Hadron calorimeter R&D plans at RIKEN

RHIC Spin Collaboration Meeting

March 9th, 2017

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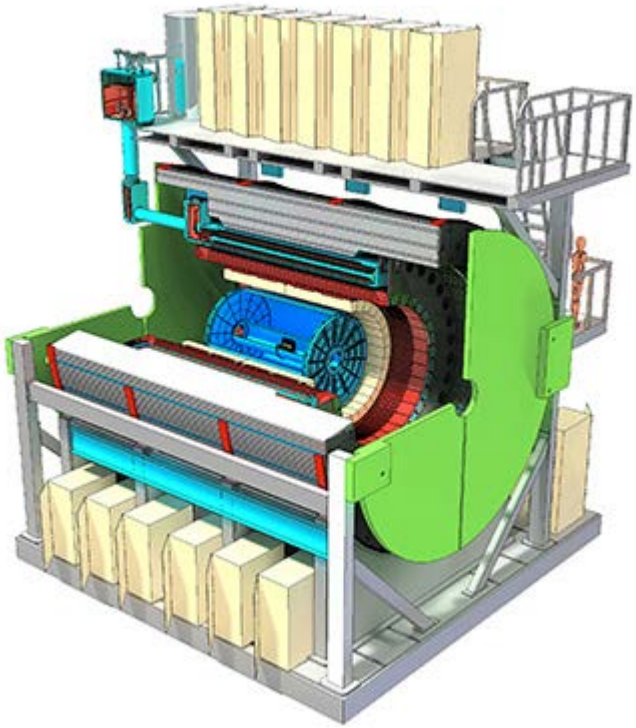
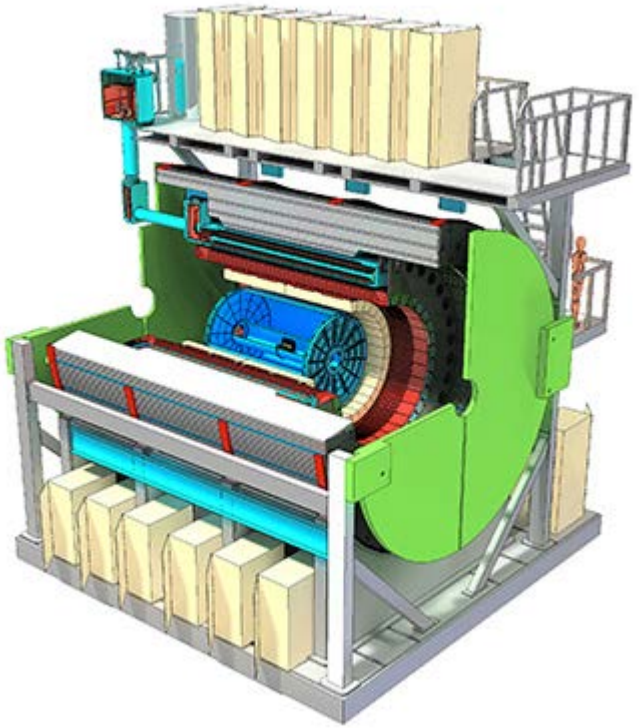
sPHENIX

- Large-acceptance jet and Upsilon detector around the BaBar magnet
  - $|\eta| < 1.1$ and $0 < \phi < 2\pi$
  - EM & Hadron calorimeters
  - TPC
  - MAPS & INTT
- Probe QGP with precision measurements of jet quenching and Upsilon suppression
- Construction schedule for 2022-2023 sPHENIX run

