EIC-ZDC R&D proposal

RBRC exp group meeting

May 27th, 2020

Yuji Goto

Call for EIC Detector R&D Proposals

- FY21 funding period
- New proposal
  - Need to be submitted by May 29, 2020
- US participants
  - BNL, U. Kansas, Old Dominion U., Stony Brook U.
- Japanese participants
  - ICRR Tokyo U., JAEA, Kobe U., Nagoya U., Nihon U., RIKEN, Shinshu U., Tokyo Tech, Tsukuba U., Yamagata U.
- Contact persons
  - YG and Michael Murray (U. Kansas)

Developing a Position Sensitive ZDC for the EIC

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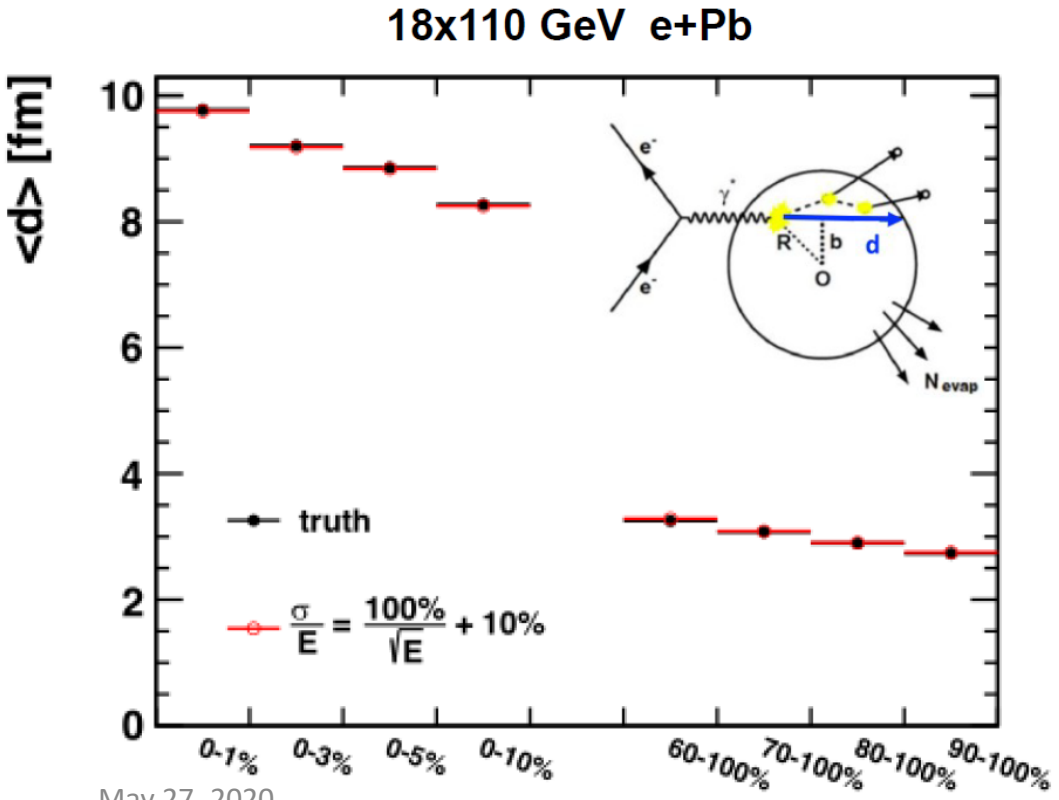
May 2020

Motivation for the research

- Technologies
  - Technical limitations, advance of the state-of-the-art
  - Soft photon detection
  - EM + hadron calorimeter
    - Acceptance
    - Energy and position resolutions
  - Radiation hardness
- Physics program
  - e+A collision geometry
    - Impact parameter sampling via forward neutron multiplicity
    - Deep exclusive nuclei (low-E photon detection)
  - Spectator tagging
    - ZDC resolution for single neutron events
  - Meson structure
  - Leading baryons and very forward asymmetries
  - Spectroscopy, …

e+A collision geometry

- Impact parameter sampling via forward neutron multiplicity
  - BeAGLE simulations (M.D. Baker, W. Chang, et al.)
  - High multiplicity events correlate with e+A centrality (large A)
  - A higher resolution calorimeter is not required for this analysis



b = impact parameter

d = effective distance traveled in nucleus by the reaction products = $\int_z^{+\infty} dz\, \rho(b,z)/\rho_0$ in fm

