Status of the Super-FRS

M. Winkler

Annual NuSTAR Meeting
GSI, March 5 – 7, 2014
1) Super-FRS Layout (Full Version)
2) Status of Civil Construction
3) Update on the Energy Buncher
4) Status on Super-FRS Components
5) Summary
Layout off the Super-FRS (Full Version)

Design Parameters:
- $\varepsilon_x = \varepsilon_y = 40 \times \text{mm mrad}$
- $\phi_x = \pm 40 \text{ mrad}$
- $\phi_y = \pm 20 \text{ mrad}$
- $\Delta P/P = \pm 2.5 \%$
- $B_0 = 2 - 20 \text{ Tm}$
- $R_{in} = 750 / 1500$ (first / second stage)

Spot size on target
- $\sigma_x = 1.0 \text{ mm}$
- $\sigma_y = 2.0 \text{ mm}$

Projectile:
- Elements p - U
- Energy up to 1.5 GeV/u
- Intensity up to $10^{13} / \text{s}$ (depending on element)
- DC or pulsed operation

In-Flight Separation:
- Universal (all elements)
- Fast (submilliseconds)
- Efficient (kinematic focusing)
- Mono-isotopic or cocktail beams

Features:
- Two Separator-stages
- Multi-branch system
- Large acceptance utilizing sc magnets
- Handling concept for high-radiation area

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Layout off the Super-FRS (Full Version)

**Design Parameters:**
- \( \sigma_x = \sigma_y = 40 \text{ mm mrad} \)
- \( \phi_y = \pm 40 \text{ mrad} \)
- \( \phi_x = \pm 20 \text{ mrad} \)
- \( \Delta P/P = \pm 2.5\% \)
- \( B_{p1} = 2 \text{ - } 20 \text{ Tm} \)
- \( R_p = 750 / 1500 \text{ (first / second stage)} \)

**Projectile:**
- Elements p - U
- Energy up to 1.5 GeV/u
- Intensity up to \( 10^{15} \text{ /s} \) (depending on element)
- DC or pulsed operation

**In-Flight Separation:**
- Universal (all elements)
- Fast (submicroseconds)
- Efficient (kinematic focusing)
- Mono-isotopic or cocktail beams

**Features:**
- Two Separator-stages
- Multi-branch system
- Large acceptance utilizing sc magnets
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FAIR CC Today

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Super-FRS Buildings (MSV)

**Build. 006a, Service building**
- 3 floors (~2000 m$^2$)
- Technique (PS, controls, ...)
- Experimental preparation
- Control room, electronics
- Gas supply, gas mixing station
- Main tunnel access

**Build. 006**
(High-Energy cave)
On top: Build. 17.2
(FAIR service building)

**Build. 018, Target building**
- 5 floors
- Target area, shielding
- Technique (PS, controls, ...)
- Hot Cell complex

**Tunnel 103**
(Separator tunnel, supply tunnel)

**FLF2**
Experimental Area

- Basic evaluation completed
- Preliminary planning completed
- Approval planning completed
- Execution planning under approval
- Running: route planning (cable, pipes, cryo)
- Formwork planning & Tendering
- Establishing cable data bank → tender of cables
(Detector) Gas Supply

- Standard Beam Diagnostic defined for each focal plane
- Detector gases defined for each focal plane (separator)
- Gas storage & mixing station
  - Security requirements to be clarified
  - LN2 storage available (piping not provided)

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Energy Buncher: S-shape layout
(using standard multiplet magnets)

Flexible operation
- large acceptance spectrometer
- high-resolution / energy buncher mode
- dispersion matching (Main-Separator and EB)

Intermediate focus at focal plane FLF4
- keep overall dispersion in limits
- in particular reduce gap size of magnets (use standard multipole magnets)
- reduce requirements on monoenergetic degrader at FLF5
- reduce technical risks

Enlarged experimental areas
- better matching of detectors / spectrometer performance
Magnets for Energy Buncher

