Summary talk for working group G of HB2010

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Working group G (new invented for HB2010)
Beam-Material Interaction

17 talks (2 in joint session with WG A, 5 posters)

Topics:

- **Activation, nuclide inventory, (residual) dose rates:**
  FLUKA, MARS15

- **Radiation damage:**
  - Experiments: Change of mechanical and physical properties,
  - Calculation of DPA, H and He production

- **Thermo-mechanical simulations as a design tool**
  - Targets, collimators and beamdumps

- **New facilities and plans for substantial upgrades:**
  - FRIB CSNS ESS Project X ISIS Myrrha J-PARC SNS

- **Irradiation facilities:**
  - HiRadMat BLIP
Particle transport Monte Carlo codes:
- FLUKA (Stefan Roesler)
- MARS15 (Nikolai Mokhov)

• Significant improvements in nuclear reaction models
  → crucial for accurate modeling of nuclides, DPA and H/He gas
• Extended capabilities & features added
  (demand by user requests and due to applications)
• Comparison to experimental data (Benchmarking)
  - nuclide inventory: looks very promising
  - dose rate predictions < 10 % deviation (FLUKA)
• Simulations play an important role in job-dose predictions
  - for work planning on activated components
  - results entered directly into the design for LHC beam dumps
• Discrepancies in DPA calculations using different codes
  $DPA(\text{MARS}) = 2.5 \ DPA(\text{MCNPX})$ (1GeV p on 3 mm Fe)

requires further effort
Activation of components/dose rates influence/consideration on the choice of material
- Cu (instead of graphite) for the 100 MeV p dump (KAERI) was chosen:
  MCNPX (J.H. Jang): Activation analysis/Nuclide inventory
- hands-on maintenance criteria in heavy-ion accelerators:
  E. Mustafin, I. Strasik, GSI
study of different primary beams:
$^1\text{H}, ^4\text{He}, ^{12}\text{C}, ^{20}\text{Ne}, ^{40}\text{Ar}, ^{84}\text{Kr}, ^{132}\text{Xe}, ^{197}\text{Au}, ^{238}\text{U}$
beam-pipe material: stainless steel
bulky target (cylinder): Cu, stainless steel, C, Al, Ta
Radiation damage:
- Change of mechanical and physical properties gets more and more important for high-power and high stored energy beams on targets, collimators, beam dumps

- Irradiation tests for various materials (at BNL, N. Simos) including new generation of materials and composites → serves as input for Thermo-mechanical Simulations

  problem: not many data available for high-energy particles
  but: lots of data for thermal neutrons

How to transfer mechanical/physical property changes measured on thermal neutrons (a lot!) to high-energy particle beams
  → damage correlation: (M. Li, N. Mokhov)

very complex problem

irradiation test experiments are needed!
Long-term perspectives: predict change of material properties:
• reliable prediction of DPA, He/H gas production rates

• relate this to changes of material properties for different energies, particles, temperatures, irradiation times

• Define parameters for irradiation experiments to benchmark predictions and get phenomenological knowledge

More accurate life time predictions are needed!
• e.g., at FRIB expected lifetime of targets is 2 weeks and dumps 1 year
• we are obliged to use very conservative limits due to lack of knowledge
• also important for machine protection
Thermo-mechanical Simulations: ANSYS-CFX, CFD-ACE
Detailed design studies for targets, beam dumps, collimators

- **Optimization of cooling**: heavy power load, often coupled with Tensile stress analysis
  - T2K target should stand up to 750 kW (C. Densham)
  - 20 MeV p beam dump, 96 kW, KAERI (J.-H. Jang)
  - 100 MeV p beam dump: 333W/cm²
  - 200 kW on Cu collimator at 3mA, 590 MeV p (Y. Lee, PSI)
  - FRIB target: 20 - 60 MW/cm³ (R. Ronningen, FRIB)

- Mechanical/physical properties for radiation damage material

- **Life time predictions** would be important but very hard to predict
  How to set Failure Criteria (radiation damage and fatigue)?
Coupled multi-physics simulation:

