SRF developments for ion acceleration

Guillaume OLRY - IPN Orsay

Featuring...

TRIUMF, ANL, MSU/NSCL,
GANIL, INFN-Legnaro,
IUAC, CERN

QWR

HWR

Soreq, MSU/NSCL,
INFN-Legnaro

CH

SPOKE

IAP-Frankfurt

ANL, Fermilab, IPN Orsay,
FZJuelich

Outline

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)

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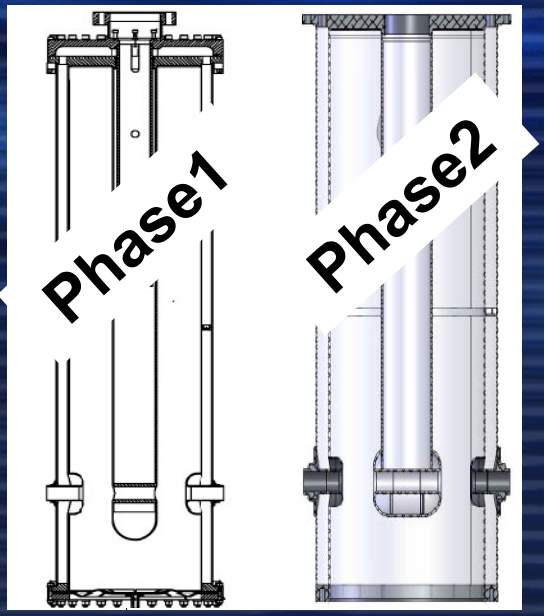
TRIUMF

ISAC-II: Phase 2

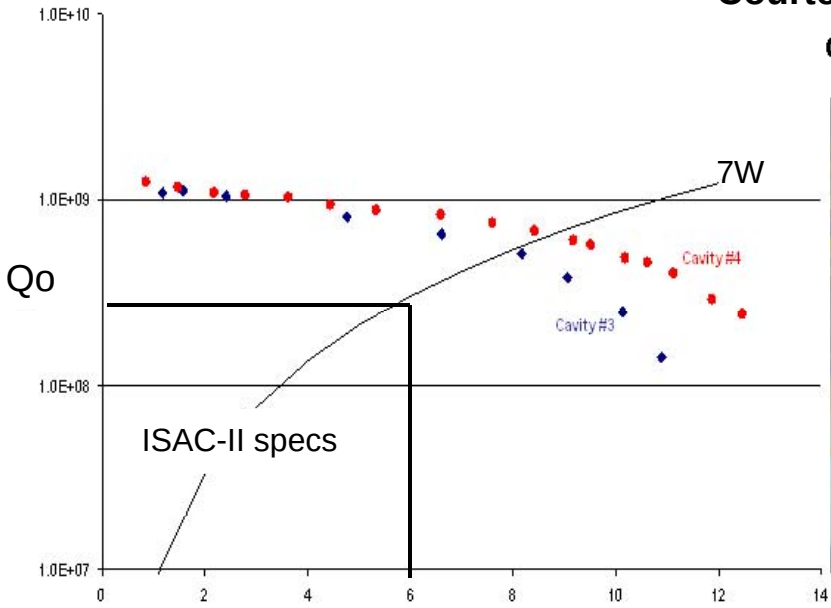
- Addition of 20 QWRs, beta=0.11, 141 MHz, housed in 3 modules → + 20 MV to the ISAC-II ions

- 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



Courtesy of R.E. Laxdal

QWR, beta 0.11, 141 MHz



THP003 R.E. Laxdal

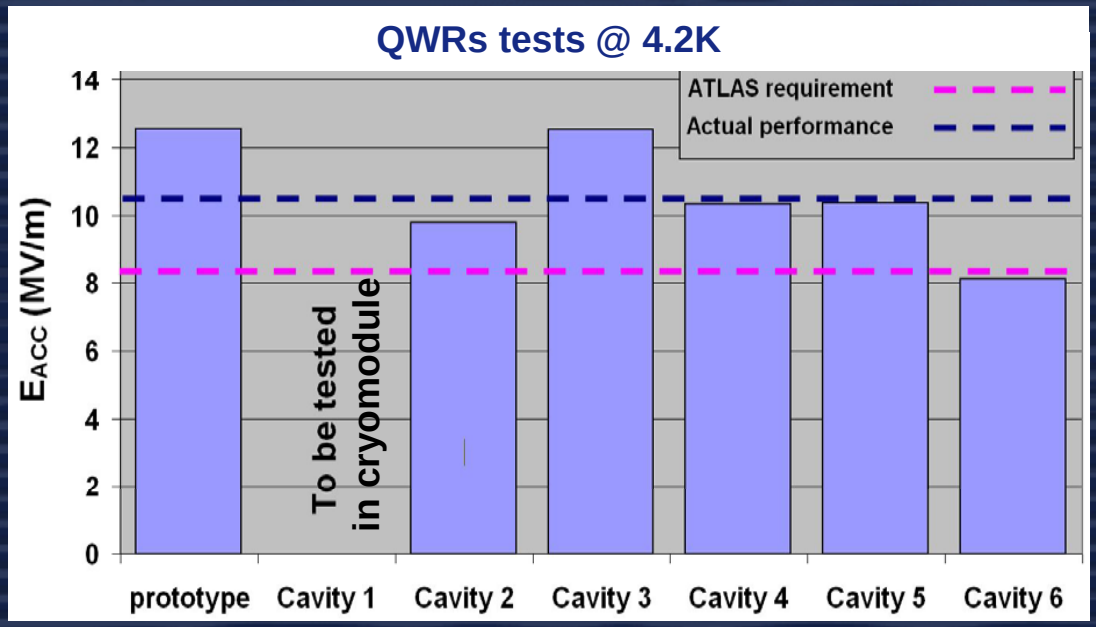
- 2 bulk Niobium prototypes produced (freq. within 10 kHz of goal)
- BCP etching and HPWR done at TRIUMF
- Vertical tests: both cavities meet the specs.
- First 6 QWRs at the end of October 2008