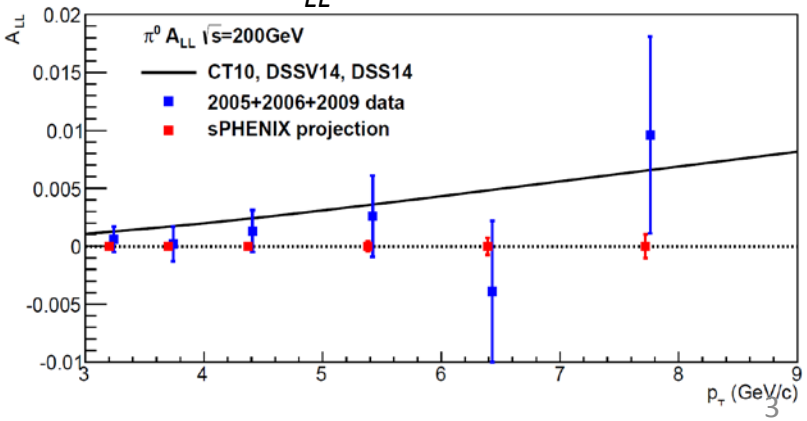


Spin physics at sPHENIX

- sPHENIX
  - 70 times of the final statistics of PHENIX at $\sqrt{s}$ = 200 GeV polarized p+p in 2023
- Gluon polarization measurement
  - π^0 A_{LL}
    - EMCal $\Delta\eta\times\Delta\phi\sim0.025\times0.025$
    - Improved statistical precision up to $p_T < 8$ GeV/c
  - Inclusive photon (EM cluster)
    - No separation of π^0 decay and direct photon above $p_T > 8$ GeV/c
    - Mixture of π^0s and direct photons
  - Jet / dijet
    - Better jet scale uncertainty with hadron calorimeter
    - Statistically small improvement from the existing STAR data

