ICFA Seminar
Matrix Summary
October 6, 2011

Hugh Montgomery

Jefferson Lab

The Frontier Convention

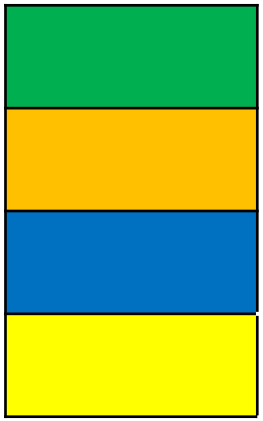
- Energy Frontier
- Intensity Frontier
- Cosmic Frontier

Note that when funding agencies put us in boxes, we object. Even when we choose the boxes ourselves the boundaries are not perfect.

General Remarks

- The idea is to display opportunities
- The level is necessarily high
  - When granularity is less, topics may seem to have disappeared in this process
- For each Matrix, there will be a few remarks intended to explain these concatenations and nuances

Color Code



Running facilities

In Construction

Proposed/planned facilities

Exp. Input Needed (not used)

Energy Frontier

- Note we didn't get to the LHC energies without predecessors
- For example LEP/SLC, HERA, not included
- Tevatron still warm so appears in the matrix
- The convenors were brave enough to suggest that some facilities need a clarification of the physics case.
- I did not include a separate phase for LHC Upgrade for Heavy Ions. This was discussed by Jurgen Schucraft in the earlier presentation.

Energy Frontier Facility Matrix

Time / preparation needed →

Topic/Facility	RHIC	Tevatron	LHC	LHC High Lum.	Linear Collider <500 GeV	LHeC	Linear Collider > 500 GeV	LHC High Energy	μ-Collider
QCD/EW Meas.									
Higgs									
SUSY									
Other BSM									
QGP Prop High T									
Color Glass C, Sat, IS									

Intensity Frontier

- The most difficult to pull together at the levels attempted here.
- I have assumed that (all) FAIR Facilities are Orange; this is different than the assumption by the Heavy Ion Group.
- I do not have the multi-color-in-single-cell technology.
- For Low Energy Tests I did not combine

Intensity Frontier Notes

- For QCD
  - Nucleon Structure
  - Spin and Semi Inclusive Deep Inelastic Scattering
  - High Energy Phenomena
  - (Light) Hadron Spectroscopy