ANL

ATLAS

- 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

Courtesy of M.P. Kelly



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

THP025 M.P. Kelly

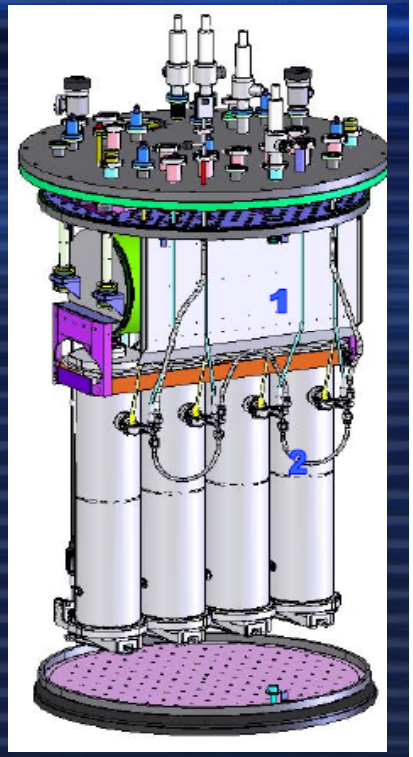
INFN-Legnaro

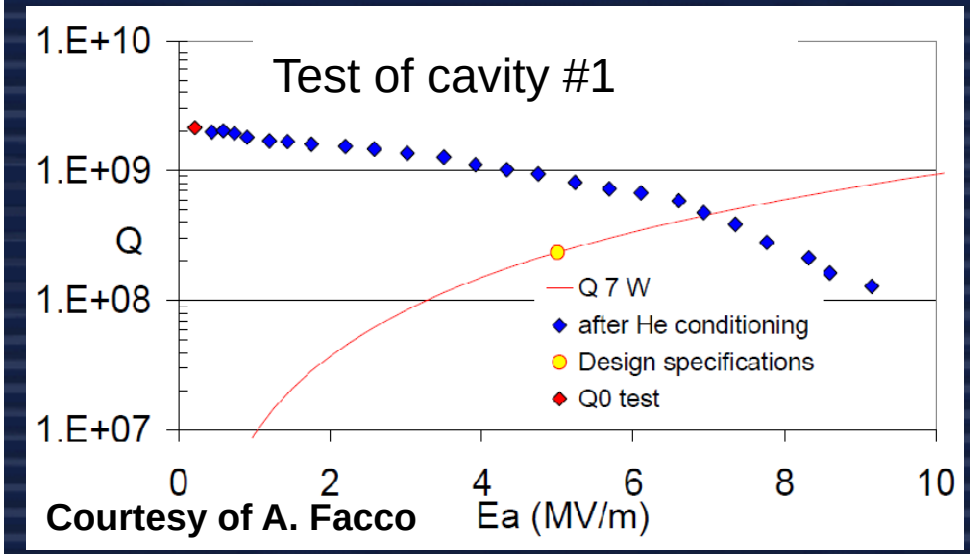
PIAVE-ALPI

- 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)





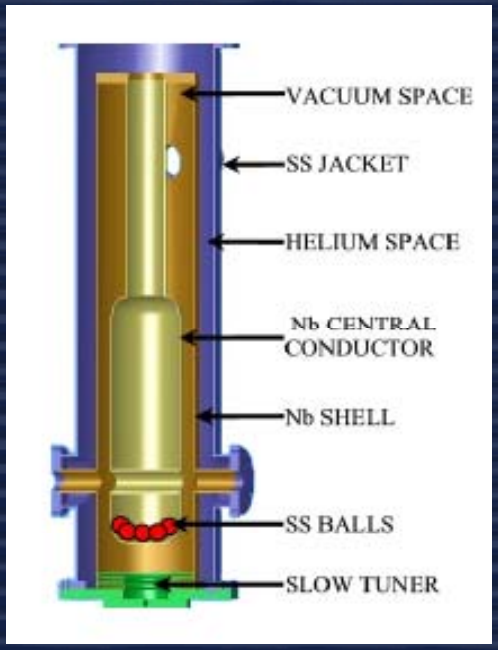
- Cavity #1 meet the specs
- Cavity #2 under test
- Cavities #3 & #4 are ready
- Validation of the new cryomodule: end of 2008
- Upgrade of the "old" cryostats (one by one) till the end of 2009

