Huizhou Hadron Spectrometer (HHaS)

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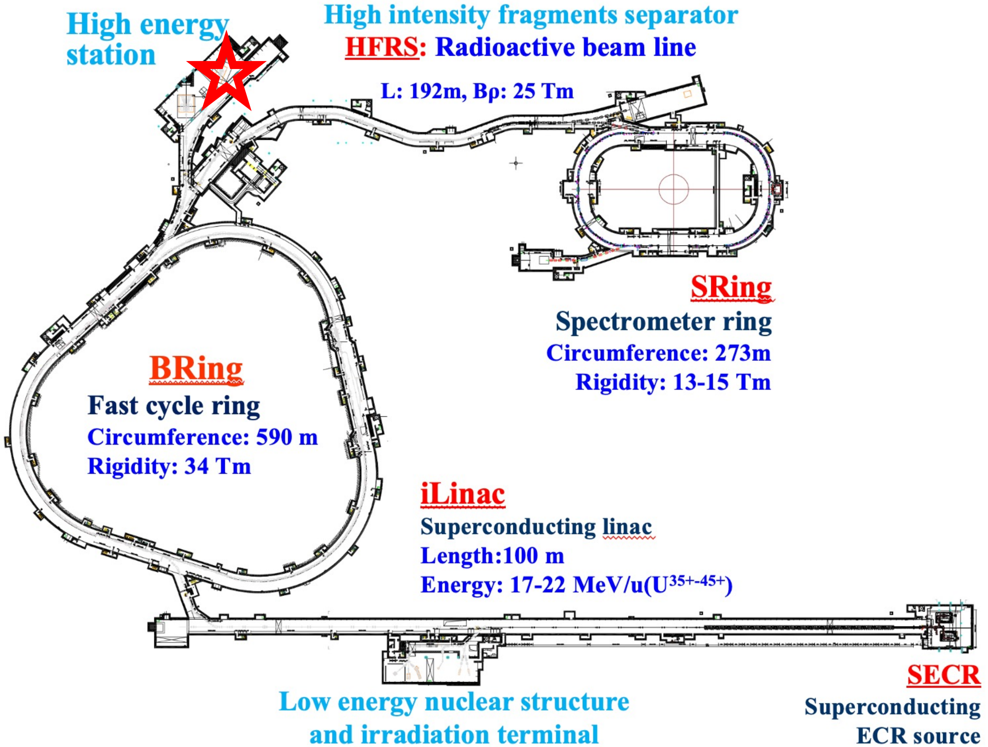
HIAF & HIAF-U

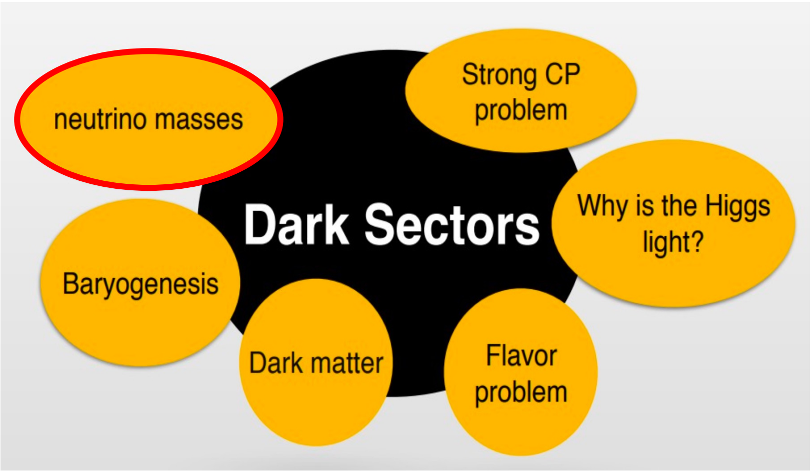


	E_k (GeV/u)	$\sqrt{s_{NN}}$ (GeV)
HIAF p beam	<9.3	<4.58
HIAF U beam	<2.45	<2.85
HIAF-U U beam	<9.1	<4.54

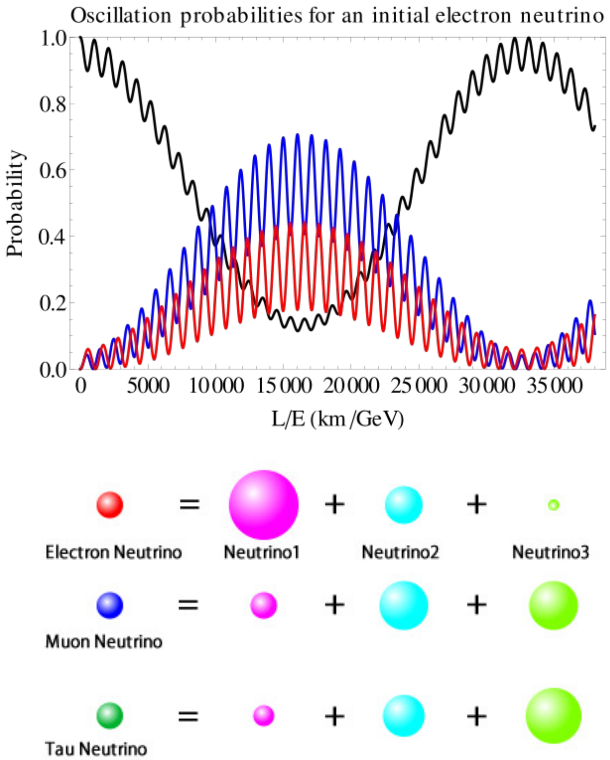
Huizhou Hadron Spectrometer (HHaS)

- Proton and potential secondary K/π beam: η meson physics, light hadron physics…
- Heavy-ion beam: nuclear matter phase structure, equation of state, hypernucleus…

Call for Physics beyond Standard Model

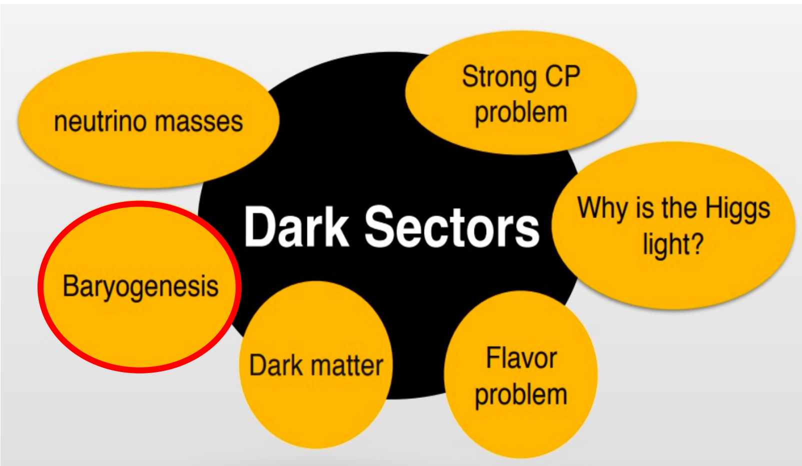


C. Gatto



- The standard model confronts several problems, calling for new physics beyond the current standard model
- Neutrino oscillation ⇒ neutrinos have mass