- Magnets are Indian in-kind, revised parameters discussed with VECC
- Maximum beam rigidity: 7 Tm
- 3 dipole units with 30° deflection angle
  - superferric, warm iron, SC coils
  - usable aperture: \((x = \pm 250\text{mm}, y = \pm 70\text{mm})\)
  - expected weight <80 ton,
  - cost reduction, easier to handle and to measure
  - VECC is working on the new design
- Multiplet (quadrupole design same as in the separator)
  - superferric, cold iron
  - usable aperture: \(\Omega 380\text{ mm}\), \(l_{eff}: 800\text{ mm}, \text{max. gradient: } 10\text{T/m}\)
  - configurations: \(1 \times QS, 3 \times QQS, 1 \times QQQ\)
  - y-steerer still in discussion
  - specifications ready
  - saving development time & costs, reducing technical risks
- Magnet testing must be discussed, in principle possible at CERN
Cave for LEB/Energy Buncher

- Architects feasibility study prepared by ION42 (FAIR architects)
- Cost estimate: 8.300k€ (2014)
  - breakdown according German CC cost type (KG xxx) provided
- Low-energy cave:
  o area ≈800 m²
  o height: 7.6m
  o 5 ton crane
- MATS/LASPEC (annex):
  o area ≈430 m²
  o height: 10m (2 floors)
  o 5 ton crane
- Annex space (technique):
  o area 2 x 68 m²
  o height: 3m / 4.5m (2 floors)
- Most important now: clarify funding
- Discussion with funding agencies/RRB has been initiated
- Additional required pillars can not be provided in an early phase (mid 2014)
- Discussion with FLAIR/SPARC concerning possible impact of FLAIR SPARC building
Radiation Resistant Magnets
(at the Target Area of Super-FRS)

- Normal conducting magnets using MIC cable
- Prototype dipole built (95 ton) and tested by BINP
- Handling tests at GSI under way
- New design of first two quadrupoles behind target (field gradients were too high)
- Remote connectors and alignment under revision
- Specification in preparation (Q3/2014)
- Tendering by FAIR, Contracts Q1/2015
SC Dipole Magnets

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Status:

✓ IMoU with CEA/Saclay signed:
  ➢ Engineering design
  ➢ Technical follow-up
  ➢ Participation at CERN testing

✓ Technical Kick-off
  • Visit IMP CW14/2014 (with CEA, GSI, FAIR?)
  • PDR CW20/2014 (includes external advisor)
  • FDR Q2/2014 (without special dipoles)
  • Tender by FAIR Q3/2014 (option on special dipoles)
  • First of Series ready for testing: Q1/2016
  • Series production and testing: Q3/16 – Q4/18

- 3 dipole units 11°
- 21 dipole units 9.75°
  ➢ 3 times modified cryostat
- Iron dominated
- Warm iron
- SC coil
- Aperture ±190mm x ±70mm
- Weight: 50 to 60 ton
- Prototype built and tested (FAIR China Group)

Branching Point

cryostat & yoke modification
small yoke modification
SC Multiplets

• 24 long multiplets (MS)
• 7 short multiplets (PS)
• Quadrupole triplet / QS configuration
• up to 3 sextupoles and 1 steerer
• Octupole coils in short quadrupoles

• iron dominated, cold iron (≈40 tons)
• common helium bath
• warm beam pipe (38 cm inner diameter)
• per magnet 1 pair of current leads
• max. current <300A for all magnets

• Tender Status:
✓ Bidder submitted quotes Q4/2013
✓ 1st round negotiation finished
• 2nd round starting March 2014
• Signing of contract expected Q2/2014
• Testing of First short Multiplet at CERN: Q1/16 – Q2/16
• Testing of first long multiplet at CERN: Q2/16 – Q4/16
• Series testing at CERN: Q1/17 – Q2/19
Super-FRS Local Cryogenics
(Including Preparation for CERN Testing)

• Flow scheme / Cooldown processes
  o FB controls: 3 dipoles / 2 multiplets
  o Total cold mass (PS + MS): ≈1.100 ton
  o Cryogenic operation modes
• Revision of feedboxes
• Updates of cryogenic interfaces
• Emergency cases
  o Normal quench → 70% of energy deposited in quench protection system
  o Worst case scenario → full energy in He
    ➢ dimensioning of safety valves/burst disc
Super-FRS Local Cryogenics Routing
(Driven by CC Planning)
GSI-CERN Agreement K1727/DG & Addendum #2 (signed)