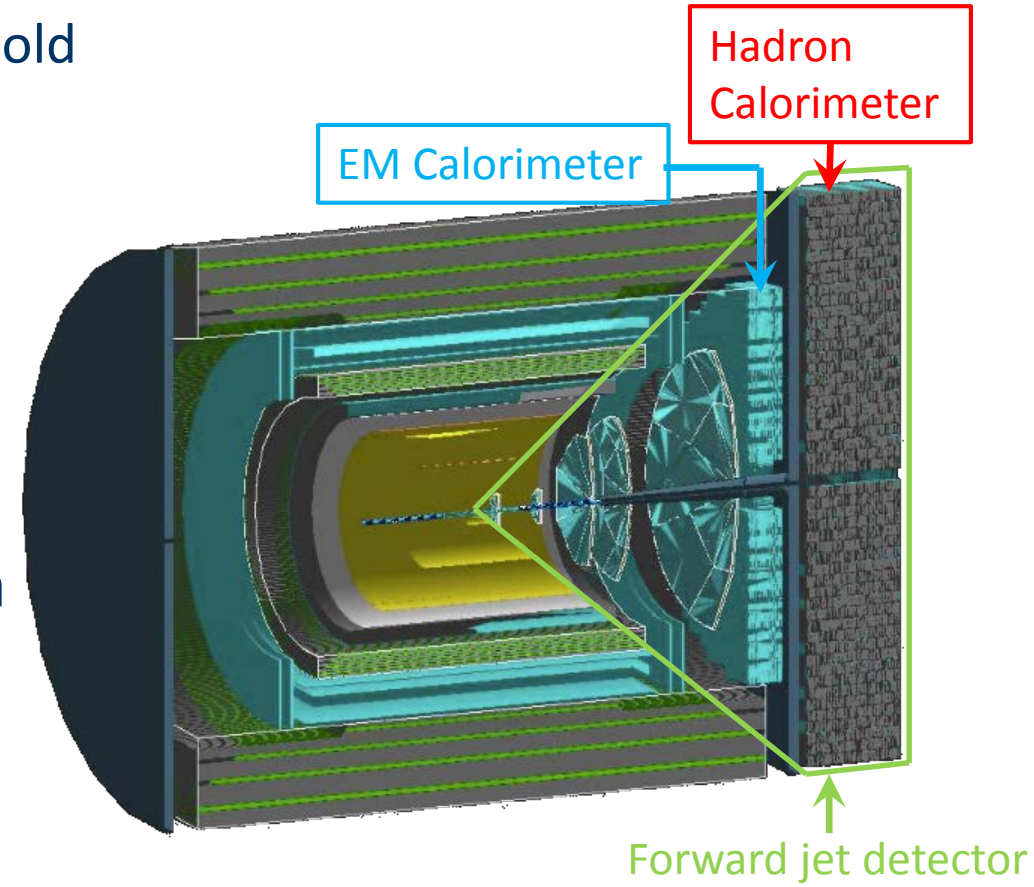


π^0 A_{LL} at $\sqrt{s}$ = 200 GeV



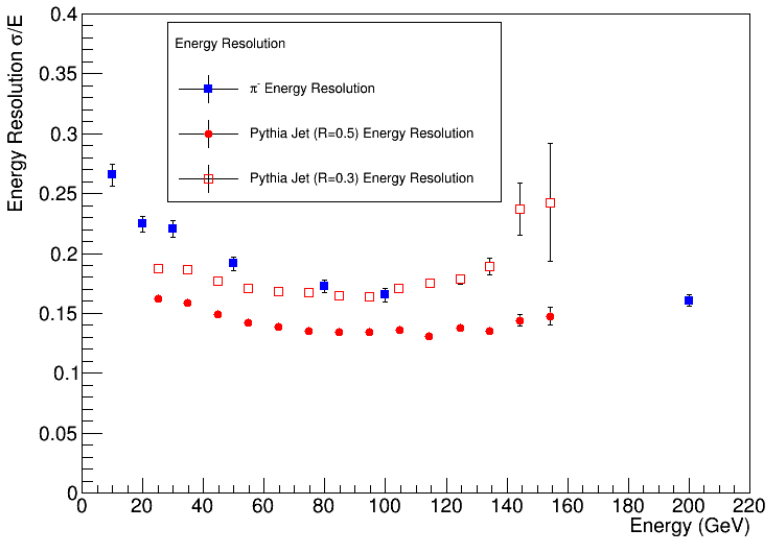
Forward sPHENIX

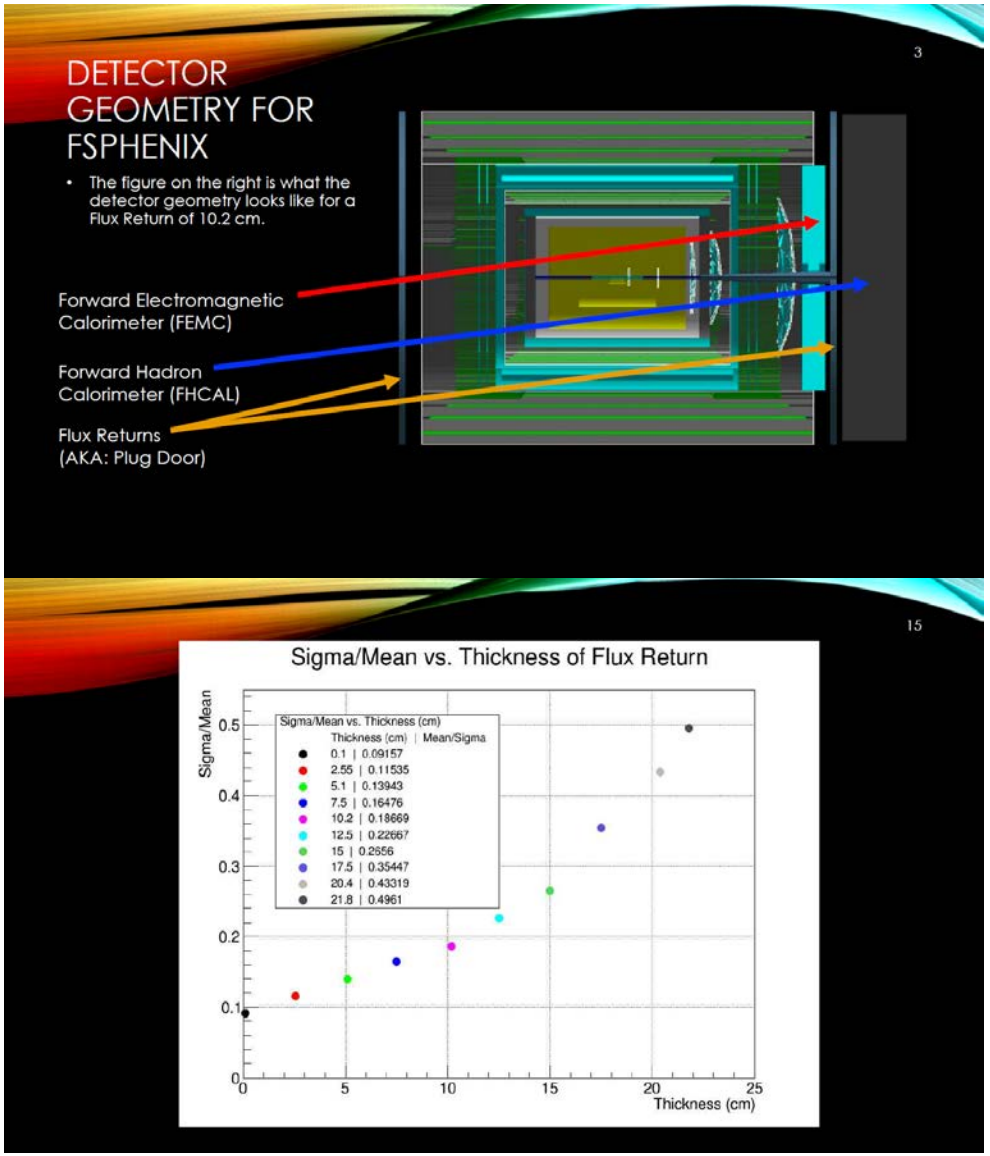
- fsPHENIX
  - For realization of the RHIC Cold QCD plan
  - $1.2 < \eta < 4$
  - GEM tracker
  - EM calorimeter
    - Refurbished PHENIX PbSc + MPC
  - Hadron calorimeter
  - magnetic field shaper
- Coexist with magnet return yoke
  - OPERA calculations show a return yoke 10 cm thick OK
- Within 4.5 m eRHIC IR constraint
  - Potential hadron arm of the eRHIC detector