IUAC New Delhi

TH202 A. Roy

- Successful acceleration of ion beams through 1st module housing 8 QWRs, beta 0.08, 97 MHz (ANL collab.) end of 2007
  - <Ea>~3 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



THP017 B.K. Sahu

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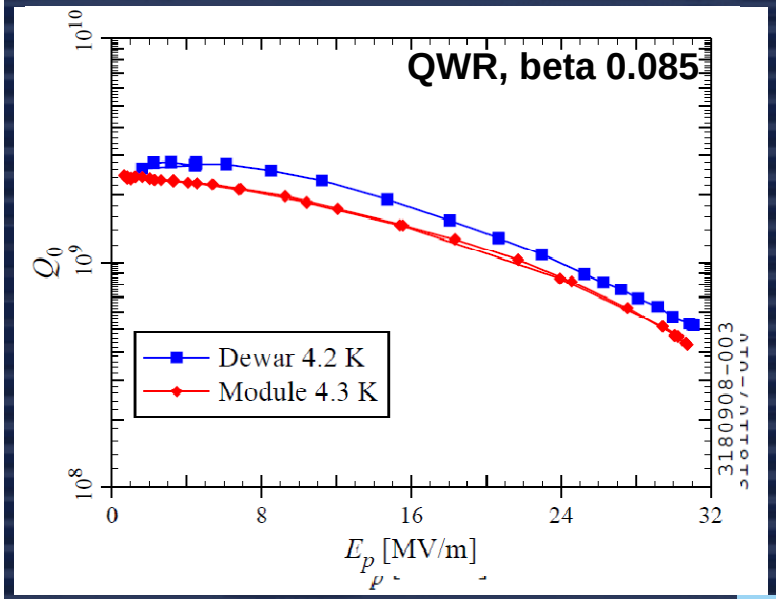
MSU/NSCL

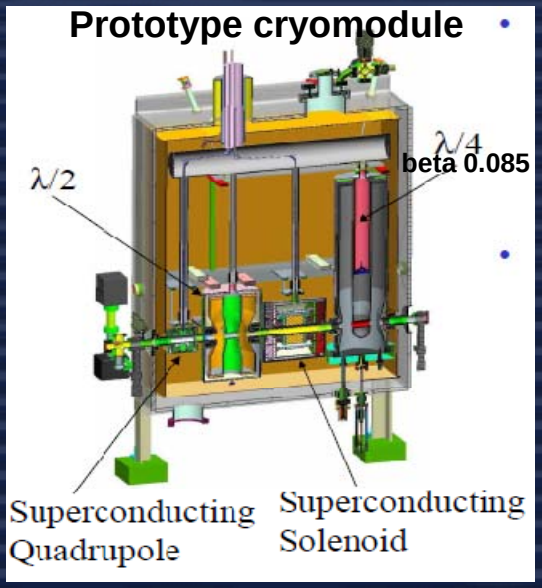
Re-Accelerator

MOP056 X. Wu

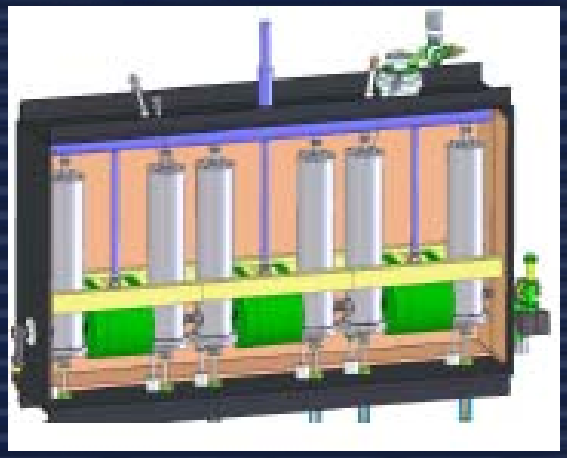
- Re-accelerate exotic ions up to 3 MeV/u
- 2 bulk Niobium QWRs (INFN-Legnaro collab.):
  - beta 0.041, 80.5 MHz
  - beta 0.085, 80.5 MHz
- In-house etching (BCP) and HPWR
- Vertical test of beta 0.041 cavity
  - Epk ~70 MV/m & Bpk~120 mT → 1.9 MV
- Prototype cryomodule test with QWR & HWR