T(b) = full nuclear thickness (normalized):
= $\int_{-\infty}^{+\infty} dz\, \rho(b,z)/\rho_0$ in fm

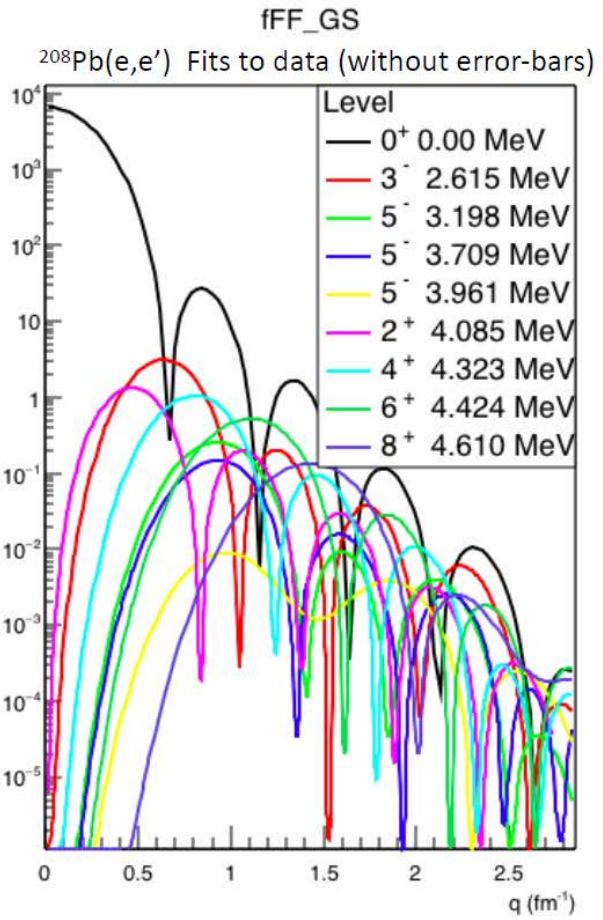
By Wan Chang

e+A collision geometry

- Slide by C. Hyde

ZDC EMCAL: DEEP EXCLUSIVE NUCLEI

- Gluon Density from e.g. ^{208}Pb(e,e'ϕ) ^{208}Pb
  - Final state nucleus is lost in beam envelope
  - Veto breakup of Pb nucleus.
  - Thousands of bound states excitable by photo-excitation
    - These will wash out diffractive minima.
    - Possible veto by detection of boosted decay photons
    - At P_{Pb} = 275•Z GeV, boost γ = 117
    - Each photon has 32% detection probability within 4mr cone



Spectator tagging

- Slide by C. Hyde

ZDC RESOLUTION: SINGLE NEUTRON EVENTS

- Measuring the properties of a bound proton: Spectator tagging: e.g. D(e,e'n)X
  - P_D = 275 GeV/c ➔ $p_n = P_D(1+\alpha)/2 \approx$ 137 GeV/c
    - Rest frame neutron momentum ≈ αM
  - If ZDC resolution = 50% $[\text{GeV}/E_n]^{1/2}$ ➔ 4.5% @ 137 GeV/c
    - $\sigma(\alpha) \approx \sigma(p)/p \approx 0.045$ ➔ Rest-frame $\sigma(p_n) \approx$ 40 MeV/c
  - Spatial resolution 1 cm ?
    - $\sigma(p_T) \approx$ (137 GeV/c) (1 cm)/(32m) = 43 MeV/c

