Summary of Working Group C: Injection, Extraction, Accelerator Systems

D. Johnson and S. Cousineau

ICFA HB2010
Sept 27 - Oct. 1
Morschach, Switzerland
Outline of Summary

1. Essence of the Work Group
   • New ring/lattice concepts
   • Commissioning efforts
   • Designs for new facilities or upgrade plans (and challenges)
   • Operational facilities
     – Problems encountered

2. Foil technology status

3. Future technology for H- injection

4. Working group perspectives
Essence of the Work Group

- **Composition:** 2 oral sessions (9 talks) + Poster session (9 posters)
  - 1st session concentrating on injection
  - 2nd session on new accelerator designs and extraction
  - Work group discussion after 1st session focused on injection issues.

- **New ring/lattice concepts**
  - Non-Scaling FixedFieldAlternatingGradient rings/lattices

- **Commissioning efforts**
  - EMMA

- **Designs for new facilities or upgrade plans**
  - CERN (PSB and PS2)
  - PAMELA
  - PEFP
  - Project X
  - Mu2e (resonant extraction from FNAL Debuncher)

- **Operational facilities**
  - SNS
  - JPARC
New Accelerator/lattice Concepts

• NS-FFAG
  – Benefit with large momentum aperture
    • With one or a few passes
      – Gantries
      – RIA’s for muons and electrons
      – p+- or proton rings for longitudinal manipulations
  • For non-relativistic particles ->a few hundred turns
    – Particle therapy machines
    – Proton Drivers
    – Heavy ion drivers

• New “solid state direct drive” linear induction accelerator
Commissioning efforts

- **Electron Model for Many Applications (EMMA)**
  - Although not High Energy or High Intensity - first demonstration of a Non-Scaling FFAG (10-20 MeV)
  - **Goals**: EMMA Experiment (verify this new concept works)
    - Rapid acceleration with large tune variation
    - Serpentine acceleration
    - Map the transverse and longitudinal acceptances
  - **Completed injection commissioning (1000’s turns)**
    - Limited diagnostics (BPM’s)
    - Injection kicker ringing
  - **Demonstration of acceleration (current focus)**
  - **Detailed bench marking with codes**
Challenges for machines under design

- **Project X:**
  - Foil issues associated with long duration (~25 ms) injection of CW beam for proton driver or multiple short pulse injections. Constrains beam current to ~1mA which increases circulating beam hits on foil.

- **CERN:**
  - Both Linac2 upgrade from 50 MeV protons to 160 MeV H- requires PSB injection upgrade to H- multiturn injection. Will try to use existing injection hardware.
  - PSB extraction upgrade from 1.4 GeV to 2 GeV and the modification of PS for 2 GeV injection (including upgrade of injection line hardware)
  - Challenge is to make the new system work with the old hardware.

- **PAMELA:**
  - 30 to 70-250 MeV NS-FFAG (orbit moves with energy)
  - Design a fast and slow vertical extraction system which matches into extraction channel without

- **Mu2e:**
  - Design a resonant extraction system with good spill quality and low losses in the presence of large space charge and momentum spread.

- **PEFP:**
  - Currently operating 20 MeV linac, cavities to extend to 100 MeV finished this year. Plans for upgrade to 1 GeV RCS
Operational facilities

• Injection Experience in Recent High Power Machines
  – Despite detailed design work, both machines have suffered problems in injection areas.
  – Injection radiation levels are the hottest areas in both machines. This was anticipated.
  – Not anticipated was the amount of manpower + monetary resources that would be dedicated to addressing injection region issues after start of operations.
JPARC + SNS Injection/Extraction Recent Issues

**JPARC:**
- High loss due to circulating beam foil hits. Full aperture model not available during design stages, so loss locations not accurately predicted.
- IDmp aperture restriction causing beam loss.
- Extraction septum stray field issue

**SNS**
- IDmp aperture restriction also a problem for SNS.
- Foil damage and failure due to vacuum breakdown.
- Foil assembly damage due to reflected convoy (H-stripped) electrons.
Foil Technology Status

- Some foils currently in use are those which were under discussion as “promising new foil candidates” at HB2002, HB2004.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Beam Power</th>
<th>Foil</th>
<th>Lifetime / Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>JPARC</td>
<td>120 kW</td>
<td>HBC</td>
<td>1 Yr</td>
</tr>
<tr>
<td>SNS</td>
<td>1 MW</td>
<td>Diamond foil</td>
<td>18 weeks</td>
</tr>
<tr>
<td>LANL</td>
<td>80 kW</td>
<td>HBC</td>
<td>2 per year</td>
</tr>
<tr>
<td>ISIS</td>
<td>200 kW</td>
<td>Aluminum Oxide</td>
<td>1 per year</td>
</tr>
</tbody>
</table>
Future Technology for H- Injection

• Unique foil injection concepts
  – “Rotating foils”

• Laser technology
  – Lasers have come a long way in the last decade, but still fall short of laser-assisted stripping injection needs for high power beams.
  – Injection stripping requires: high peak power (MW), large pulse energy (mJ-mJ), high average power (kW), high pulse frequency (100’s Mhz)
  – Burst mode laser system
  – Recycling helps but has it’s own challenges.
  – Coherent beam combining
  – Cryogenic laser amplifiers
Gap between application requirements and available specs

Pulse Energy (J)

Repetition Rate (Hz)

- 1 mW
- 1 W
- 1 KW
- 1 MW
- 1 GW

- LLNL PW
- Vulcan
- HERCULES
- Gekko
- LOA
- X-ray (U. Tokyo)
- FLASH Photoinjector
- LCLS Photoinjector
- γ-ray source (AIST)
- Project X Stripping
- SNS Laser Stripping
- Beam diagnostics
- Current LPA/LIA Experiments

10/1/2010
Average power dropped more than 1000 times!

Pulse Energy (J) vs. Repetition Rate (Hz)

- 1 mW
- 1 W
- 1 KW
- 1 MW
- 1 GW

X-ray (U. Tokyo)
FLASH Photoinjector
LCLS Photoinjector
Project X Stripping
γ-ray source (AIST)
SNS Laser Stripping
Question: What do we need to get to 5 MW and beyond?

Response:
1) “A model versus measurement benchmark of foil temperature.”

We need to validate the foil models before we can rely on them to give us limits. This is a complicated diagnostics measurement because of the high radiation in the environment of the injection foil.
Working Group Conclusions

Working Group Comment:

Dump lines are not getting enough attention during the design stages.

For high power beams, the waste beams contain a significant amount of beam power and beam loss can be an issue.

Dump lines need more aperture, more knobs, e.g., more flexibility overall.
In the End

• There were many enlightening presentations
• There were many fruitful discussions
• There was much food and coffee
• A wonderful banquet
• Superb presentation and support personnel
• Friendly smiles everywhere
• And a big round of applause for PSI.