Courtesy of W. Hartung



THP033 W. Hartung



2nd cryomodule housing 6 QWRs with beta 0.041

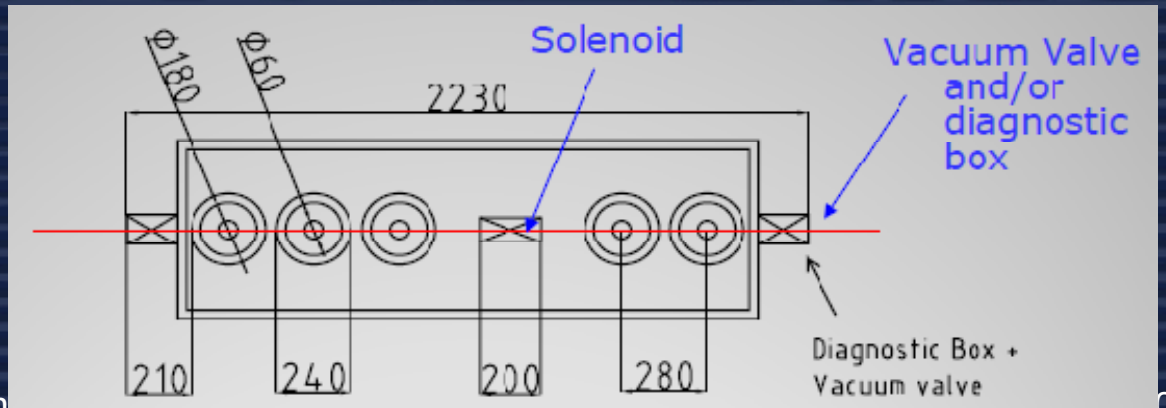
CERN

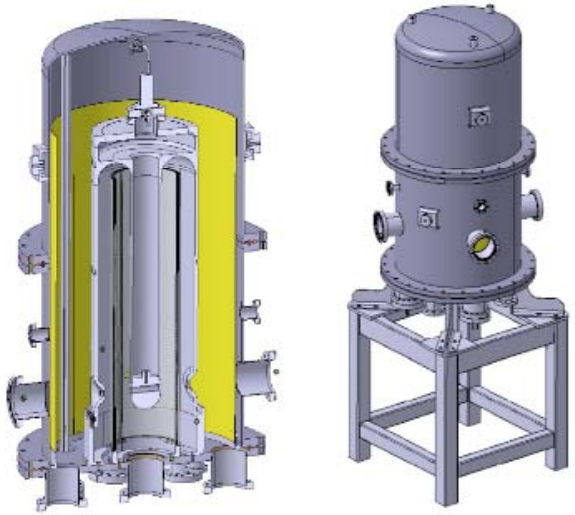
HIE-ISOLDE

MOP028 M. Pasini

- 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

Courtesy of M. Pasini





Sputtering chamber

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Soreq

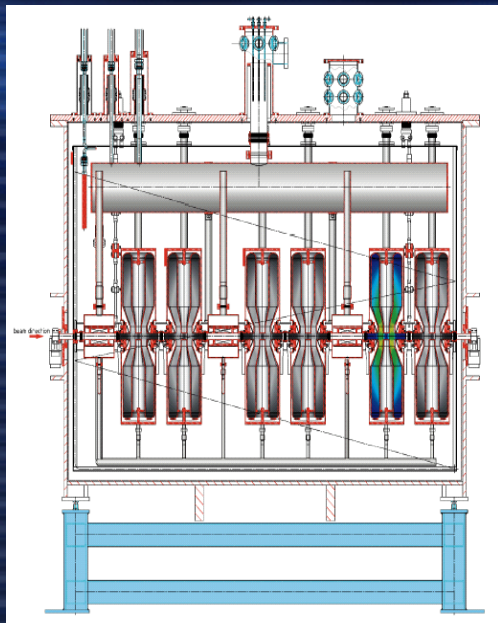
SARAF

- 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 @ Epk=25 MV/m (Ea=5MV/m)
- Cold tests @ Soreq since sept 2007
  - <Ea>~6 MV/m
  - Low Q-value on 3 cavities
  - Ponderomotive oscillations (>Epk=16 MV/m) → should be fixed with piezo tuner
  - No major perturbations from microphonics

Cavity		vertical Test			10/2007 PSM Test			03/2008 PSM Test	
location	name	max field	losses at	Q at	max field	losses at	Q at	losses at	Q at
		[MV/m]	25 MV/m	25 MV/m	[MV/m]	25 MV/m	25 MV/m	25 MV/m	25 MV/m
			[W]			[W]		[w]	
HWR1	LB-2	40	7,3	6,0E+08	30	6,3	7,0E+08	6	8,00E+08
HWR2	LB-3	43	7,3	6,0E+08	28	31,4	1,4E+08	9	5,00E+08
HWR3	LB-5	33	6,3	7,0E+08	32	22,0	2,0E+08	24	2,00E+08
HWR4	LB-7	46	6,3	7,0E+08	29	22,0	2,0E+08	39	2,00E+08
HWR5	LB-4	36	5,5	8,0E+08	31	11,0	4,0E+08	13	4,00E+08
HWR6	LB-6	38	7,3	6,0E+08	29	14,7	3,0E+08	42	1,00E+08
		sum	40,0			107,3		133	

