FFAG 2004 SUMMARY

- General FFAG aspects
- High-intensity proton drivers
- Muon accelerators
- Muon cooling
- Electron model
- Technical considerations
- Public relations, politics, funding
- Next workshop

General FFAG Aspects

- We shall not investigate full continuum of machines.
- Rather: 2 extremes and 1 particular intermediate:
  - scaling (fixed tune, non-linear fields)
    - fixed tune, non-scaling (non-linear fields)
  - variable tune, non-scaling (linear fields)
- Find names which will be better understood outside our group.

e.g. scaling FFAG, flat-tune adjusted-field FFAG, variable-tune linear-field FFAG

- Analytic investigation of the linear non-scaling m/c is complete and should be published.
- Analytic work on the non-linear non-scaling machine needs to grow and continue (see Sandro's *to do* list).
- Analytic work on resonance crossing should continue.

General FFAG Aspects continued

- Move argument away from scaling versus non-scaling, and toward application driven and operations driven choices.
- Need further investigation of the intermediate m/c (fixed-tune nonscaling): it is an *important* idea, but does it have the advantages or disadvantages of the two extremes?
- Dynamic Aperture Studies
  - KEK performed many DA studies for the scaling machines. Conclusion: large DA is a matter of finding a good working point away from resonance lines.
  - Need DA studies of the fixed-tune non-scaling m/c. Who?
  - Need tracking studies of resonance crossing in variable-tune nonscaling m/c with element errors and multipoles. Who?
- m/c = machine

High-Intensity Proton Drivers

- Time-line of ORNL SNS ruled out FFAG in favour of SC linac.
- Replacement of BNL AGS Booster gives another opportunity if we act quickly.
- Spallation source or waste burning device could be important application of FFAGs, as might be cancer therapy m/c.
- Who will work on 0.1-1 MW FFAG?
  - KEK has scaling m/c design for 1 GeV, 1 mA, 1 kHz
  - BNL has interest in Booster & RA
  - FNAL has interest in Booster & openings for students
  - IHEP has motive (spallation source) and opportunity window of 2-3 years.

High-Intensity Proton Drivers continued

- Identify relative merits and disadvantages of linac versus FFAG, (e.g space charge limits). But time-line is short. Who?
- Identify potential show-stoppers that arise when you move from 10 Hz to 1 kHz operation (e.g. powerful rf) Who?

Other Applications ?

- Cancer therapy machine in hospital environment
  - More beam due to higher repetition rate, more compact size – d.c. magnets can be SC, less maintenance (*c.f.* NMR), less expensive
  - Firm up this argument *c.f.* Loma Linda synchrotron, etc.
- Spec: 5 grey/minute at 250 MeV
- Move m/c intensity from “experimental” to “treatment” level
- Encounter space-charge limits
- KEK to set up “FFAG Project Office” as resource to consortium of industry and academia.

Muon Accelerators

- Nonscaling lattice design is mature
- Cost model dominates selection of lattice
- Cost model needs more detailed input from technical

and magnet experts (volunteer Palmer & Johnstone, see later under electron model)

- *Lattice selection criteria to be documented*
- Refine & *distribute* s/c cost model *before* next w/s
  - See Berg's slides for partial documentation of cost model
  - Work needed on costing of civcil engineering e.g. tunnel
- Goal: adopt 1 standard lattice (e.g. Scott) at next w/s
- All future work (2^{nd} order effects, detailed tracking, etc) to be performed on standard lattice.

Muon Cooling

- Garren *et al*: making paper study for their own independent designs.
- Kuno *et al*: making detailed technical proposal for a funded project (PRISM) to demonstrate (ranked by priority)
  - Storage
  - Phase rotation
  - Cooling
- Advantageous to everyone if all designers focus some efforts on PRISM – determine/enhance suitability for cooling, etc.

Electron Model

- Objective to demonstrate two novel aspects of accelerator physics: fast, asynchronous acceleration and fast resonance crossing.
  - Is resonance crossing harmless or not?
  - It is a crossing regime which cannot be accessed in any existing machine.
- We are not yet in a position to select and engineer an electron model lattice. Need:
  - Resonance crossing study (work started, e.g. Keil)
  - Error tolerance study
  - Criteria for lattice selection including a cost formula (complex: permanent vs electric magnets)
  - To answer "does model have features not found in muon m/c?" e.g. small ring effects (fringe fields, etc)

Electron Model continued

- Include controlled nonlinearity (but *one* element only).

  Do not force model to face "manufactured" problems.
- PoP proton machine was critical for re-acceptance of scaling FFAG.
- Electron model will be instrumental for nonscaling case

  R&D must be pushed to technical design addressing:
  - Injection (<10 ns rise time), Tunability
  - Alignment issues, Diagnostics
  - Permanent magnets vs. electric magnets
  - Engineering design, Cost estimates
- Different players are needed. How do we get them involved?
- Model needs a *home* with services e.g. BNL ATF
- *Bottom line* – model cannot fail; m/c must be tunable; cost implications for magnet design & power supply.

Technical Considerations

- Injection and extraction – just begun; pursue further!
- Magnet design – full with edge effects, etc.
- Improve level of costing, particularly magnets
- Cross reference BNL estimates with those from FNAL
- Need formulae for 3 ranges 7T, 4-2 T with same aperture, 1.5 T; RT vs SC magnets (volunteer Palmer & Johnstone).
- Refine & *distribute* cost model *before* next w/s.
- Can cost formulae be used for comparison with KEK scaling m/c (whose costs are known)?
- Move efforts into this area (rather than more lattice work).
- Different players are needed.

Public Relations, Politics, Funding

- Clearly PR work is in order – staged approach
  - Popularising articles in *CERN Courier* (Craddock et al) and in *Physics Today* (Sessler et al)
  - Longer term: prepare "white paper" before approaching funding agencies (DoE & NSF)
- Theme of both is *diversity:* emphasize wide range of applications: proton driver (for spallation neutron source, waste treatment, accelerator-driven reactor, medical) as well as muon and electron. Not competing with NLC.
- In this respect (*diversity*) KEK approach is much more advanced.
- FFAG Community Website? – raise profile and echo diversity theme; needs commitments for host and content!

Public Relations, Politics, Funding continued

- Continue to write technical papers
- PAC 2005 – *lobby program cttee* – consistent message!
  - Plenary talk across all FFAG applications (unbiased overview)
  - Plenary talk on a funded FFAG, e.g. PRISM - Prof. Kuno
- Various proton applications (spallation, transmutation, medical, replacement Booster machines, etc) – see earlier slides.
  - These need a dedicated one-off workshop to “kick start”
  - BNL, FNAL consider a spring 2005 meeting on “Booster” machines

Next Workshop

- Dates: 13-16 October (Wed-Sat) before Cyclotron Conf
- Format will follow previous KEK workshop
- Meeting will split into two distinct parallel sessions: (i) proton driver/industrial applications; and (ii) muons

– as very different machines.

- Interaction between groups will occur at the daily (am) summary sessions.
- Will not attempt to attract wider audience (e.g. JAERI) as only 4 days (must avoid too many talks)

– but attract some delegates from Cyclotron Conf. in Tokyo

Next Workshop Goals

- Establish 1 standard design for each of four applications
  - Proton Driver – one each of several application specific variants, distinguished by intensity and repetition rate.
  - Cancer Therapy
  - 10 MeV, 10 mA electrons for industrial applications
  - Muon accelerator
  - Electron Model
- Must set requirements/specifications before workshop
- Mori will post these on KEK website in advance of workshop
- Refine & distribute cost formulae before w/s