Call for Physics beyond Standard Model



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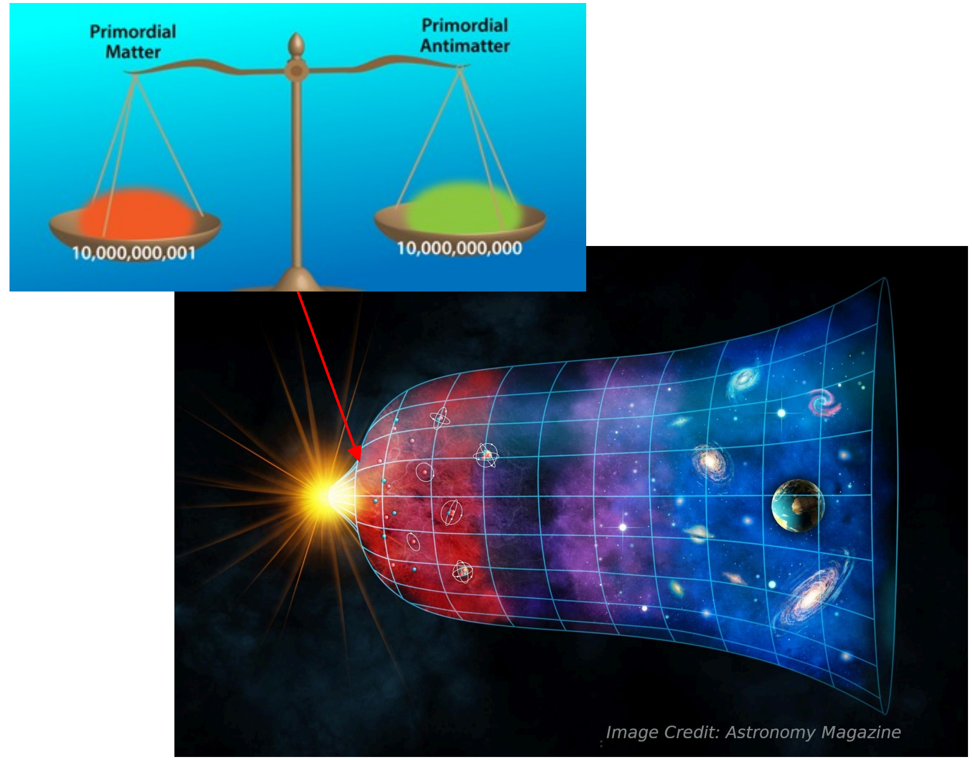
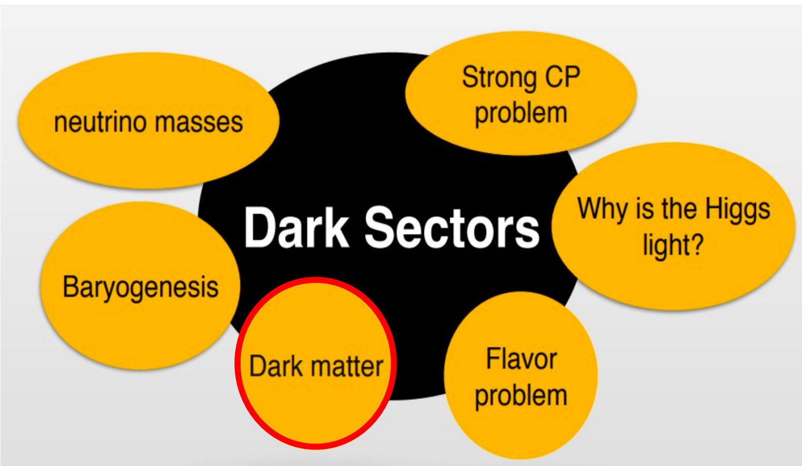
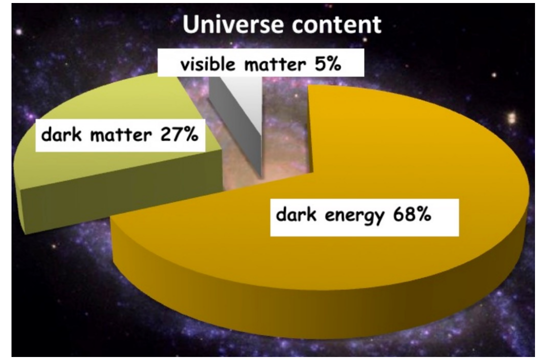


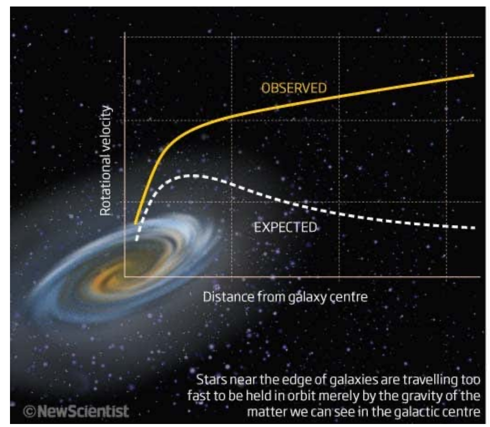
- The standard model confronts several problems, calling for new physics beyond the current standard model
- Tiny amount of matter-antimatter asymmetry in the early universe is the basis for the matter world today

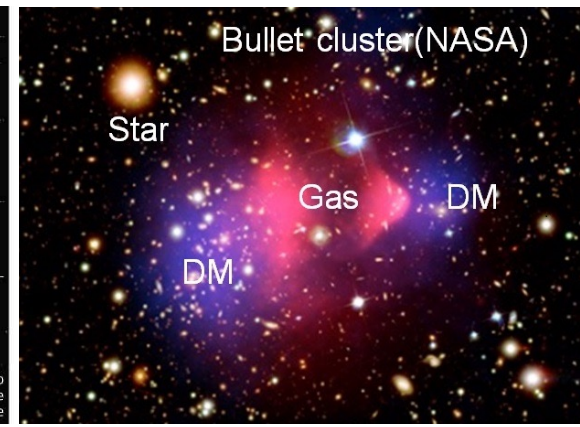
Call for Physics beyond Standard Model



C. Gatto

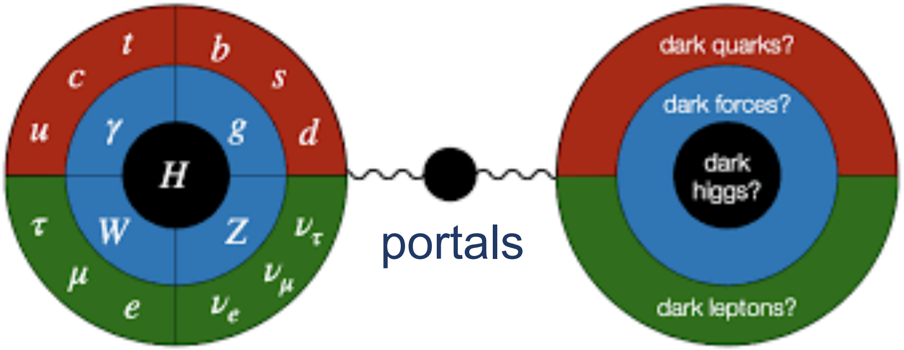






- The standard model confronts several problems, calling for new physics beyond the current standard model
- There are ~5 times more dark matter than normal matter in our universe