Forward sPHENIX

- G4 simulation
  - sPHENIX cold QCD topical group
  - Magnet return yoke study
    - David Kapukchyan (UC Riverside)





Physics at fsPHENIX

- Cold QCD plan: arXiv:1602.03922
- A portal to the EIC
  - "providing a comprehensive set of measurements in hadronic collisions that, when combined with data from the EIC, will establish the validity and limits of factorization and universality"
- Transverse-spin asymmetries
  - A_N for charged hadrons and flavor enhanced jets
  - Hadron asymmetries in jet modulations
  - A_N for Drell-Yan / photon
- nPDF and saturation measurement
  - R_{pA} of photon / Drell-Yan / dihadron / …
- Gluon polarization measurement at small-x
  - A_{LL} for jet / dijet / hadron / photon / …

Spin physics at fsPHENIX

- Jet asymmetries tagging positive/negative hadrons
  - Flavor dependence of the twist-3 ETQS distribution
  - Evolution of the twist-3 ETQS distribution function
- EM + Hadron calorimeters & tracker are necessary
  - For jet + hadron measurement & triggering

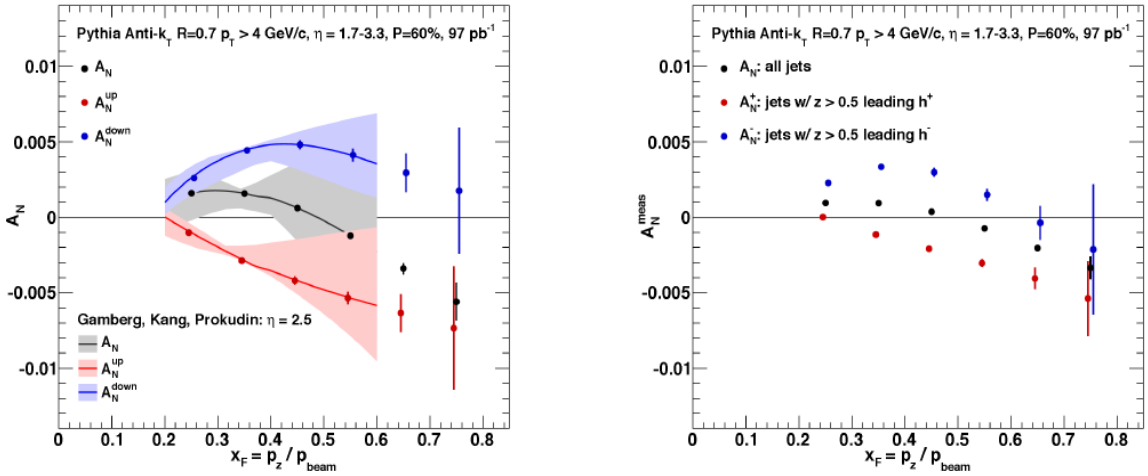


Figure 2-11: Left: up quark (red points), down quark (blue points) and all jet (black points) single spin asymmetries as a function of x_f as calculated by the ETQS based on the SIDIS Sivers functions. Right: Expected experimental sensitivities for jet asymmetries tagging in addition a positive hadron with z above 0.5 (red points), a negative hadron with z above 0.5 (blue points) or all jets (black) as a function of x_f. Note: these figures are currently for 200 GeV center-of-mass energy proton collisions – the 500 GeV results are expected to be qualitatively similar but with reduced uncertainties due to the larger luminosities expected.

Spin physics at fsPHENIX

- Hadron angular distribution in jets
  - Transversity & Collins function

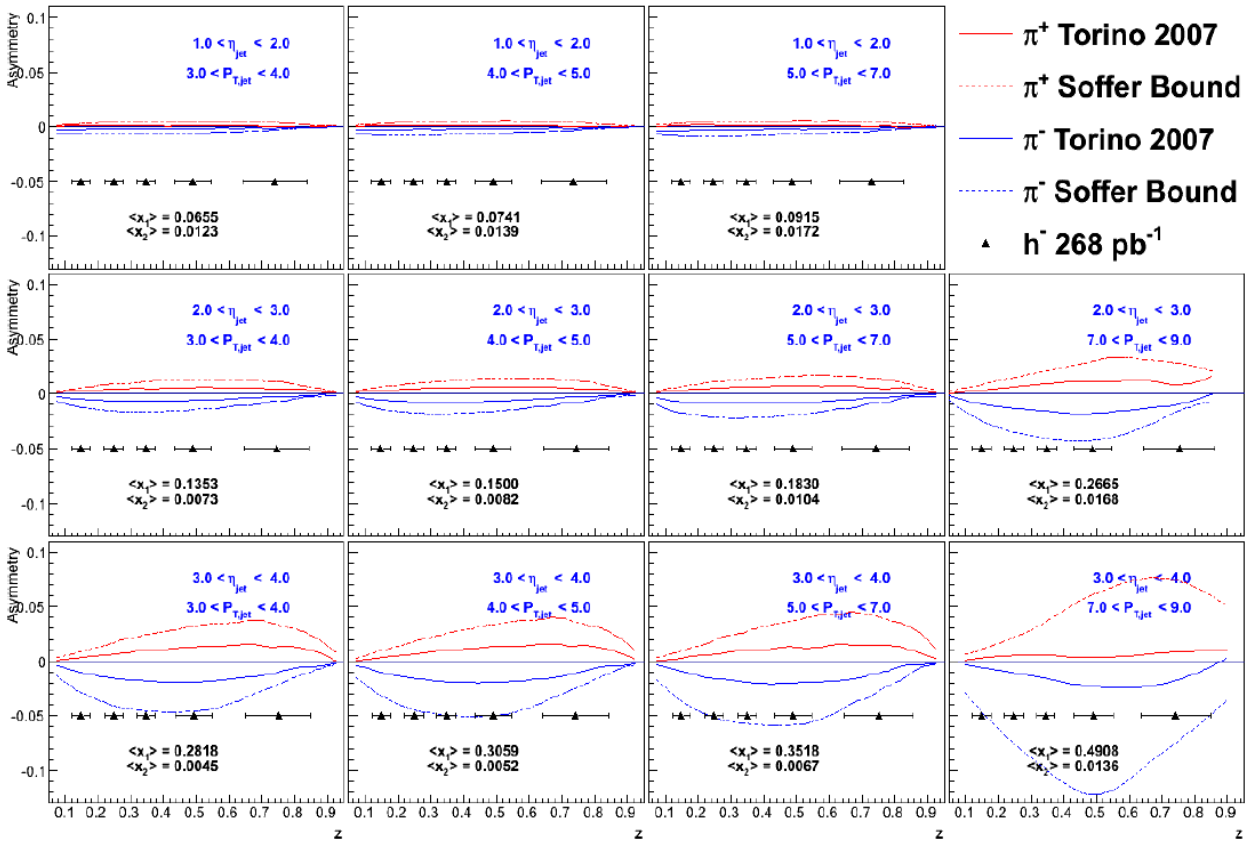


Figure 2-14: Expected h^- Collins asymmetry uncertainties (black points) compared to positive (red) and negative (blue) pion asymmetries based on the Torino extraction [45] (full lines) and the Soffer bound [83] (dashed lines) as a function of fractional energy *z* for various bins in jet rapidity and transverse momentum.