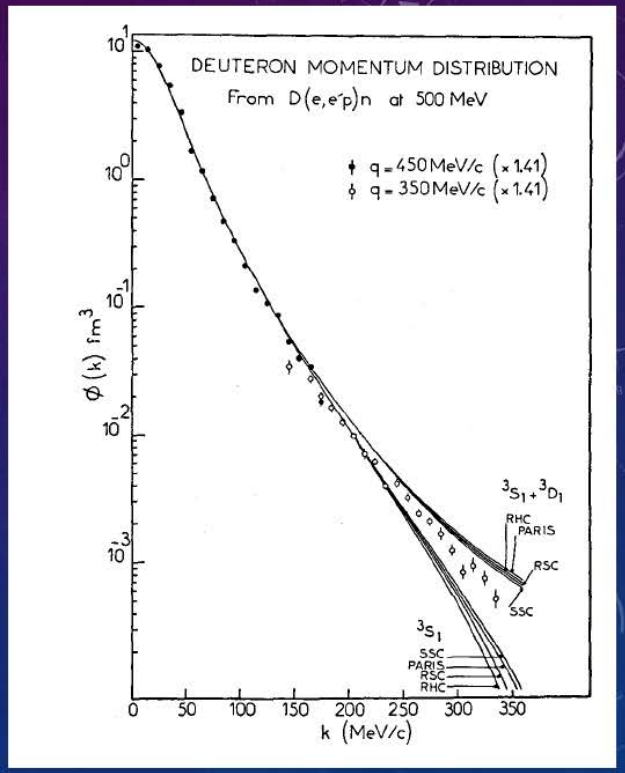


Table of performance requirements

Detector R&D	Physics	Performance requirements	Resource requested	Support & collaboration
Soft photon detection	e+A nuclear breakup veto	$E_\gamma \leq 300$ MeV	detector simulation	This proposal Calorimeter consortium
		acceptance	acceptance simulation	This proposal BeAGLE group
		detector technology	detector R&D	N/A in FY21
EM + hadron calorimeter	e+A collision geometry	neutron multiplicity	high resolution not necessary	BeAGLE group
	spectator tagging	energy & position resolution	detector simulation	This proposal
	meson structure	neutron & Λ acceptance	detector simulation	This proposal Meson structure WG
		detector technology	FoCal R&D	RIKEN
			LHC-ZDC R&D	Kansas Univ.
		calibration scheme	design & simulation	This proposal
			system test	N/A in FY21
Radiation hardness		radiation dose	simulation study	This proposal Kobe Univ.
		detector technology	radiation test	This proposal Calorimeter consortium

Simulation studies

- Collaboration with BeAGLE group (eRD17) and calorimeter consortium (eRD1)
  - ALICE FoCal geometry included in Geant4 (g4e framework)
- Soft photon detection
  - Acceptance & efficiency
  - Detector simulation & evaluation
  - Effect for downstream calorimeter (resolution, pID)
- EM + hadron calorimeter
  - Detector simulation
    - EM + hadron configuration & evaluation
    - Energy & position resolution
      - Leakage (size), e/h (technology)
    - Calibration system evaluation
  - Physics simulation
    - Evaluation for spectrum measurement
- Radiation dose

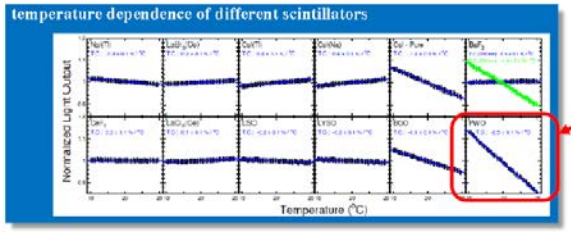
Calorimeter Consortium

Slide by T. Horn

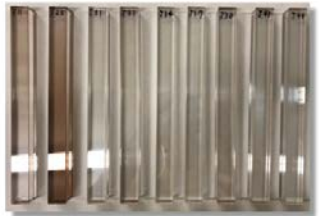
- Crystal calorimeter
  - PWO
  - For soft photon detection < 300 MeV
    - Full absorption
- Glass scintillator
  - Radiation hard