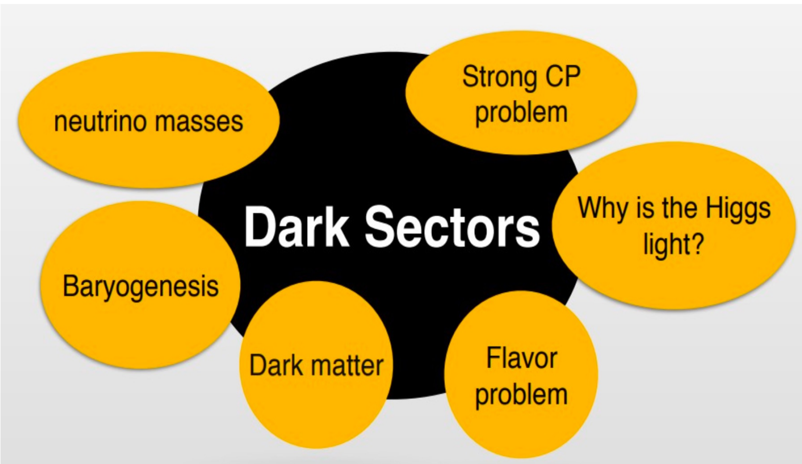
Call for Physics beyond Standard Model



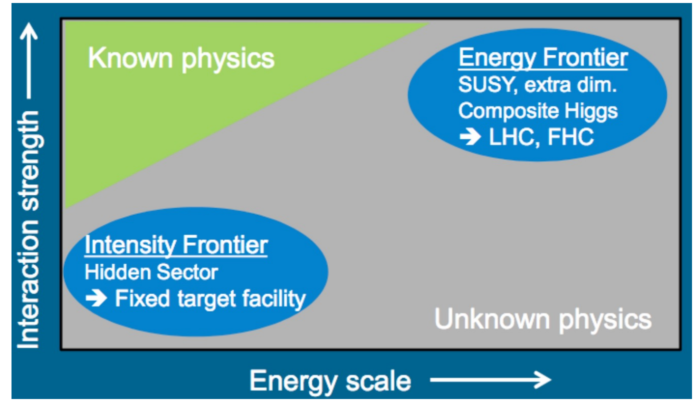
C. Gatto

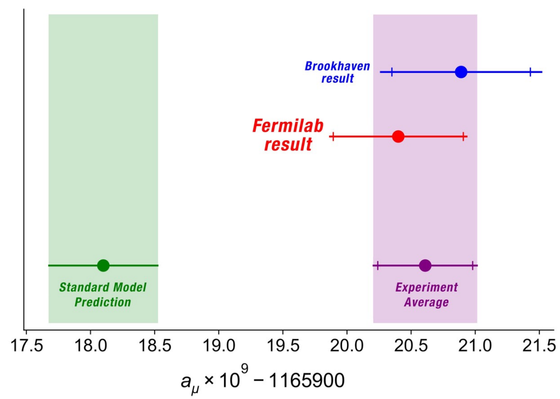
- The standard model confronts several problems, calling for new physics beyond the current standard model
- Possible portals connecting the dark sectors and the standard model
  - Dark photons (vectors), dark Higgs (scalars), axion(-like particle), sterile neutrinos

