Paul Scherrer Institut

Daniela Kiselev (PSI)
Nikolai Mokhov (Fermilab)
Rüdiger Schmidt (CERN)

Summary talk for working group G of HB2010

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 prominsing
  - 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(MARS) = 2.5 DPA(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}H, ^{4}He, ^{12}C, ^{20}Ne, ^{40}Ar, ^{84}Kr, ^{132}Xe, ^{197}Au, ^{238}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/cm^2
- 200 kW on Cu collimator at 3mA, 590 MeV p (Y. Lee, PSI)
- FRIB target: 20 - 60 MW/cm^3 (R. Ronningen, FRIB)

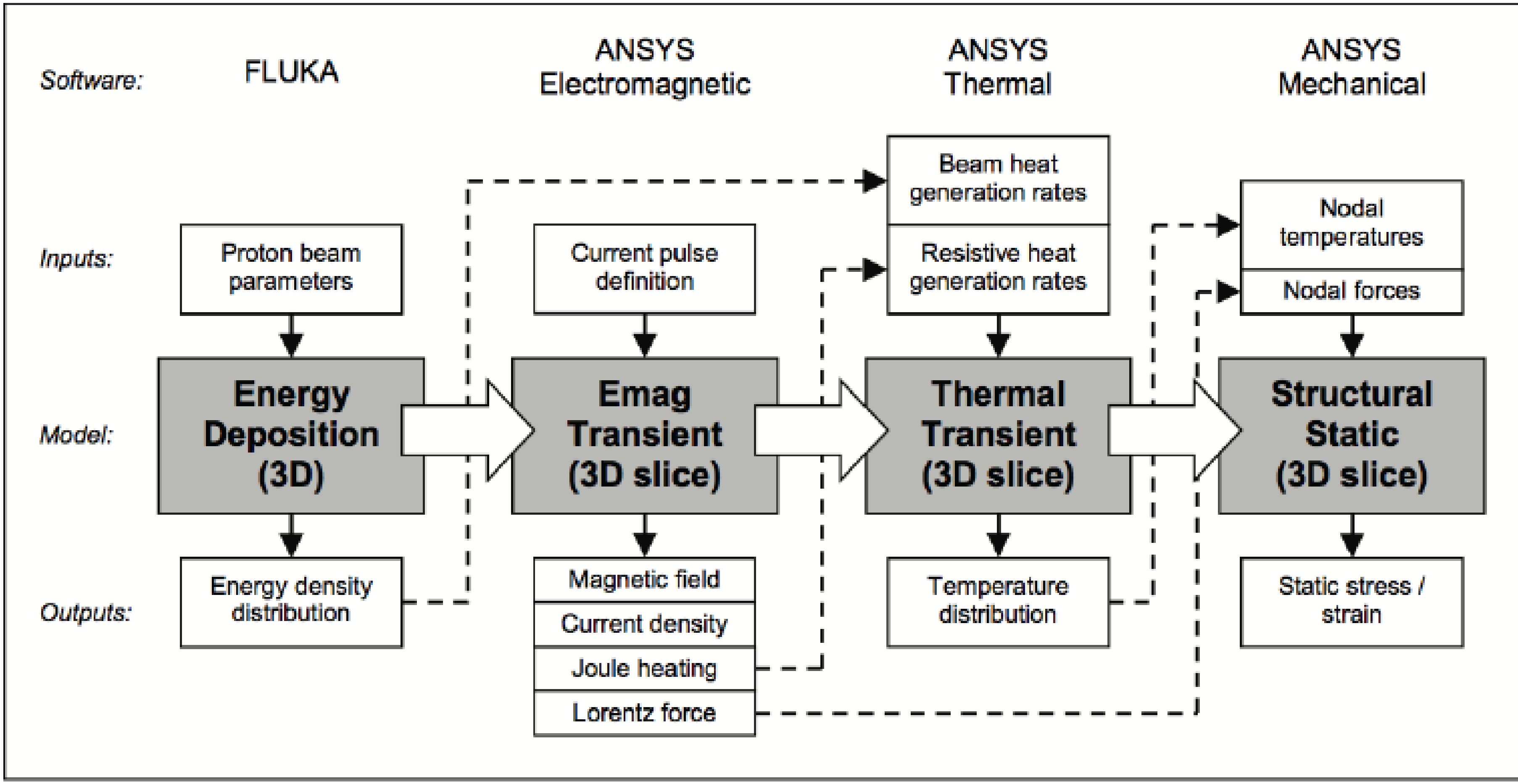
- Mechanical/physical properties for radiation damage material

- Life time predictions would be important
  but very hard to predict
  How to set Failure Criteria (radiation damage and fatigue)?

Coupled multi-physics simulation:

P.Hurh

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
→ sets condition for beam interlock

Upgrade of RIKEN RI Beam Factory (RIBF):

–Goal intensity of U^{35+} >15 pμ A (1pμA @ 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^{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 ν–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 → 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