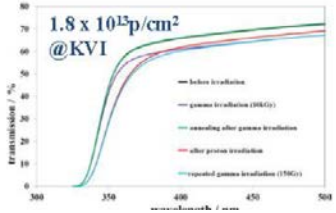
Crystals in EMCal: $PbWO_4$

- $PbWO_4$ material of choice for many EMCals – high density, fast response, large and granular solid angle, etc., but also limitations, e.g. hadron radiation damage



$PbWO_4$ light yield temperature dependence: 2%/°C



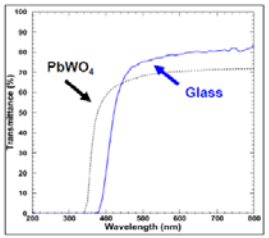


Glass Scintillator – optical and radiation hardness

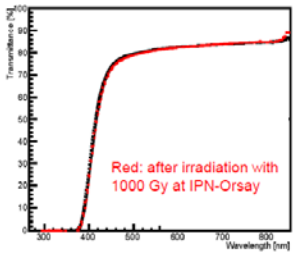
- Glass scintillators being developed at *VSL/CUA/Scintilex*
  - Optical properties comparable or better than $PbWO_4$
  - Preliminary tests on radiation damage look promising
  - Ongoing optimization work

Scintilex samples

Transmittance



Radiation Hardness



Light Yield

Material/ Parameter	$PbWO_4$	Sample 1	Sample 2	Sample 3	Sample 4
Luminescence (nm)	420	440	440	440	440
Relative light output (compared to $PbWO_4$)	1	35	16	23	11

SCINTILEX

ALICE FoCal

- RIKEN participation in FoCal
  - FoCal-E pad readout and trigger development
  - Test beam
- Participants
  - Yuji Goto (scientist): 0.25 FTE
  - Itaru Nakagawa (scientist): 0.25 FTE
  - Minho Kim (new postdoc from Oct. 2020): 1 FTE
- Budgetary contribution
  - Additional FoCal-E pad sensors in 2020-2021
  - Student support for Japanese & non-Japanese universities
    - Tsukuba U.
  - Travel support for visiting staffs

ALICE FoCal

- We'd like to build approx. 10cm x 20cm prototype FoCal-E detector to be used at RHIC/sPHENIX in 2024
  - Approx. size of 10cm x 20cm
  - Located at zero degree, in front of ZDC
  - Measurement of photon, pi0, and neutron cross section and left-right asymmetry in polarized p+p and p+A collisions
  - Construction in 2022-2023 by RIKEN budget
  - We'll need appropriate contract with FoCal group for technology transfer and purchase
- In 2023, we may consider prototype test at RHIC/sPHENIX in A+A collisions

RHICf-II upgrade

- Larger EM calorimeter
  - ALICE-FoCal 2 modules (~10cm x 20cm)
- π^0 (and neutron) asymmetry in p+A collisions
- K^0_S (4 photons) / Λ (neutron + 2 photons) / …
- p+O collisions for cosmic-ray study
- 2022 STAR p+p run at 510 GeV
  - ALICE-FoCal not available yet
  - LHCf detector not available due to conflict with LHC Run3 in 2023
- 2024 sPHENIX p+p 200 GeV & p+A run

Cooperation with high-energy groups

- Y. Yamazaki (Kobe U.), K. Nagano (KEK), K. Kawade (Shinshu U.), J. Tojo (Kyushu U.), M. Togawa (KEK)
  - Experts from HERA
  - Cooperation with LHC, LHeC, …
    - Silicon Lab. in KEK
- IR configuration / radiation dose (zero degree)
  - HERA / LHC $\rightarrow$ EIC zero degree
- Energy or position resolution?
- CMS HGCAL / ILC calorimeter

Summary

- Call for EIC detector R&D proposal
  - Motivation for the research
  - Performance requirements
  - Schedule for yearly deliverables
  - Funding requests and budget in FY21
    - Postdoc support & simulation studies
- Collaboration with BeAGLE group and calorimeter consortium
- ALICE FoCal
  - RIKEN participation in FoCal
  - Prototype in 2020-2021
- RHICf-II upgrade
  - FoCal-E prototype
  - 2024 at sPHENIX
- Cooperation with high-energy groups in Japan
  - Workshop on EIC-LHC cooperation