- Scope (separator magnets):
  - 24 Dipoles (PS & MS),
  - 31 Multipletts (+ 2 spare)

- Place: CERN building 180

- 3 universal test benches, basically:
  - 1 setting-up & cool-down
  - 1 measuring
  - 1 warm-up & disassemble

- Ready for testing: Q4/2015
- Time estimate (single multiplet): 44 days
  - Installation, connection, cool-down: 15 days
  - Cold test (powering, magnetic field): 15 days
  - Warm-up, disassembly: 14 days

- Overall series measurement time: ≈ 3-3.5 years
Magnet Testing Area @ CERN

✔ Existing equipment
  - magnet-measurement station, crane
  - Cryo: Ghe Buffer, distribution box
    pre-cooler (10kW) + compressor

✔ New required equipment (mainly cryo-parts):
  - 2nd pre-cooler (10kW) + compressor
  - 3 satellite valve-boxes & cryogenic lines
  - LN2 & LHe tank

Layout, 3 benches & two pre-coolers
brief detector up-date
  o GEM-TPC (Finnish in-kind), running WP
    ✓ prototype ready
    ✓ low-energy, high-rate beam test: JYU
    ✓ high-energy beam test: GSI
    ✓ final specification (Q1/15) → production
  o SEM-GRID & ladder system
    ✓ accepted as Finnish in-kind (Q4/2013)
    ✓ Project engineer hired (Kari Rytkönen)
    ✓ integrated together with GEM-TPC
    ✓ pre-design for SEM-GRID ready (HEBT)
    ✓ ladder integration to be designed
  o various test beam-times in 2014
    ✓ Dubna (radiation hard ToF)
    ✓ GSI (MUSIC)
    ✓ JYV & GSI (GEM-TPC)
    ✓ Catania (Diamond)

Slit-systems & Secondary Target
✓ accepted as German In-kind (Q4/13)
✓ Collaboration MoU with KVI-CART
✓ project group at KVI established
✓ kick-off / regular meetings with KVI
  ✓ specification, pre-designs
  ✓ technical aspects (e.g. weight)
  ✓ cost aspects (material)
Target Area Installation

- Target chamber & plug inserts (German in-kind)
  - dimensional design ready
  - proposed to be contracted to KVI
- Target wheel & plug inserts (German in-kind)
  - prototype target wheel with drive available,
  - revision ongoing (wheel size, moving mechanism, design for remote handling)
- Beam catcher (Indian in-kind)
  - chamber design adjusted
    (additional pumping channels)
  - two-halves catcher concept design added
    Be/Al for slow extraction
    Graphite for fast extraction
  - clarification with India on scope of work
- Shielding flask
  - accepted as Finnish in-kind (Q4/2013)
  - Finnish collaborators: Hollming Works Ltd., ENMAC, Aalto University
  - Preplanning to go into approval process, then order production.
Hot Cell / Mock-up Installation (German in-kind)

• Based on study by nuclear engineering company (includes new tooling required for waste handling)
• Mock-up installed on ESR roof
  o metallic frame & two MS manipulators (load capacity 20kg, slave extension 3270 mm)
  o validation of design concepts
  o training of personnel
  o Collaboration with SPIRAL 2 (EU CRISP)
• Manufacturing of window frames for hot cell
• Next step: full realization by contract with company
Large Size Pillow Seals

- Pillow seals to be used in the Target Area
- standard will be round Pillow Seal with Ø500mm
- special large size rectangular (1200x160 mm²) seals between dipole and beam catcher
- Developed together with MEWASA
- Test setup at GSI
- Requirements fulfilled
- Long time stability tests running (temperature, ...)
- Next steps: full plug design

Leak rate by measuring pressure increase after stopping pumps on 16.5 l volume.
Summary

- Civil Construction progressing
  - execution planning under approval
  - route planning running
- Energy Buncher redesigned
  - new LEB cave proposed
  - S-shape solution using standard multiplets
  - dipole magnets to be redesigned by VECC
- Procurement of long-term items (magnets) started
- Magnet test facility at CERN under preparation
- Development of various items (beam instrumentation, target area) in progress