Expected h^- Collins asymmetry uncertainties

Forward HCal

- Technology choices
  - UCLA HCal for STAR FCS (O. Tsai)
  - E864 SPACAL (J. Lajoie)
  - …
- UCLA Hadron calorimeter for STAR FCS
  - 10cm x 10cm x 81cm tower
  - 4 interaction length
  - 64 layers of 10mm Pb (or Fe) absorber + 2.5mm scintillator
  - WLS plate for light collection
  - SiPM for readout

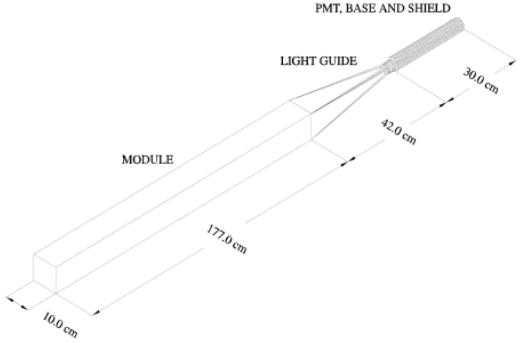


Fig. 3. Calorimeter Tower Layout. Scintillating fibers are imbedded longitudinally in a lead substrate. The light readout proceeds through a tapered lucite light guide with a single photo-multiplier tube per tower.

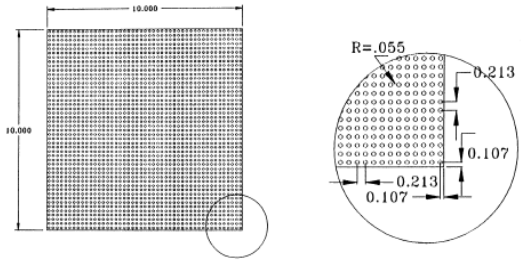
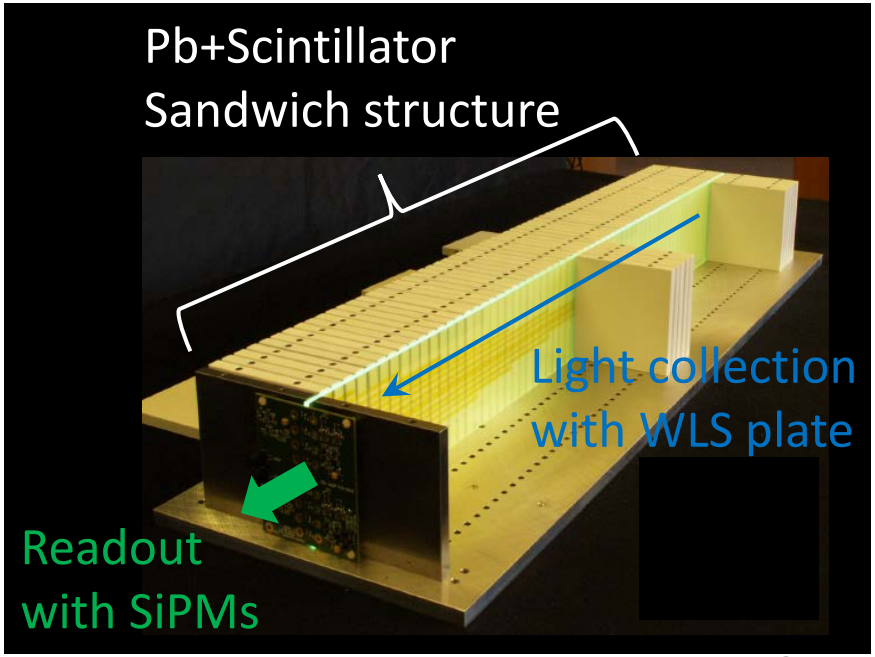


Fig. 4. Cross sectional view of a calorimeter tower: 47 × 47 scintillating fibers are embedded in a square lead matrix with a regular 0.213 cm spacing. The insert shows the position and dimension of the fibers. All dimensions in cm.