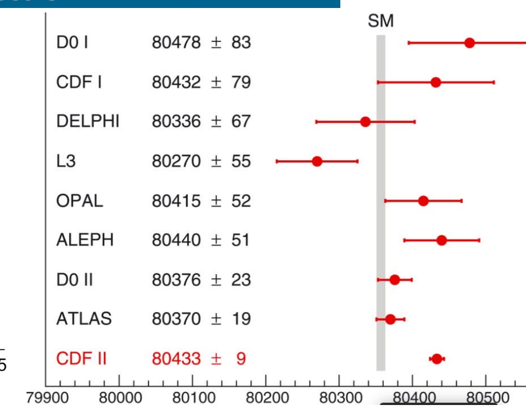
Call for Physics beyond Standard Model



C. Gatto

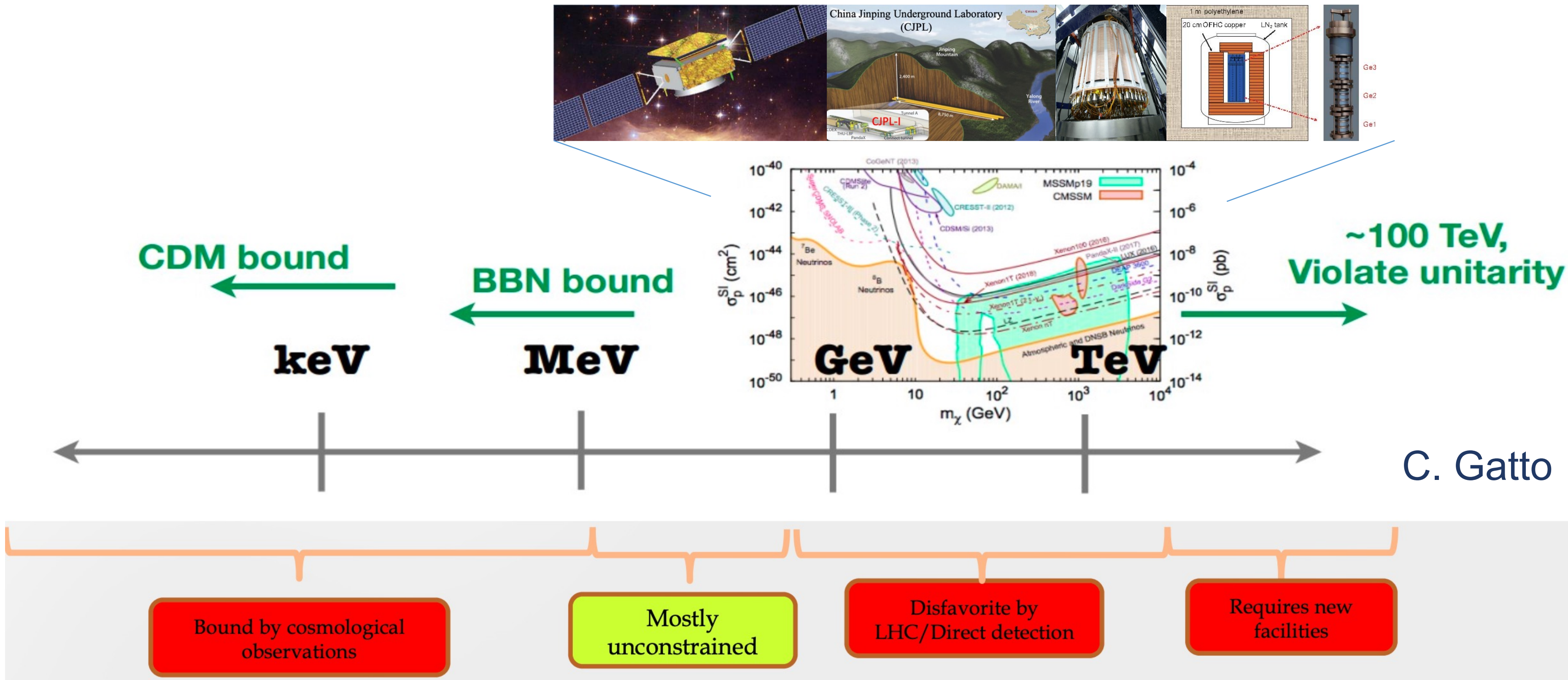






- The standard model confronts several problems, calling for new physics beyond the current standard model
- High-luminosity / high-precision is an important frontier for the discovery of new physics, e.g. abnormal magnet moment of μ (g-2), W mass

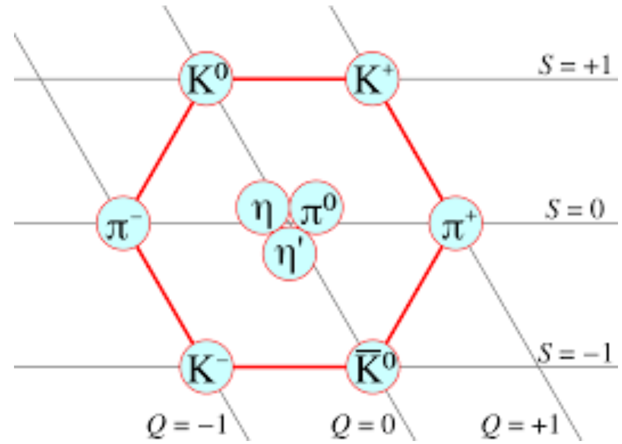
Call for Physics beyond Standard Model



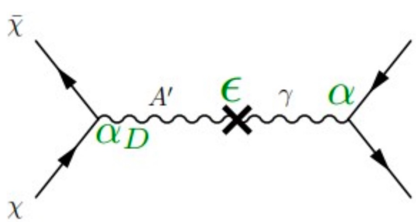
- In the search for dark matter particles, the parameter space for traditional WIMP (GeV~100TeV) is gradually being excluded by experiments
- Light dark matter particles (MeV~GeV) are currented less constrained by experiments
- High-intensity accelerators are powerful tools for light dark matter particle search

η meson physics – new particles & forces

- η / η’ & Higgs are the only known particles with all-zero quantum numbers
  - Q = I = J = S = B = L = 0
- ⇒ Standard-model decays are suppressed
- ⇒ BR with new physics are relatively enhanced



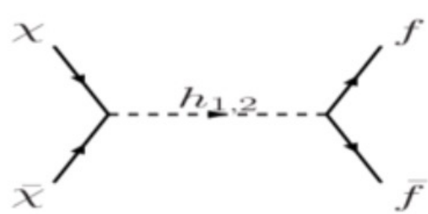
- η / η’ decays can be used to explore various portals to the dark sector



dark photon

$\eta \to \gamma A'$

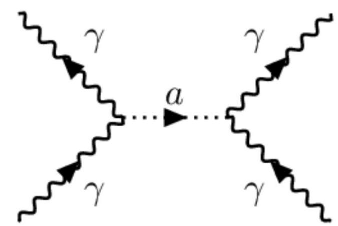
$A' \to \mu^+\mu^- / e^+e^-$



dark Higgs

$\eta \to \pi^0 H$

$H \to \pi^+\pi^- / \mu^+\mu^- / e^+e^-$

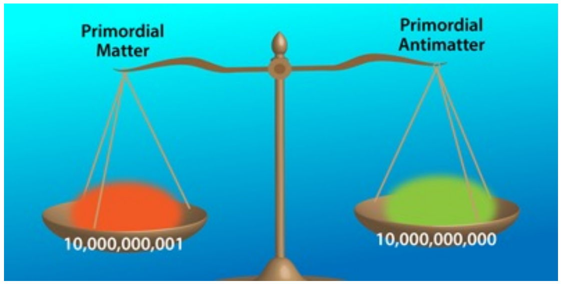


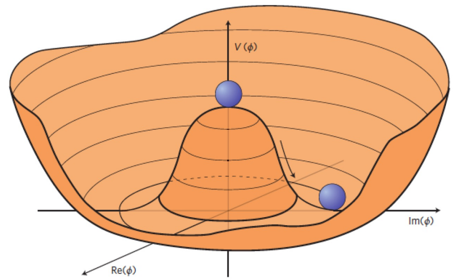
axion(-like particle)

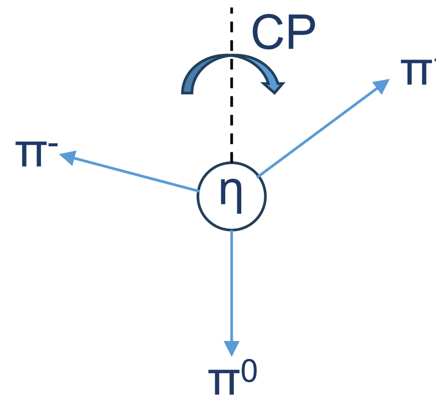
$\eta \to \pi\pi a$

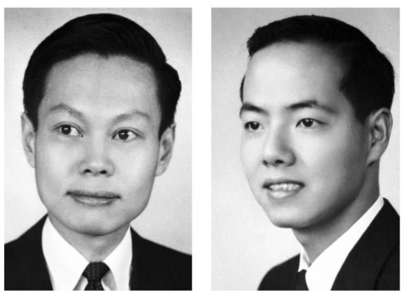
$a \to \gamma\gamma / \mu^+\mu^- / e^+e^-$

η meson physics – fundamental (a)symmetry

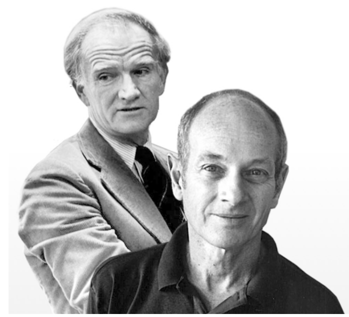








杨振宁、李政道



James W. Cronin & Val L. Fitch

~~P~~: 1957

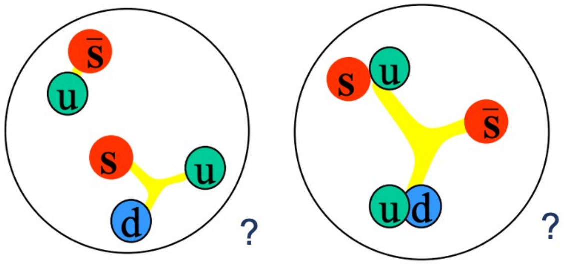
~~CP~~: 1980

- Foundamental (a)symmetry is an important question in physics
- η / η’ decays can be used to search for new fundamental asymmetries

