



# The S.P.E.C.T.R.E of a Workshop Proceedings\*



Nuclear Physics Old and New

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# What use is a Proceedings?

- Pedagogical introduction to a field
  - Less formal than the primary literature
  - More detailed than posted slides



# A useful format?

- What are the big questions of QCD Nuclear Physics?
- What Experiments can shed light on these questions?
- `High-Level' description
  - No quantitative claim that any experiment can `measure' and `answer'
  - No discussion Factorization theorems
  - No Detector Monte Carlo studies

# Questions in QCD Nuclear Physics

- What is the QCD Origin of  $NN$ ,  $NNN$ , forces
- How are nucleons modified in a nucleus?
- How does color convert to hadrons in fragmentation
  - Role of vacuum, cold nuclear matter, hot nuclear matter
  - Interaction of a jet with cold or hot vacuum, and cold or hot nuclear matter
- What is the detailed manifestation of Shadowing and the transition to Saturation
- Can Quark-Gluon dynamics explain the Semi-Empirical Mass Formula?
- What is the QCD phase diagram at low- $T$  and high baryon density
- . . .



# Experiments to Probe these Questions

## I. DIS

- Refinements of the EMC Effect
  - Flavor and Isospin Dependence
  - Gluons
  - Sea-Quarks (Nuclear Drell-Yan?)
  - Tagged DIS
    - Neutron from low  $p_R$  on D,  $^3\text{He}$
    - Short distance from high  $p_T$  on D,  $^3\text{He}$ , Nuclei
- Shadowing
  - Improved diffractive data as input
    - $p(e,e'p)X$ ,  $p(e,e'n)X$
    - $D(e,e'pn)X$   $D(e,e'pp)X$
  - Extended  $Q^2$  range
  - Flavor, glue dependence

# Experiments

## II. Fragmentation

- Correlate  $p_T$  broadening,  $x_F$  softening with
  - Nuclear size (target  $AZ$ )
  - Target excitation
    - Forward spectra, multiplicities,  $p_T$ , of  $p$ ,  $n$ , light fragments, evaporation residues, meson/baryon ratio
  - Centrality Tagging
    - Jet propagation distance tagging event-by-event on a single nuclear species.



# Experiments

## III. Exotics

- Search for  $J/\Psi^{AZ}$  Bound States
  - LHCb:  $J/\Psi p$  resonances
- Hypernuclei
- Charmed Nuclei?
- Beautiful Nuclei?

# IV: Correlations and the Nuclear Force

- Correlations: Inclusive
  - $x > 1$
  - $x > 2$
- Correlations: Semi-Inclusive
  - 1, 2, and 3 nucleon knockout



# V. Imaging: GPDs and TMDs

## 1) Light Nuclei

- Reactions on the Deuteron and  $^3\text{He}$ 
  - Tagged quasi-free neutrons and protons in  $d$ ,  $^3\text{He}$
  - Coherent DVMP/DVCS on tensor polarized deuteron
    - spatial probe of the tensor force
- DIS/DVCS/DVMP/SIDIS  $e d \rightarrow e' x pn$ 
  - Low mass  $pn$  system: ordinary NN interaction
  - High mass  $pn$  system: short-distance component of NN interaction
  - Apply also to NN or NNN knockout from nuclei?

# V. Imaging: GPDs and TMDs

## 2) Medium to Heavy Nuclei

- Old nuclear physics question
  - What are the neutron and proton distributions in nuclei?
    - PREX, CREX
- Modern nuclear physics question:
  - How do the up-quark, down-quark, gluon, anti-quark spatial- or momentum-distributions differ in both  $N=Z$  and  $N>Z$  nuclei?
  - How do the matter and charge distributions differ?
  - Can these systematics be linked to the various terms of the Weizsäcker Semi-Empirical Mass Formula?
  - Will this help us understand the structure of Neutron stars?



# VI. Weak Interactions

- Charged-Current reactions on nuclei?