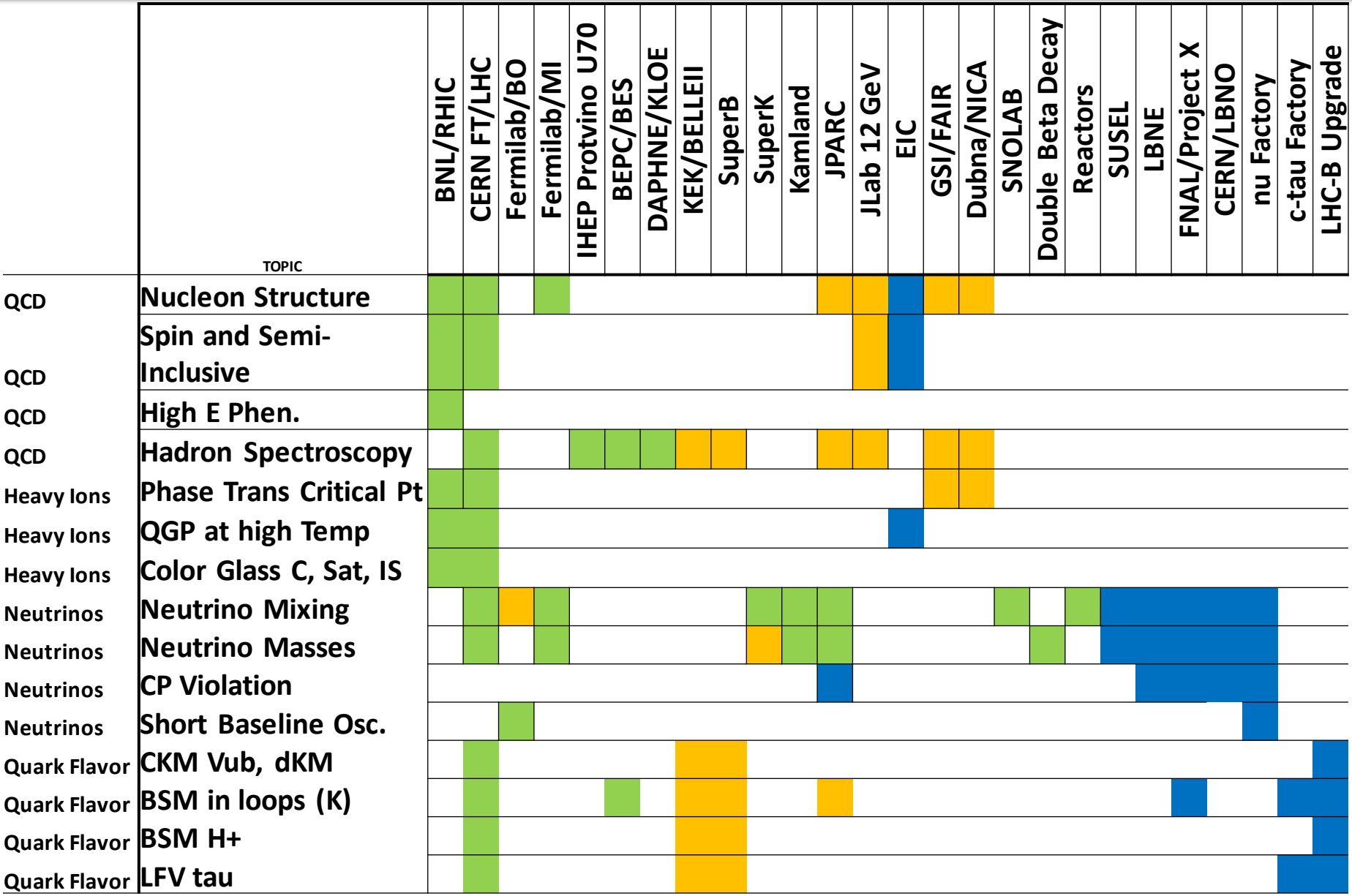
- For Heavy Ion
  - phase transition at large density $\rho_{B,}$ QCD critical point
  - QGP properties at high temperature
  - CGC/saturation/initial state

Intensity Frontier Notes

- **Neutrinos**
  - **Neutrino mixing**
    - Theta_13 by electron neutrino appearance (accelerators and reactors)
    - Theta_23 by muon neutrino disappearance
    - Theta_12 by electron neutrino disappearance in solar and reactor neutrinos
  - **Neutrino masses**
    - Neutrinoless double beta decay
    - Neutrino propagation in matter
  - **CP Violation**
    - Prospects for MNS-matrix phase
  - **Short baseline oscillations**
    - Fourth generation/sterile neutrinos

- **Quark Flavor**
  - CKM parameter extraction from trees ($|V_{ub}|$ and δ_{KM})
  - Search for deviations from SM in loops and their flavour dependence
  - Search for deviation from SM due to charged Higgs
  - LF number violating τ decay

Intensity Frontier Matrix



Precision Sub-Frontier

PVES: parity violating electron scattering experiments

EDM: electric dipole moment searches of neutrons, muons, nuclei, atoms, molecules

MFVD: muon flavor violating decay: $\mu \rightarrow e\gamma$, $\mu \rightarrow eee$, $\mu \rightarrow e$ conversion

DPA: dark photon/axion searches

nnpd: nuclear, neutron and pion decay studies; lepton universality, exotic interactions

exat: exotic atoms (μ/pbar)

	p-beam-facilities BNL, CERN, COSY, FNAL, J-PARC, LANL, PSI, RCNP, SNS, TRIUMF, ...			e-beam-facilities BINP, DESY, J-LAB, MAMI, Super(KEK)B		University labs & reactors
T-Violation	EDM PSI	EDM PSI	EDM BNL, COSY, FNAL, J-PARC, PSI, RCNP, SNS, TRIUMF			EDM, nnpd
Charged lepton flavor violation	MFVD PSI	MFVD FNAL, J-PARC	MFVD FNAL, J-PARC, PSI, RCNP			
New flavor conserving interactions		g-2 FNAL, J-PARC	g-2 FNAL, J-PARC	Qweak J-LAB	PVES, g-2 J-LAB, MAMI, Super(KEK)B, BINP	g-2
New charged current interactions	nnpd J-PARC, LANL, PSI	nnpd	nnpd PSI, SNS, TRIUMF			nnpd
Bound state QED, CPT	exat CERN, PSI	exat CERN, PSI	exat CERN, J-PARC, PSI			atoms and ions
Other exotic interactions	DPA CERN			DPA DESY, J-LAB, MAMI	DPA DESY, J-LAB, MAMI	DPA