MO023 I. Mardor

Prototype Superconducting Module



Courtesy of I. Mardor

- The module is now on-line, “almost” ready for beam tests

GANIL

SPIRAL2

TU102 T. Junquera

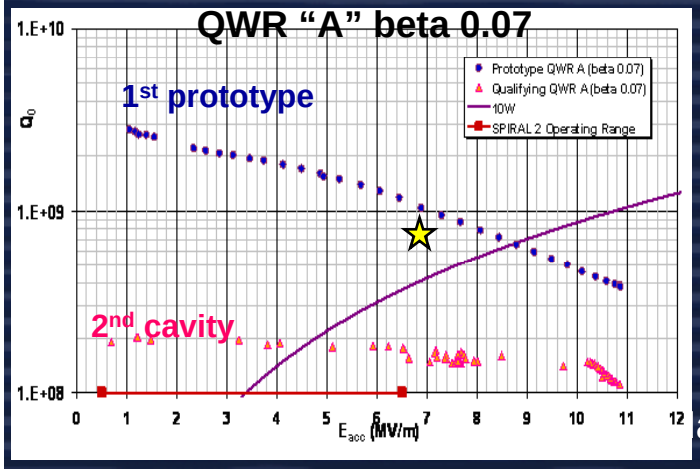
- Specs: P<10 W/cav @ Epk=32 MV/m (Ea=6.5MV/m)
- QWR "A" series: fab. just started → 2 first cavities in march 2009
  - Opening bottom plate, tuning by deformation
  - Vertical test: Ea=11 MV/m (low Qo for 2nd cavity)
  - Cryomodule test: November 2008
- QWR "B" series: fab. under progress, 3/16 delivered, 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.

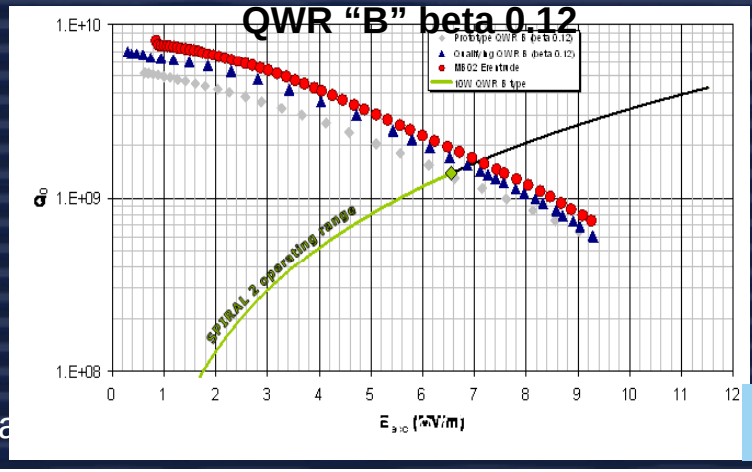
THP007 G. Devanz

SC plunger for tuning

THP008 D. Longuevergne

THP009 H. Saugnac





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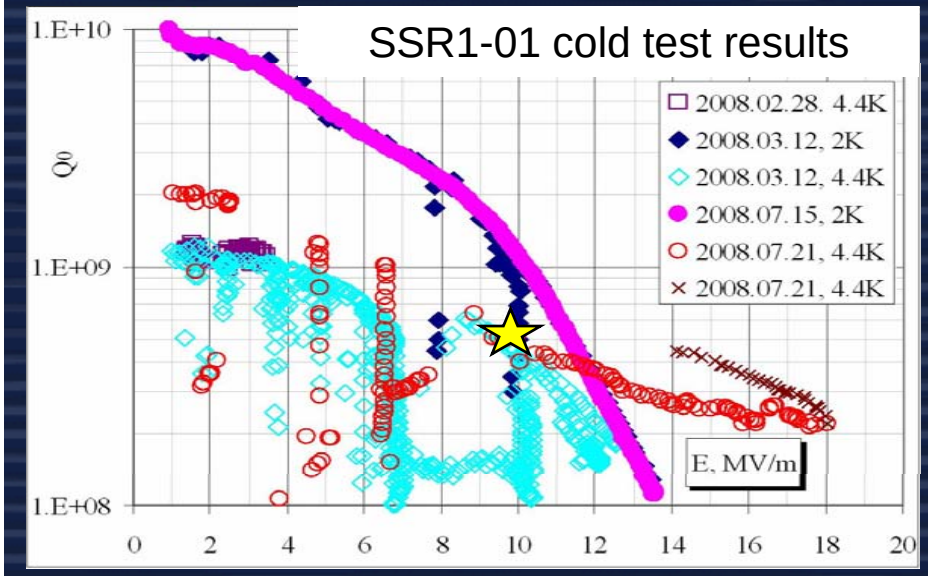
Fermilab

MO301 R.C. Webber

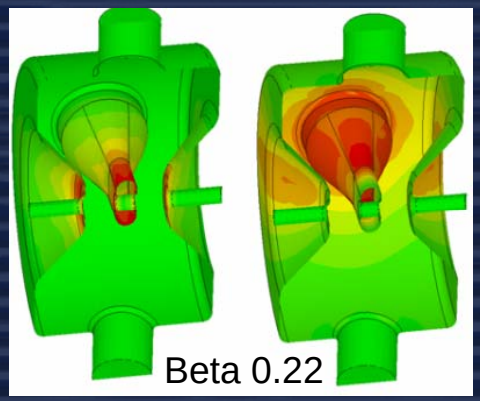
HINS

- 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)

