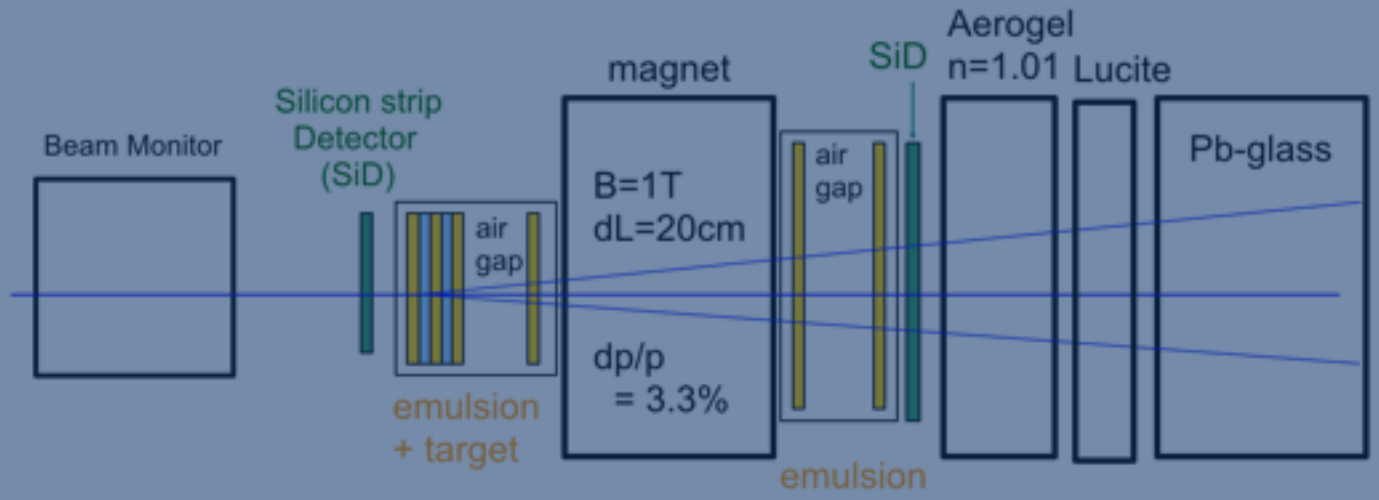


Workshop on Hadron Production Measurements using Nuclear Emulsions

Opening address

Akira Konaka (TRIUMF/RCNP)

4 Supporting programme

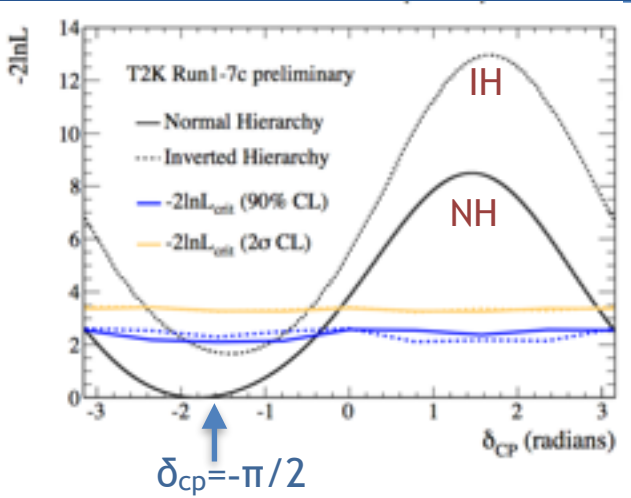
4.1: An appropriate programme of hadro-production and neutrino cross-section measurement is required to allow the present and next generation of long- and short-baseline experiments to achieve their full potential.