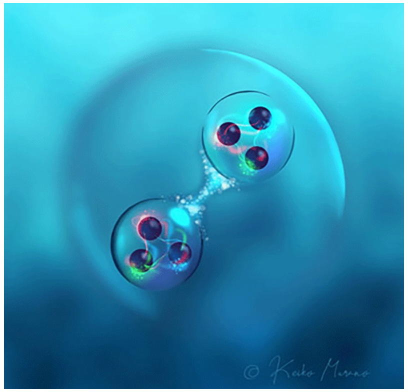
Light hadron physics

Particle	J^P	overall	$N\gamma$	$N\pi$	$\Delta\pi$	ΣK	$N\rho$	$\Delta\eta$
$\Delta(1232)$	$3/2^+$	****	****	****				
$\Delta(1600)$	$3/2^+$	****	****	***	****			
$\Delta(1620)$	$1/2^-$	****	****	****	****			
$\Delta(1700)$	$3/2^-$	****	****	****	****	*	*	
$\Delta(1750)$	$1/2^+$	*	*	*		*		
$\Delta(1900)$	$1/2^-$	***	***	***	*	**	*	
$\Delta(1905)$	$5/2^+$	****	****	****	**	*	*	**
$\Delta(1910)$	$1/2^+$	****	***	****	**	**		*
$\Delta(1920)$	$3/2^+$	***	***	***	***	**		**
$\Delta(1930)$	$5/2^-$	***	*	***	*	*		
$\Delta(1940)$	$3/2^-$	**	*	**	*			*
$\Delta(1950)$	$7/2^+$	****	****	****	**	***		
$\Delta(2000)$	$5/2^+$	**	*	**	*		*	
$\Delta(2150)$	$1/2^-$	*		*				
$\Delta(2200)$	$7/2^-$	***	***	**	***	**		
$\Delta(2300)$	$9/2^+$	**		**				
$\Delta(2350)$	$5/2^-$	*		*				
$\Delta(2390)$	$7/2^+$	*		*				
$\Delta(2400)$	$9/2^-$	**	**	**				
$\Delta(2420)$	$11/2^+$	****	*	****				
$\Delta(2750)$	$13/2^-$	**		**				
$\Delta(2950)$	$15/2^+$	**		**				

- Baryon spectroscopy

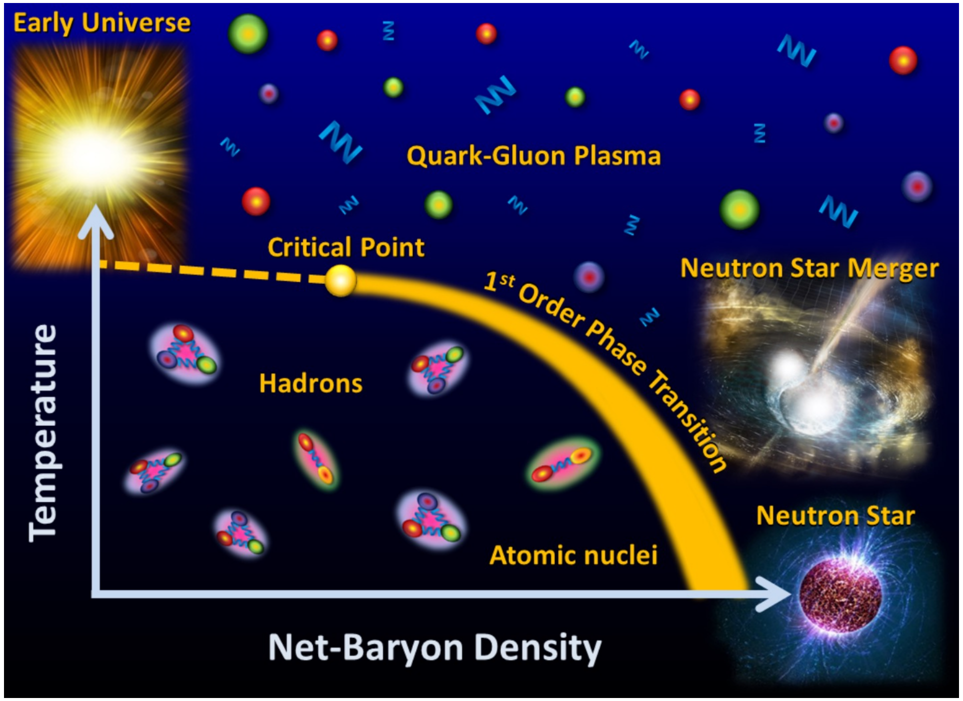


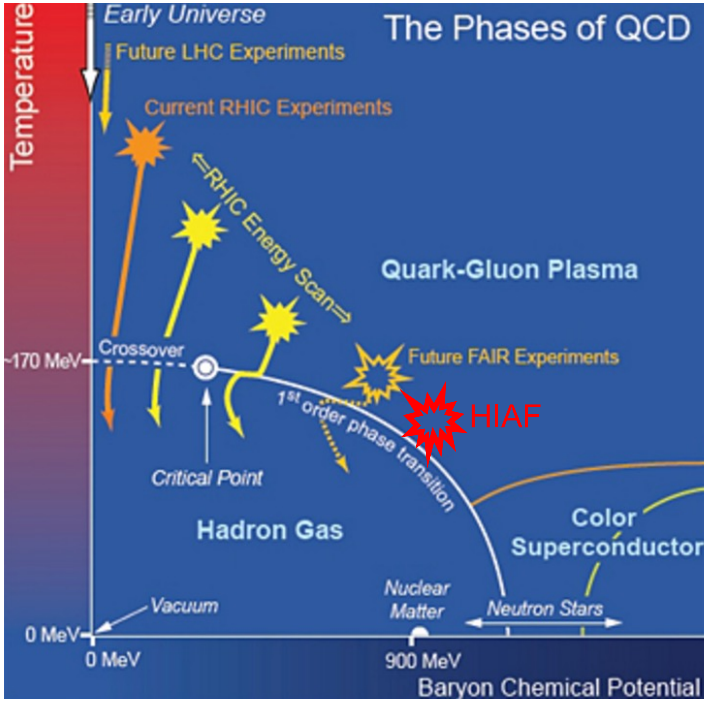
- Pentaquark states with only light quarks?



- Di-baryons?