color code:
Green: running
Orange: under construction
Blue: proposed

PVES: parity violating electron scattering experiments
EDM: electric dipole moment searches of neutrons, muons, nuclei, atoms, molecules
MFVD: muon flavor violating decay: $\mu \rightarrow e\gamma$, $\mu \rightarrow eee$, $\mu \rightarrow e$ conversion
DPA: dark photon/axion searches
nnpd: nuclear, neutron and pion decay studies; lepton universality, exotic interactions
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Special Request

Please include:

PROTON DECAY

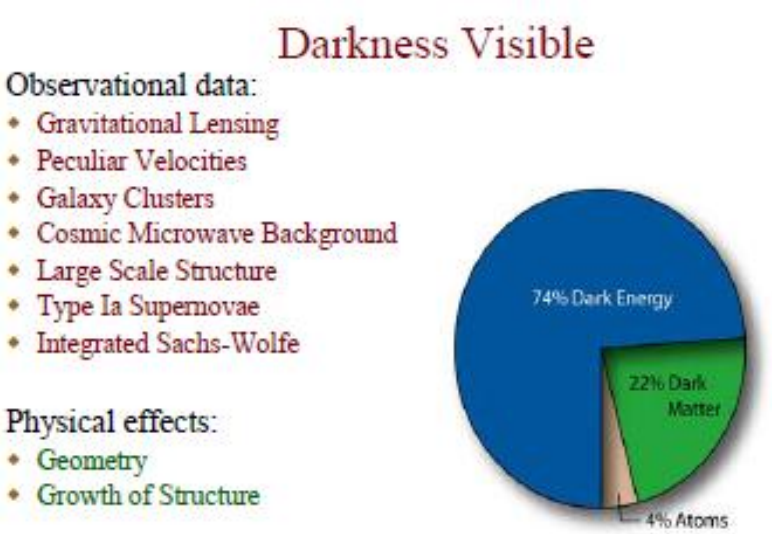
(Sachio Komamiya)

I think it likely fits with the big neutrino detectors, but it is interesting how their technology decisions interact with this issue.

Cosmic Frontier

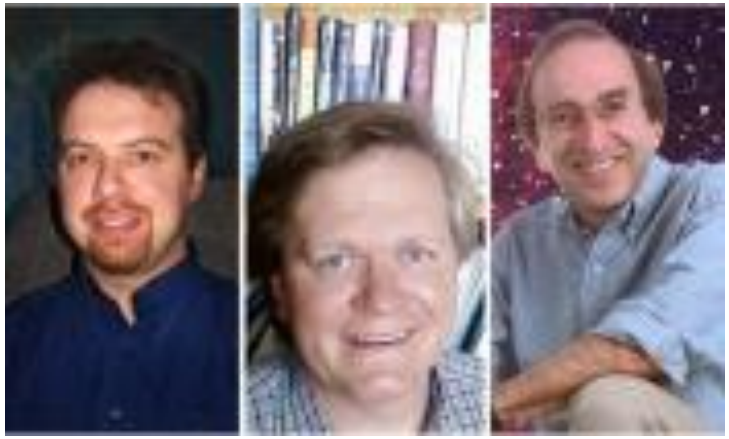
- This is a field which extends beyond particle physics
  - By definition, this seminar is not exhaustive
- Nevertheless the ratio of numbers of projects to topics is the highest of the week.
- In Dark Energy, as Ofer Lahav argued, the legacy surveys have lasting value often beyond their original motivation.

Cosmic Frontier: Facility Matrix



	Underground laboratories	Ground based observatories	Space based observatories	Accelerators
What is dark matter?				
What is dark energy?				

Nobel Prize for Acceleration of Expansion



- Now the hard work begins

- Thanks to the organisers
- Thanks to the support staff
- Thanks to the Convenors and Speakers
- Thanks to the participants

Conclusion

- One might have imagined that with the advent of the LHC, that would be the only game in town.
- This week we have seen how far such a view is from the truth.
- The LHC can and will do much.
- But there is a plethora of physics problems at all scales, a fount of ingenuity in the field and numerous facilities either in operation, in construction and in dreams.