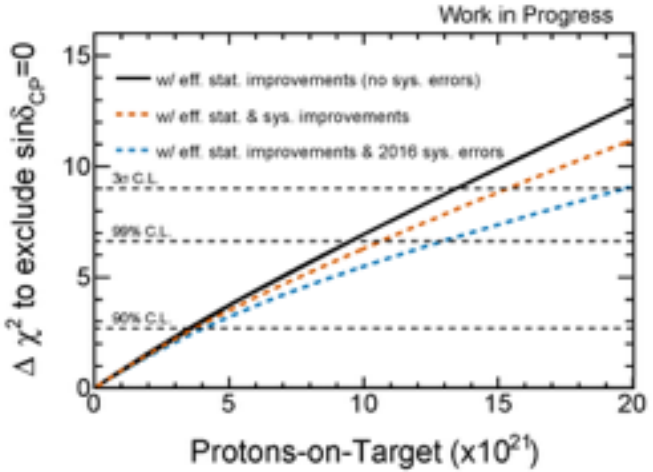
4.2: Measurements of hadro-production cross sections are critical to reducing the systematic error budget of future accelerator-based neutrino-oscillation measurements. At present, the only experiment that is in operation is NA61/SHINE, which is scheduled to complete operation in 2018. It is timely to consider the requirements for measurements of hadron spectra beyond those that NA61/SHINE will provide.

Recommendation 4.1: ICFA should encourage careful and timely consideration of the requirements for a hadro-production measurement programme to follow NA61/SHINE including possible extensions to the NA61/SHINE programme.

Impact of hadron production measurement

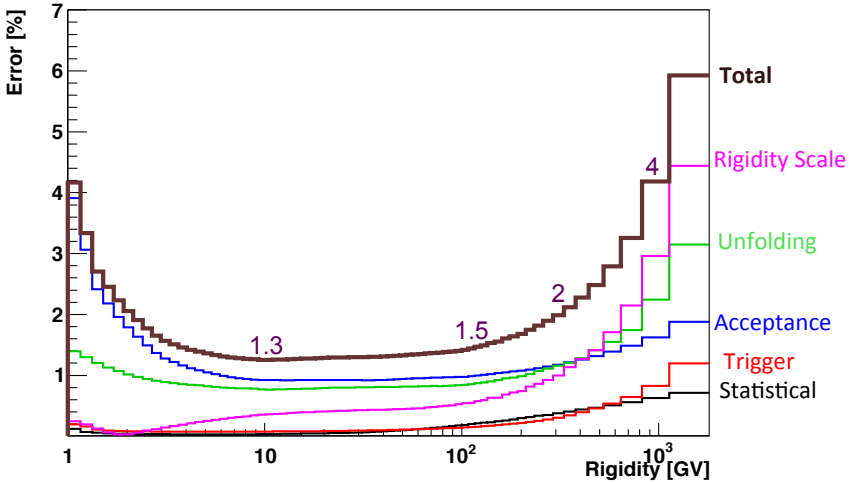
- Neutrino oscillation physics
  - Next decade: CP violation discovery
    - Precision study (1-2%) required
- Hadron production: key uncertainty
  - ν flux
    - hadron production @ target or air
  - ν cross section
    - hadronic effect inside the nucleus
  - Detector response
    - hadron interaction in the detector
- No reliable hadron interaction code
  - Cannot predict from first principle
  - Rely on data and empirical models