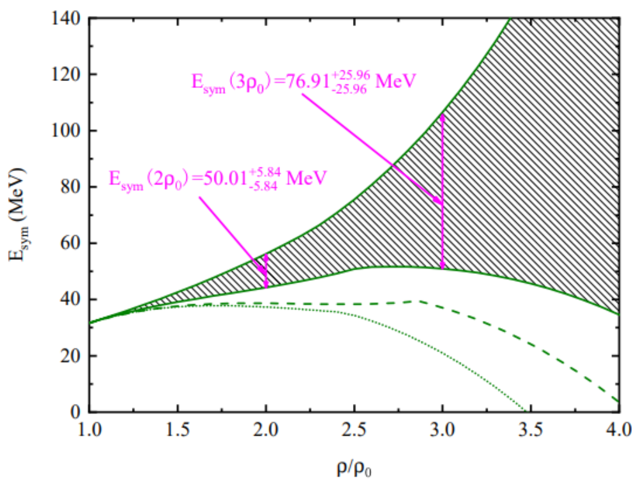
Nuclear matter phase diagram

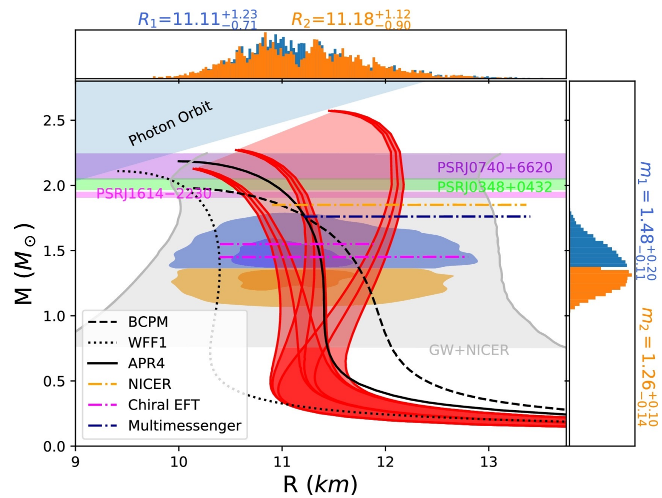


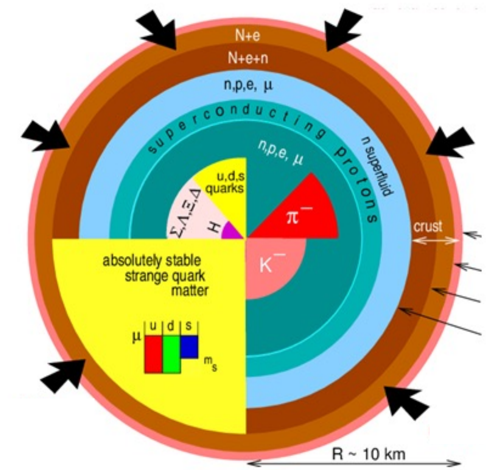


- The nuclear matter phase diagram can be scanned by heavy ion collisions at different energies.
- The 1st order phase transition and the critical point can be searched.

Nuclear matter equation of state

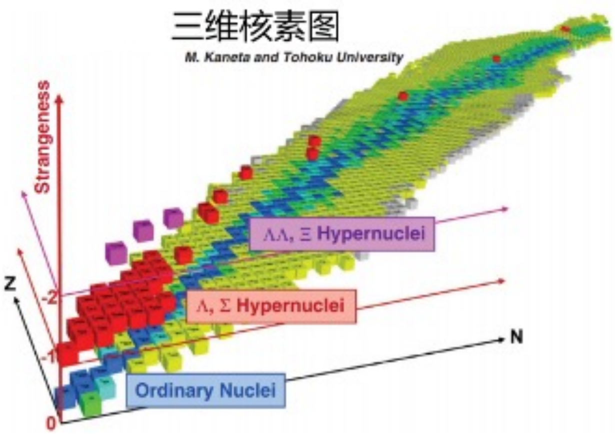


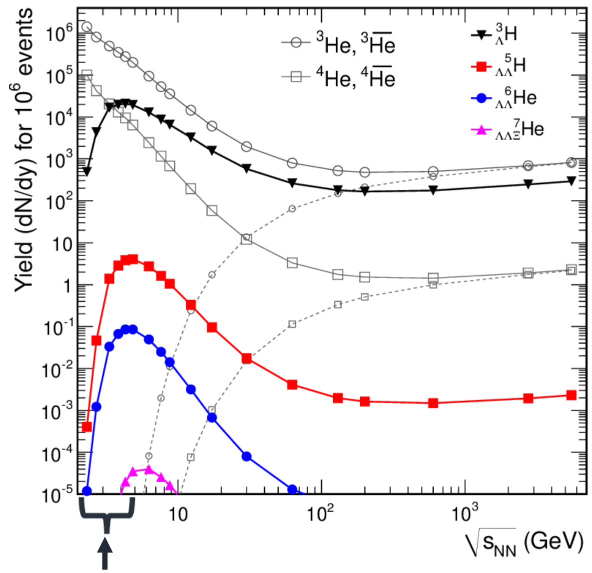




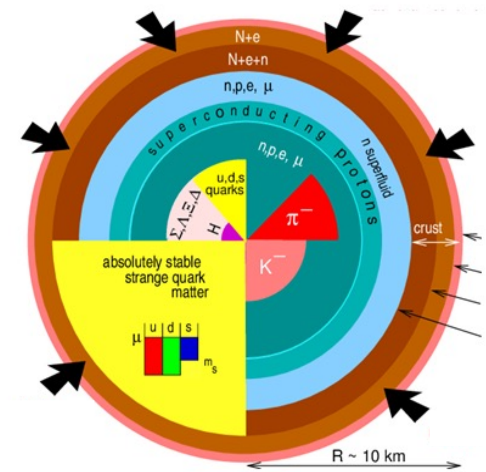
- nuclear matter equation of state
- ⇒ structure and properties of neutron stars

