISAC-II accelerator is running with no deterioration in gradient performance since its commissioning in Spring 2006

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