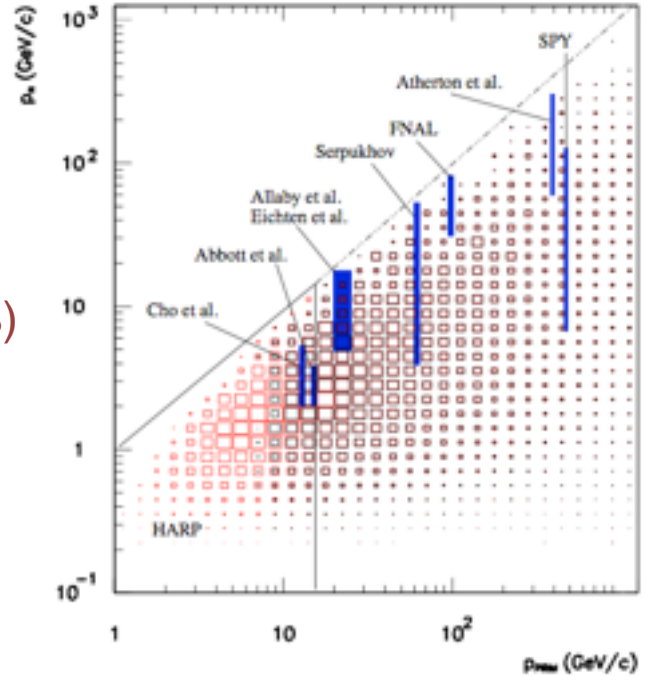




Comprehensive hadron production information needed

- Accelerator based neutrino
  - T2K, NOvA, HyperK, DUNE, SBND, JSNS2, …
- Atmospheric neutrino
  - SuperK, ICECUBE, Km3net, INO, …
  - Precise primary cosmic ray study by AMS (~1-2%)
    - hadron production provides precise neutrino flux





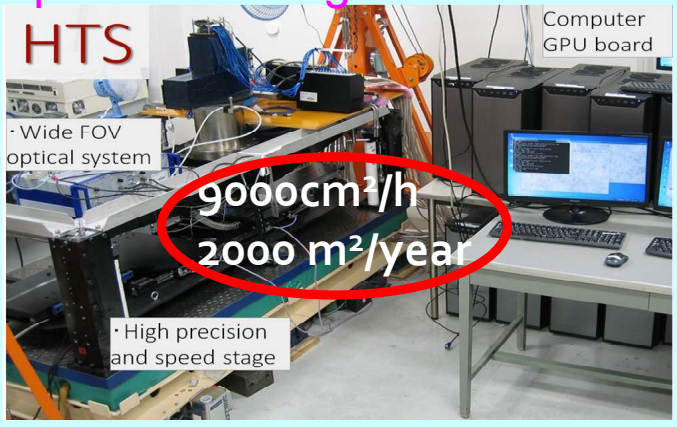
- Collider and fix target experiments
  - detector responses
- Hadron interaction models

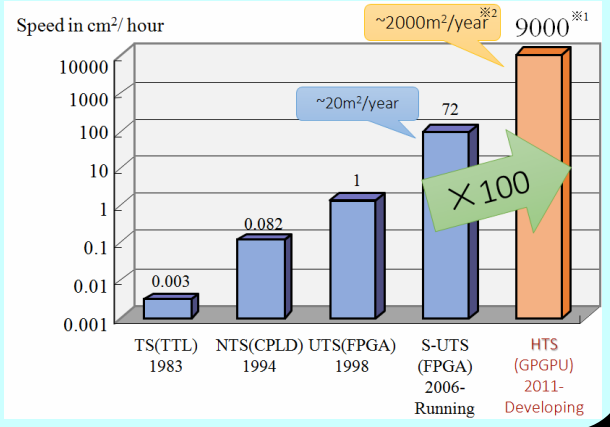
Why emulsion hybrid spectrometer?

- Systematic uncertainties in hadron production experiments
  - Vertex reconstruction: interaction in the tracking detector
    - Emulsion: Precise tracking with minimal materials
  - Limited phase space in particular in the forward direction
    - Emulsion: Full acceptance in the forward direction
  - Limited beam availability
    - Emulsion: Compact and can be placed at different beam lines
      - Fermilab: 1-120GeV, CERN: 10-500GeV
- Challenges in emulsion spectrometer: high statistics
  - High event density
    - Emulsion moving system
  - Event scanning:
    - Automated readout system