Hypernuclei



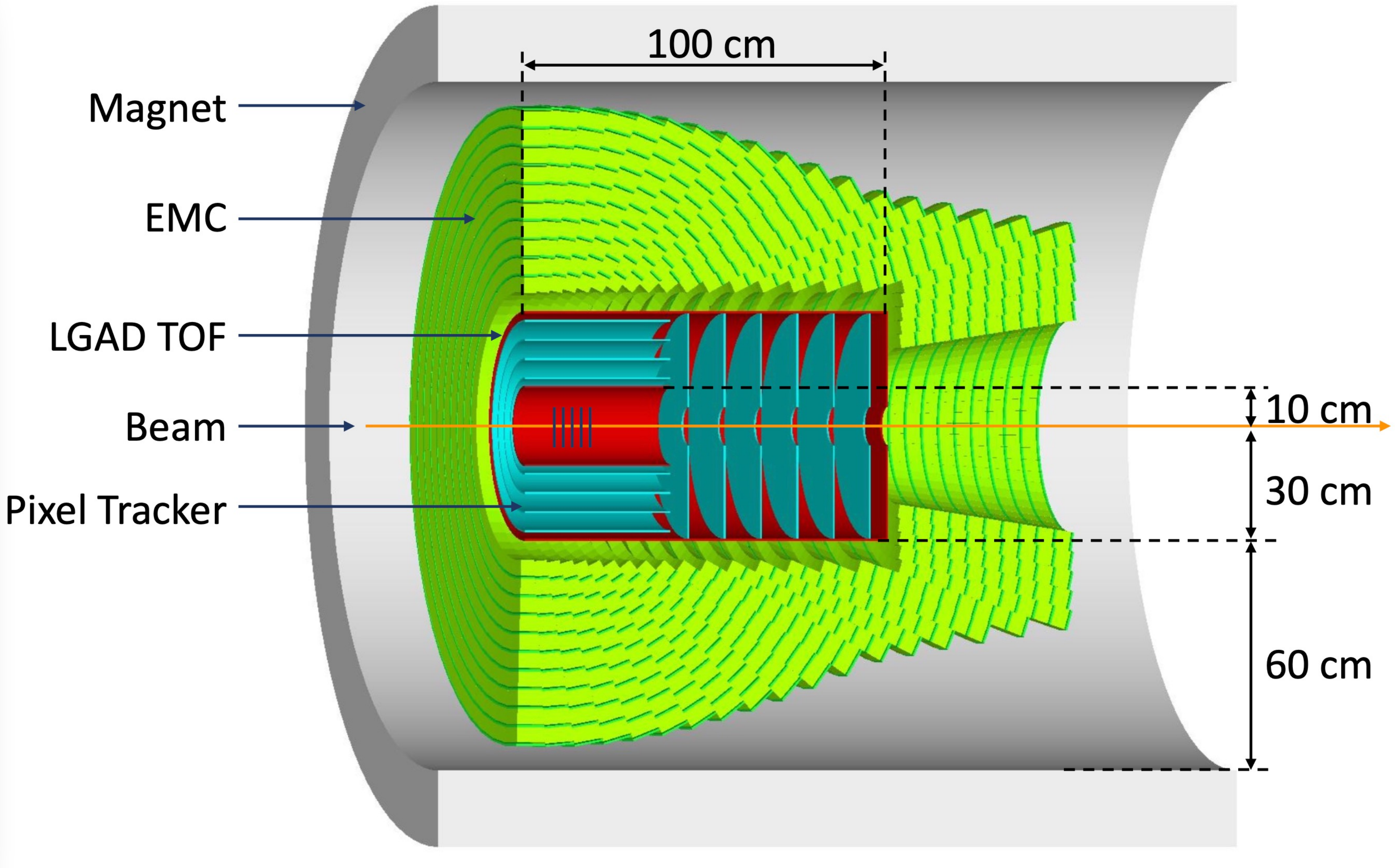


HIAF & HIAF-U

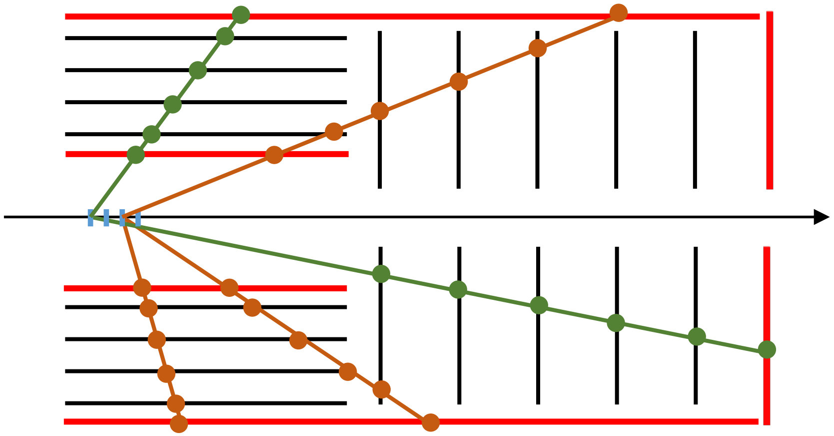


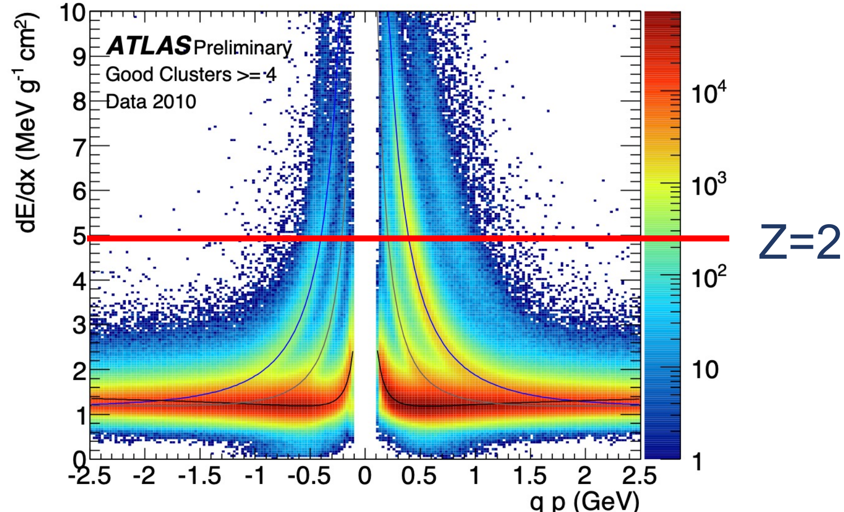
- hypernucleus properties & discovery of new (multi-strange) hypernuclei
- ⇒ hyperon-nucleon & hyperon-hyperon interactions
- ⇒ structure and properties of neutron stars