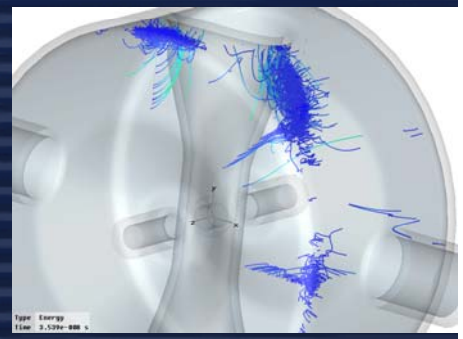
SSR1-02 by Roark



Courtesy of L. Ristori



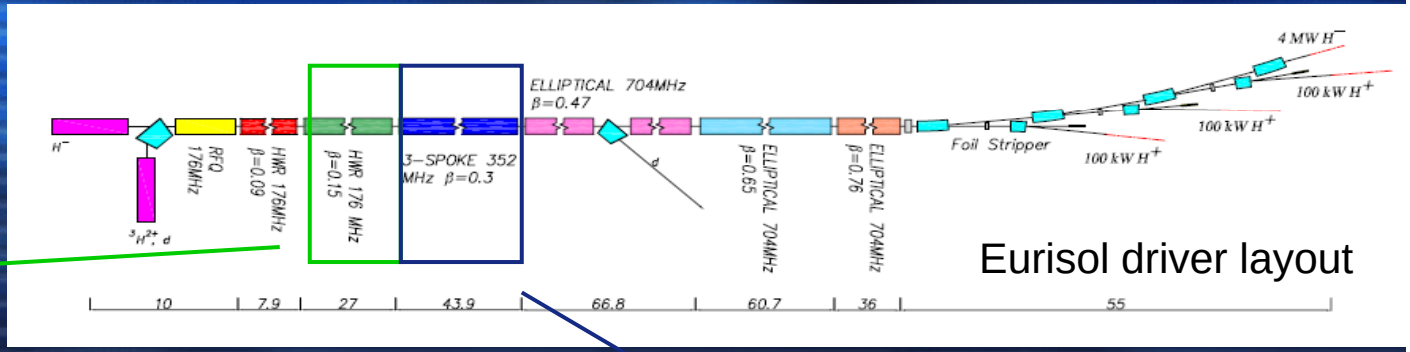
Beta 0.22



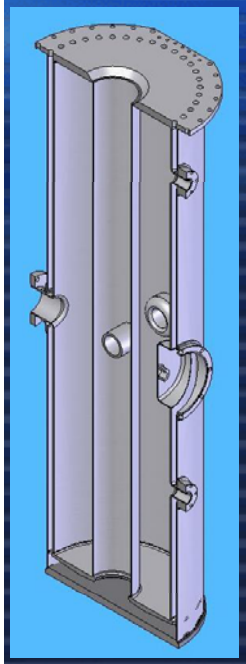
MP studies (Particle Studio)

MOP043 G.V. Romanov

EURISOL



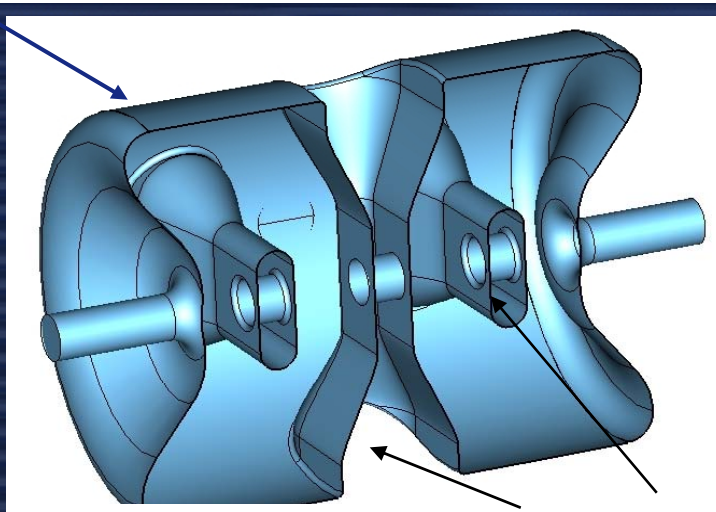
Eurisol driver layout



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



Racetrack shape for spoke base & centre

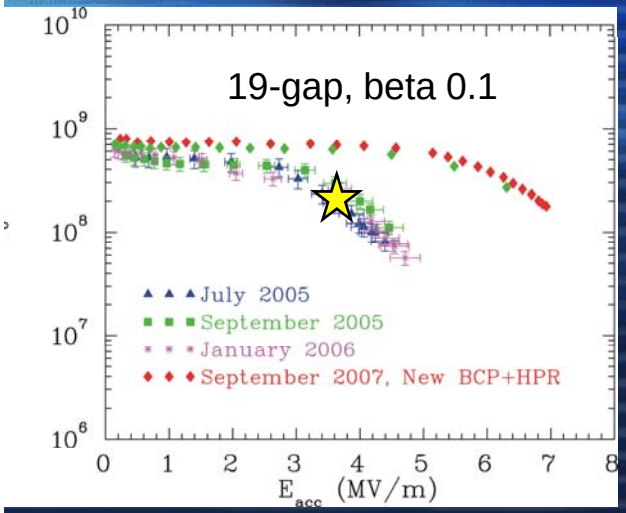
IPN-Orsay

- Triple Spoke, beta 0.30, 352 MHz, bulk Niobium
- Design gradient: 8 MV/m
- RF design finished: Epk/Ea=4.12, Bpk/Ea=9.05mT/(MV/m)
- Frequency tuning with a SC plunger (SPIRAL2-type)