Impressive progress in emulsion technology

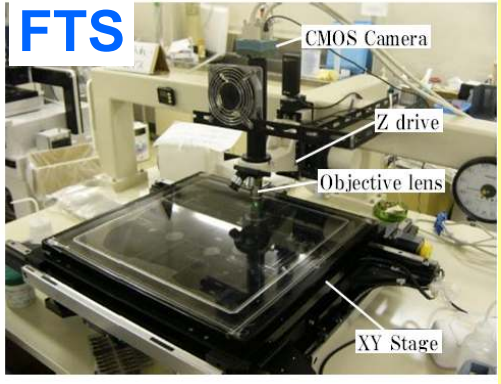
High speed scanning

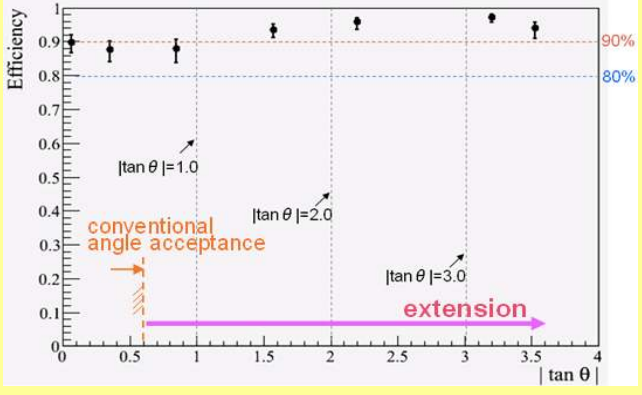


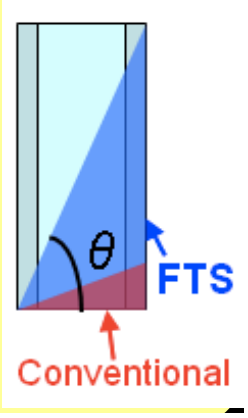


T.Fukuda's slide

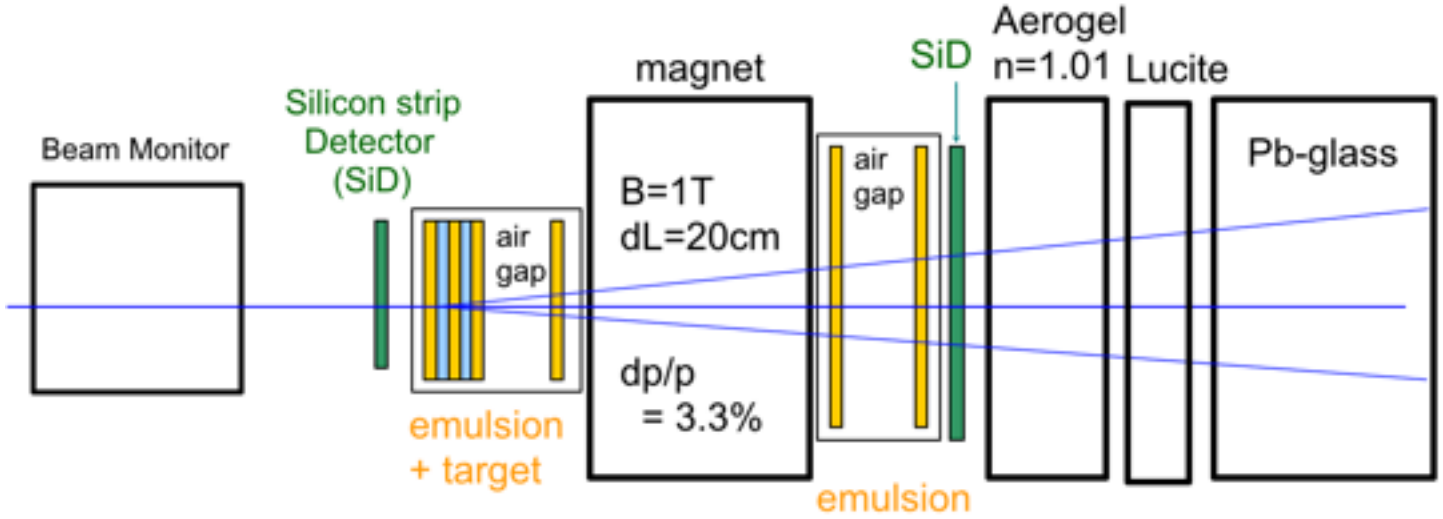
Large angle scanning





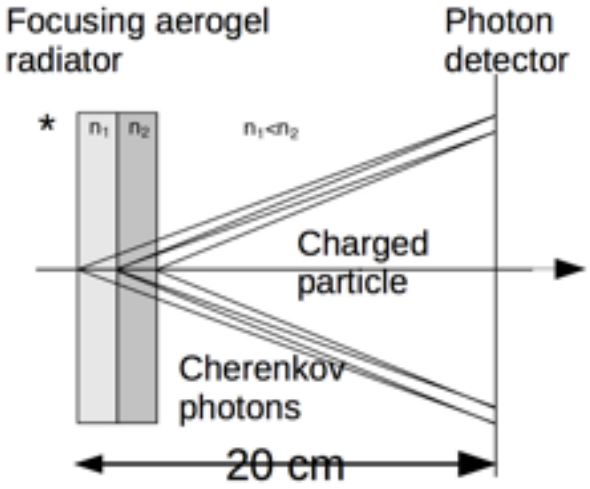


Hybrid emulsion detector



- Hybrid emulsion spectrometer
  - Emulsion+target, silicon strip, magnet, particle ID Cherenkov
- Secondary hadron beam at Fermilab (p,π up to 120GeV/c)
  - Six silicon strip detector to match the timing

Particle Identification by A-RICH (Belle2)?



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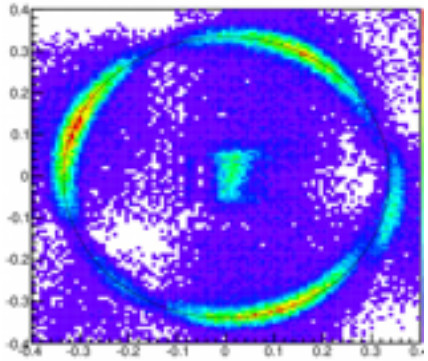
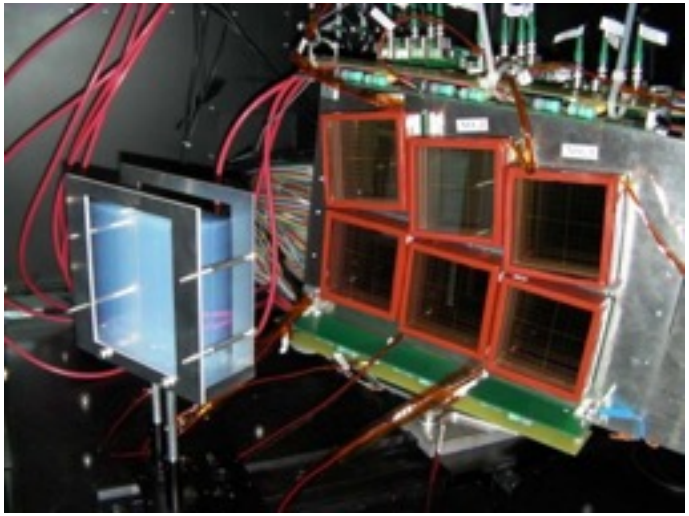


- Aerogel ring imaging Cherenkov
  - π / K / p separation in 1-5 GeV/c
    - more flexible than threshold Cherenkov
    - Lower index aerogel extends momentum range
  - Multi-track capability!



Summary

- Comprehensive hadron production data is needed
  - for accelerator/atmospheric neutrino experiments
    - Neutrino flux, Detector response, Neutrino cross section
    - Physics: CP violation, mass hierarchy, τ appearance, etc.
  - for collider/fixed target experiments
- Hybrid emulsion detector opens up a new era in precise hadron production studies
  - Precise vertex reconstruction, Forward acceptance coverage
- Let's have an active discussions at this meeting to develop this exciting opportunity.