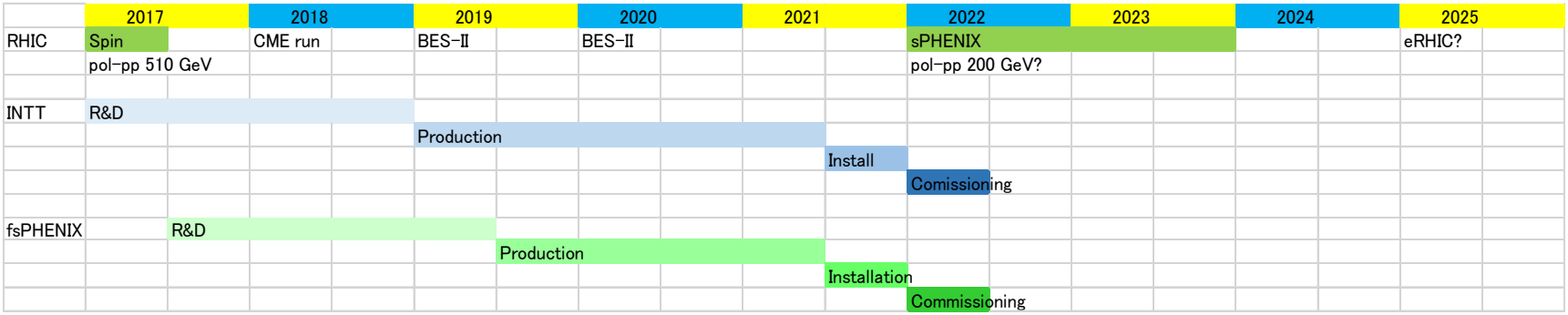


Forward HCal R&D

- JSPS KAKENHI application (Kiban-B)
  - Goto, Seidl (RIKEN), Shibata, Nakano (Tokyo Tech), Miyachi (Yamagata)
  - Students from Tokyo Tech / Yamagata
  - Lajoie, Feege (fsPHENIX) & Tsai (STAR/UCLA)
  - 2017-2019 about 20M yen ($170K) in total
  - 2017
    - Preparation for 1st prototype construction at RIKEN
    - Hamamatsu APD modification by EIC R&D / STAR / fsPHENIX
  - 2018
    - 1st prototype construction at RIKEN
    - Test at STAR
  - 2019
    - Beam test at FNAL (with 4x4 fHCal)?

RIKEN timelines

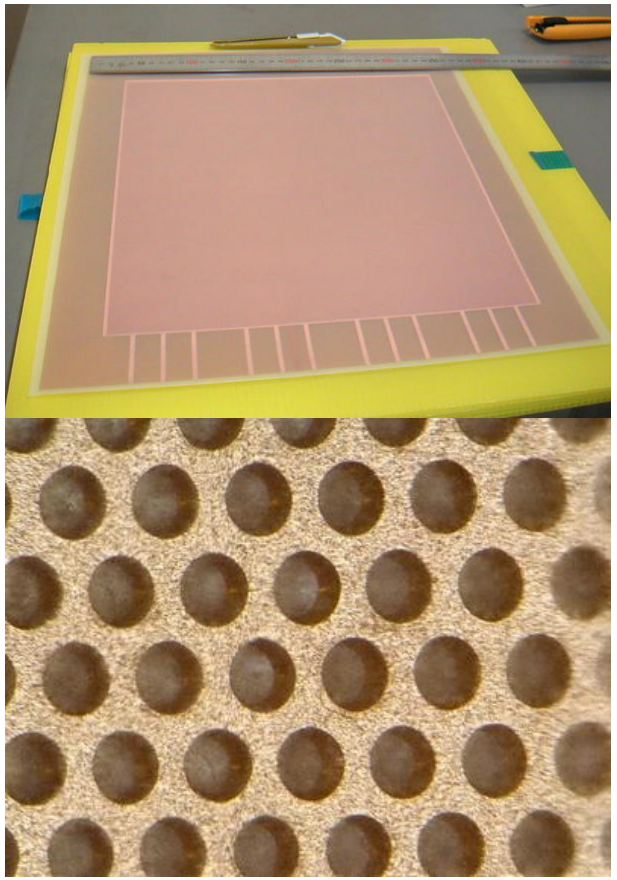
- RIKEN budget in 2017-2021
  - Interval between PHENIX run and sPHENIX run
  - Maintenance budget for operation available for detector R&D and construction
    - Nominally for sPHENIX (not for STAR)
    - Or collaboration between sPHENIX and STAR?
  - sPHENIX INTT (intermediate silicon tracker) & fsPHENIX