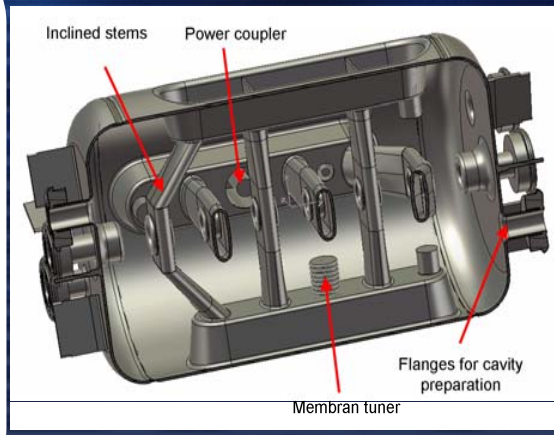
EUROTRANS

Frankfurt

TPH011 H. Podlech

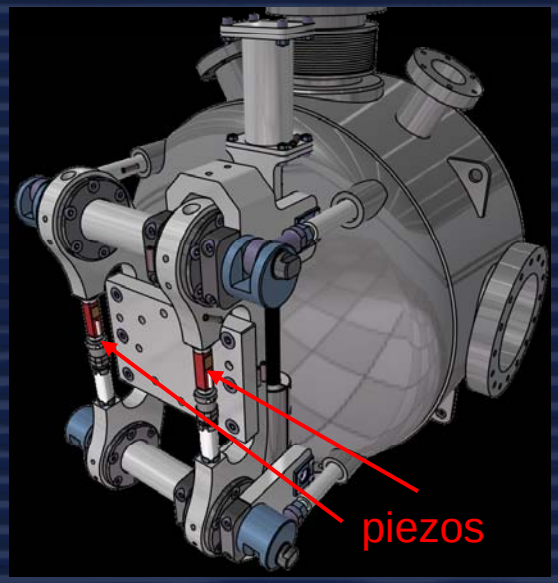


- CH-type cavity: 19-gap, beta 0.1, 360 MHz
- Vertical test: 7 MV/m (design 4 MV/m)
- Horizontal test: Nov. 2008 with its tuning system
- Design of a new 7-gap cavity