Backup Slides

e+A collision geometry

- Slide by C. Hyde

IMPACT PARAMETER SAMPLING VIA FORWARD NEUTRON MULTIPLICITY

- BEAGLE Simulations, (M.D. Baker, et al.)
- High multiplicity events correlate with *eA* centrality (large A)
  - $P_n \approx ZP_0/A \approx 0.4$ (275 GeV/c) = 110 GeV
    - Evaporation neutrons $T_n(rest) \leq 10$ MeV $\rightarrow |\alpha|<0.14$
    - Ballistic (Fermi-Gas) neutrons $|\alpha|<0.27$
  - Example event with neutron multiplicity 10.
    - Energy fluctuation of 10 neutrons is ≤ 5% for evaporation, 10% for ballistic
    - Total neutron energy ~ 1.1 TeV, global resolution = 1.5%
    - Typical neutron shower separation ~ (0.14/110)*32 m = 4 cm
      - All showers merge

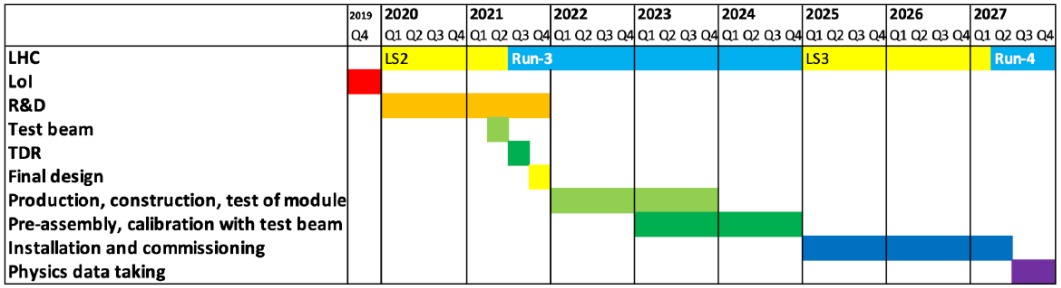
Resources requested

- Low-E photon detection
  - Crystal scintillator
    - Collaboration with the calorimeter consortium
- ZDC
  - ALICE FoCal
    - RIKEN project – no request?
  - LHC ZDC
    - Request from Kansas Univ.?
- Rad hardness
  - Glass scintillator
    - Collaboration with the calorimeter consortium
  - Plastic scintillator
    - Kobe Univ. project – no request?
- Physics simulations
  - Collaboration with BeAGLE group
    - Old Dominion Univ. (Charles)
    - Stony Brook Univ.
    - BNL
  - ALICE FoCal geometry included in Geant4 (g4e framework)

Schedule for yearly deliverables

- FY21
  - Physics simulations in the EIC geometry
  - ALICE-FoCal prototype & test beam

Timescale till Run-4 8



- FY22

- FY23 and after
  - ALICE-FoCal prototype
    - Test at RHIC/sPHENIX
    - Test at ALICE in Run3 (2024)

Funding requests and budget

- FY21: Oct. 1, 2020 – Sep. 30, 2021
- Ordered by group and by subject
  - Costs for manpower, hardware, and travel
  - 3 budget scenarios, deliverables for each
  - Intermediate milestones
  - Money matrix (institutions vs subprojects)

Example:

	R&D Subproject 1	R&D Subproject 2	R&D Subproject 3	
University A	$	$	$	Sum A
University B	$	$	$	Sum B
University C	$	$	$	Sum C
Nat. Lab. X	$	$	$	Sum X
	Sum 1	Sum 2	Sum 3	

- Kansas Univ.
  - LHC ZDC
- Stony Brook Univ.
- BNL
- Collaboration with the calorimeter consortium

Funding requests and budget

- Postdoctoral fellows not to be granted for FY21 and not encouraged
- Travel under the current COVID-19 situation

Front page

- Title of the project
- All proponents and institutions
- PIs
  - Kansas Univ.
  - Stony Brook Univ.
  - BNL?
- One (or two) contact person (typically a PI)