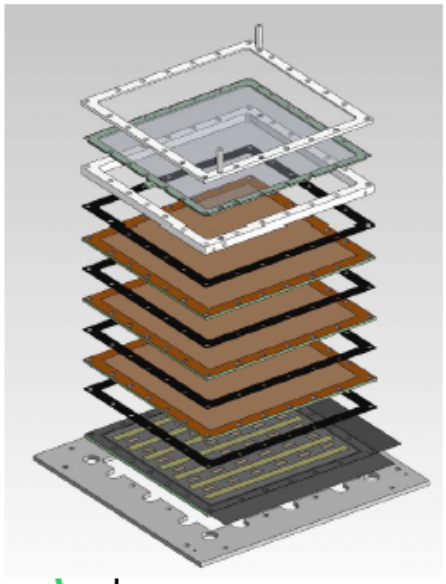
- RIKEN budget + JSPS KAKENHI application for construction 2019-?
  - Partial coverage: $2 < \eta < 4$ ($2m \times 2m$)
  - > $1M

Discussion

- We want both hadron calorimeters and trackers for the forward spin physics
  - For jet + hadron measurements
- Detector priority?
  - GEM tracker?
    - Priority on hadron
    - Hadron trigger issue
    - Possible collaboration with RIKEN J-PARC exp. Group
      - 300mm $\times$ 300mm
  - Hadron calorimeter?
    - Priority on jet
    - Jet physics, e.g. jet A_{LL} measurement

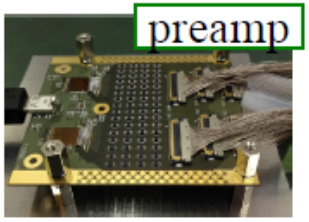


GEM at RIKEN

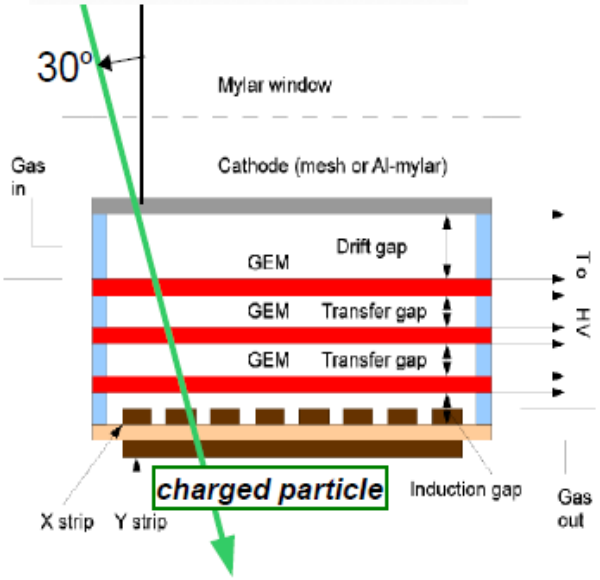


GEM Tracker

- 100x100, 200x200, and 300x300 mm^2
- Ar+CO_2 (70:30), Gain: 1~4 x 10^4
- 2D strip readout PCB
- Readout electronics:
  - preamp using APV25 chip
  - FEM: SRS (by RD51)



- position resolution
  - 100um for angled track(up to 30°) in the bending plane (x-direction), and 300um for the vertical (y) direction
  - confirmed for all three sizes by beam tests



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