Beryllium R&D:
Integrated Target Conceptual Design
Criteria for the design of collimation systems:
- machine and detector protection
- keep beam loss in ring < 1W/m

Steps:
1) Beam dynamics calculations:
   N. Wang (CSNS), J. Barranco (PS2, CERN)
   for 2-stage collimation system
2) Thermo-mechanical simulations:

   e.g. at PSI combination of both:
   Y. Lee, D. Reggiani et. al.

   in addition:
   beam misalignment studies
   \(\rightarrow\) sets condition for beam interlock
Upgrade of RIKEN RI Beam Factory (RIBF):
  –Goal intensity of $U^{35+} > 15 \mu$A (1$\mu$A @ SRC)
Hiroki Okuno, RIKEN

Design of a long-life stripper foil with charge state of U
Low-Z Gas stripper (H, He): long lifetime, uniform distribution but low density: needs 7m at 10 torr

Idea: plasma window to keep gas pressure (“windowless”)
• New facilities coming up:
  1) HiRadMat at CERN (R. Lositio): end of 2011 in operation
     450 GeV protons, $10^{16}$ protons/year available
     demand driven by LHC
  Fields of investigations:
  - Failure from pulsed beam impact
  - Shock waves
  - Changes of material properties/fatigue

  - Validation of tunneling effect:
    density variation penetration depth of LHC beam
    35 m instead of 1.4 m in Cu
    (J.Blanco, CERN, N.A. Tahir, GSI)
2) FRIB Rare Isotope Beams (R. Ronnigen):

400 kW at 200 MeV/u for uranium

• High power demands on target and beam dump

• Prediction of damage is necessary

• Experiments to measure heavy ion damage can be difficult

• Data on damage of materials, such as targets, at existing facilities could prove useful if irradiation parameters are documented
3) FAIR at GSI: T. Seidl
   Investigation of (possible)
   radiation damage on FAIR-Magnet (SIS 100 Dipole
   Insulation materials like polymers, fiber reinforced, plastics)

   Irradiation-Experiments:
   1) UNILAC: C-U ions 11MeV/u
   2) SIS 18: Xe ions ~ 280 MeV/u
   3) LINAC: protons, 21 MeV
   4) Synchroton: protons 0.8 GeV
   5) Fast neutrons ~ 800 MeV/u
   6) Gammas from Co\textsuperscript{60} –source

   Tests:
   • Breakdown Voltage
   • Thermal Properties: Thermal conductivity, specific heat
4) THE NEUTRINO BEAM AT FERMILAB (P. Hurh)
start with 700 kW beam, upgradable to > 2 MW
- **Graphite R&D:**
  Irradiation Testing at BLIP, 181 MeV protons
- **Beryllium R&D:**
  thermal and stress simulations for Conceptual Design Studies

Target degradation effect on $\nu$–spectrum
(S.I. Striganov, Fermilab)

Possible Origin of target degradation:
not clear yet, need help from material experts
- **Atom displacements by hadronic cascade:**
  Significant dependence on carbon/graphite type
- **Helium produced in target $\rightarrow$ density reduction**
  Distribution of produced helium atoms
  is very similar to DPA distribution.
Discussion session:

- One of next steps: irradiation experiments
  - 1 GeV would be ok, or less
    → Material experts required
- Measurements can only calibrate models
- List of specs for irradiation facilities, CERN, Fermilab, GSI, PSI, BNL, Los Alamos, … reactor data not sufficient
- List of users
- Infrastructure: BLIP + Hot Cell (very powerful equipment)
- Transport to be addressed, facility limits, … can be done
- Calculation of DPA different between programs
• How to scale from accelerators to thermal neutrons?
• Handbooks with Material data from Los Alamos and ITER
• Can we build our own database? From our experience?

• Next May; **High-Power Targetry workshop in Lund/ESS**, can be extended to discuss these issues?
  – what parameters?
  – what facilities?
  – extend workshop by 1-2 days
    for session on radiation damage issues