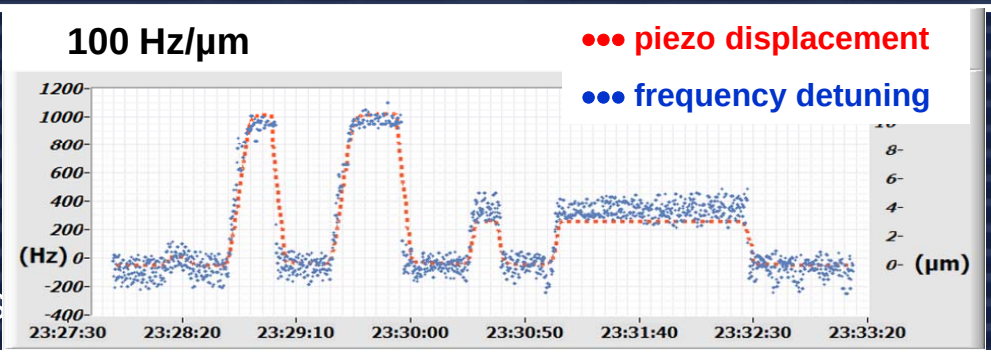


New 7-gap cavity

IPN-Orsay



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



Spoke all-around-the-world

Tests results @ 4K

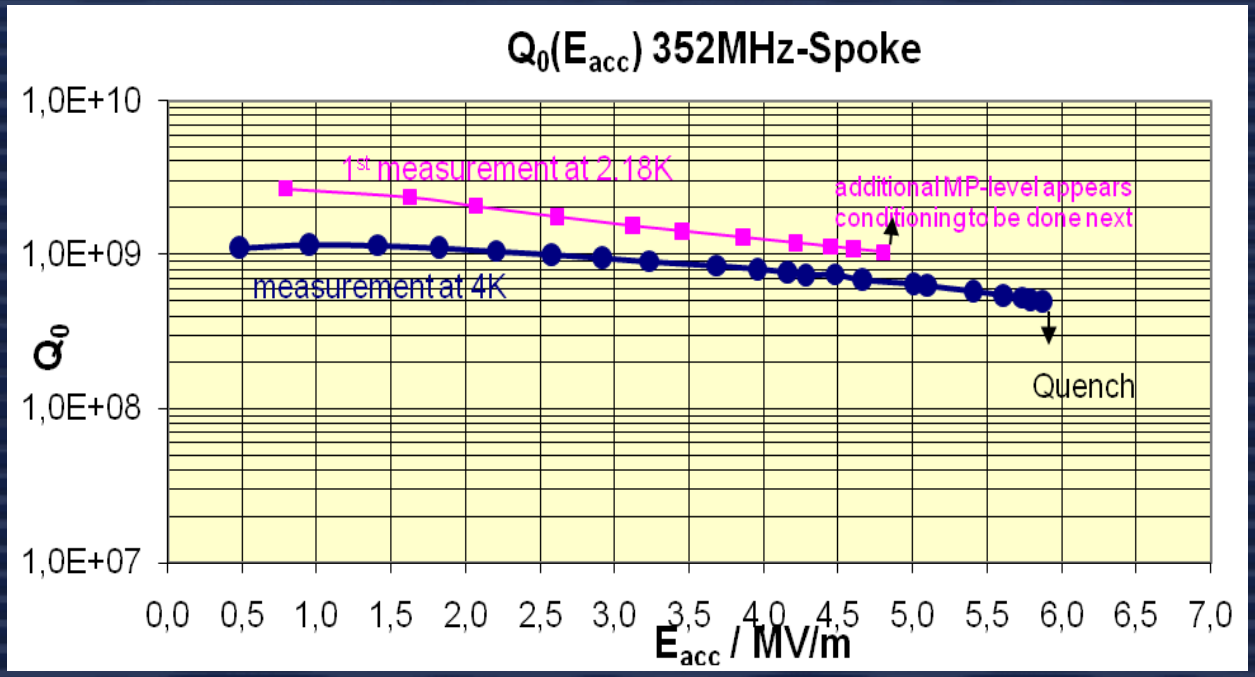
*Lacc = (number of gaps x optimal beta x lambda)/2

Lab	Type	Frequency [MHz]	Optimal beta	Ea* [MV/m]	Epk [MV/m]	Bpk [mT]	Voltage [MV]
IPN Orsay	Single	352	0.20	4.8	32	69	0.82
	Single	352	0.36	8.1	38	104	2.49
ANL	Single	855	0.28	4.4	24	56	0.26
	Single	345	0.29	8.8	40	106	2.21
	Single	345	0.40	7.0	44	117	2.44
	Double	345	0.40	8.6	40	79	4.49
	Triple	345	0.50	7.7	28	88	6.65
	Triple	345	0.62	7.9	31	95	8.70
FZ-Juelich	Triple	760	0.20	8.6	43	87	1.36
LANL	Single	350	0.21 (EZ01)	7.5	38	100	1.35
	Single	350	0.21 (EZ02)	7.2	37	96	1.30
Fermilab	Single	325	0.22 (SSR1-01)	12.0	70	113	2.43
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

BCP etching @ CEA/Saclay



HPWR @ IPN Orsay

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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	Single	345	0.29	12.5	40	106	2.21
	Single	345	0.40	11.0	44	117	2.44
	Double	345	0.40	11.5	40	79	4.49
	Triple	345	0.50	10.2	28	88	6.65
	Triple	345	0.62	10.6	31	95	8.70
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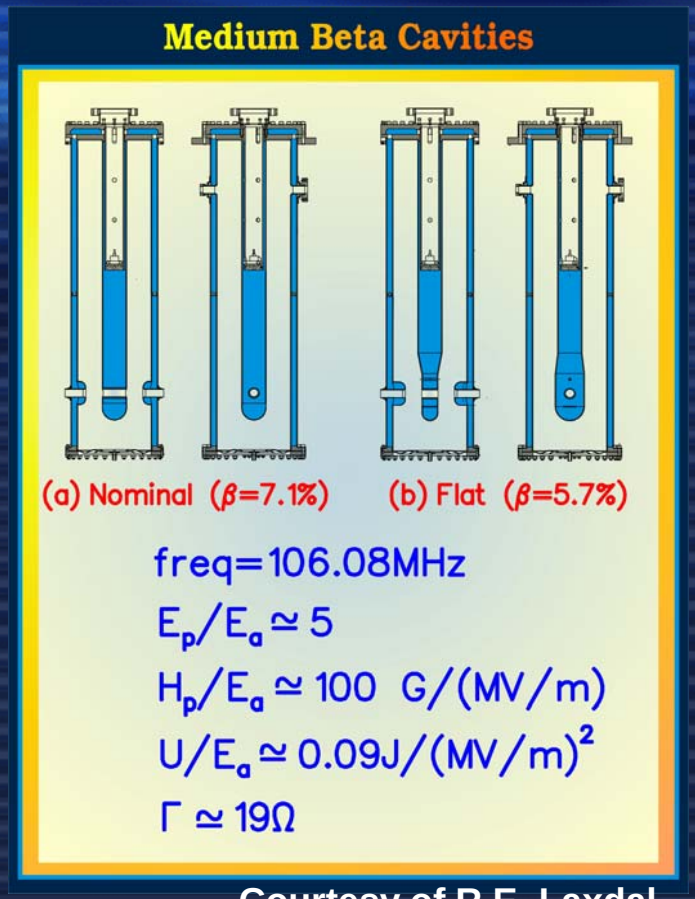
Mean values for ~350 MHz spoke cavities				12.2	41	97	

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
  - <Eacc>~7.2 MV/m (design 6 MV/m)

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



Courtesy of R.E. Laxdal