Conceptual design

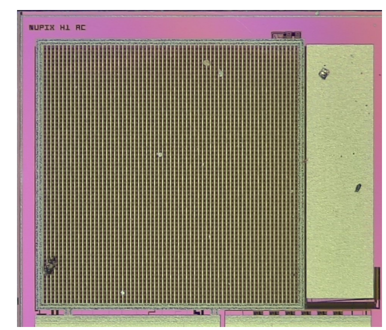


5D pixel tracker



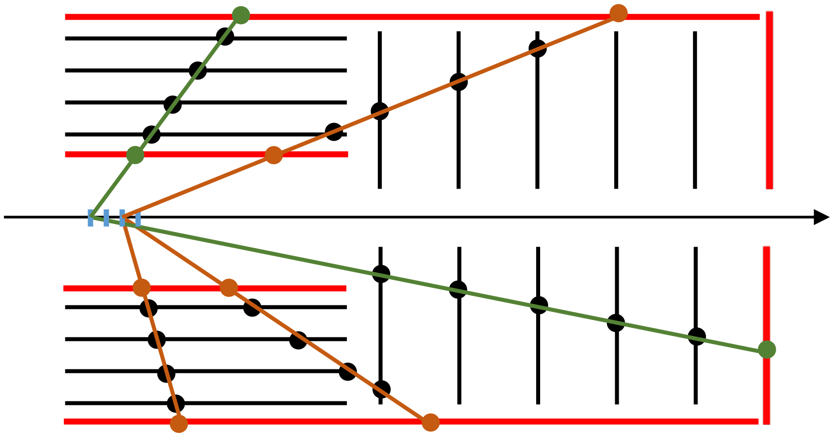


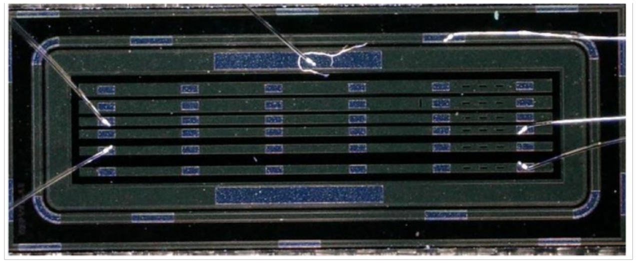
- 5D-tracking: 3D position + time + energy loss readout
  - Distinguish hits from different events by time: Δt ~10ns (1/100MHz)
    - rare physics search, high precision measurements
  - dE/dx to identify light nuclei with different Z (d, ^{4}He, ^{6}Li…)
    - hypernucleus measurements
- pixel size ~<100μm ⇒ Δx ~<30μm
- X/X_0 ~ 0.3%
- Single pixel dead time ~10μs ⇒ control occupancy when running with high event rate

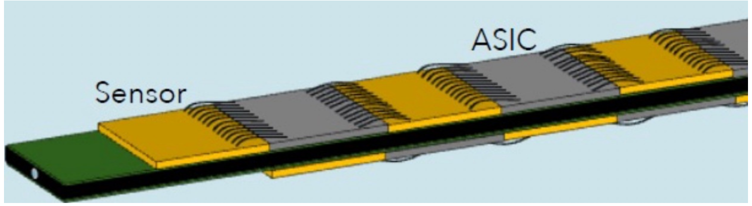


Nupix-H1 sensor

LGAD TOF

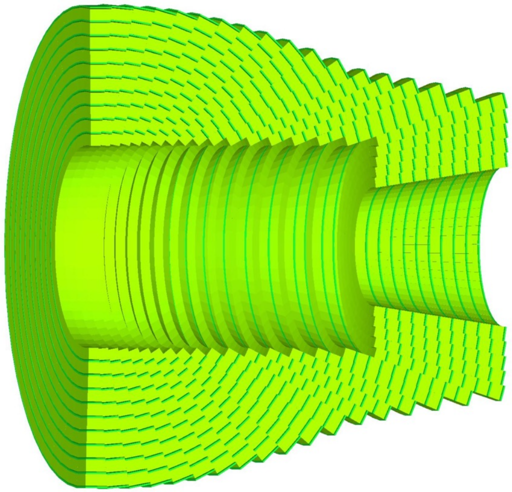
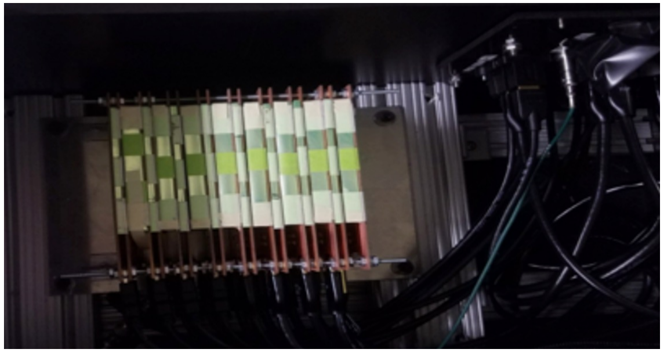
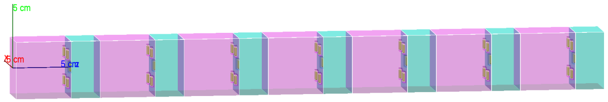
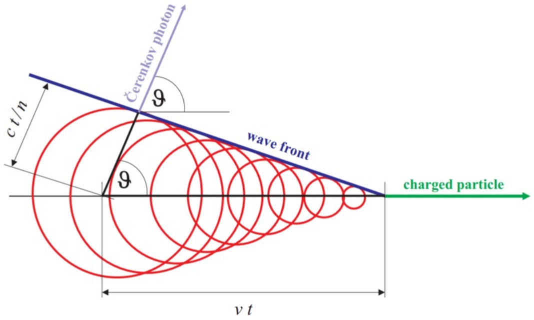






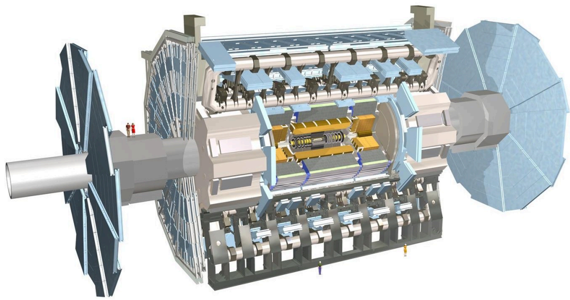
- Low Gain Avalanche Detectors
- Inner barrel (start time) + outer barrel & end cap (end time)
- $\Delta t \sim 30$ps
- AC LGAD with strip read-out electrode
  - $\Delta x_{r\varphi} \sim< 30\mu m \Rightarrow$ also used in track fitting
  - No in-chip dead area
- $X/X_0 \sim< 3\%$

Dual-readout calorimeter

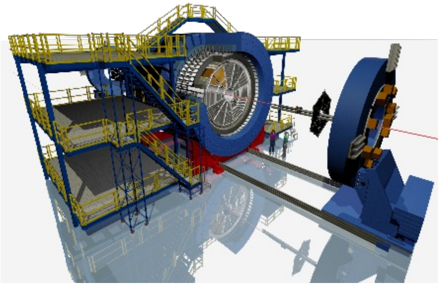





- "ADRIANO2" type of calorimeter adopted by the REDTOP collaboration
- Pb glass + scintillator dual-readout ⇒ very good e^{+-} vs. π^{+-} & γ vs. n PID
  - Pb glass: Cherenkov light, signal only for EM showers
  - scintillator: signal for both EM and hadronic showers
- $\Delta E/E \sim 3\%$ @1GeV
- $\Delta t \sim 200$ps ⇒ distinguish signals from different events
- shaping time (module dead time) < μs ⇒ control occupancy

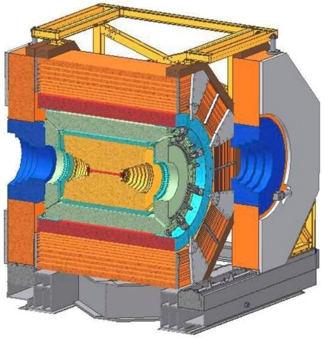
Key feature I: Ultra-high event rate – why?



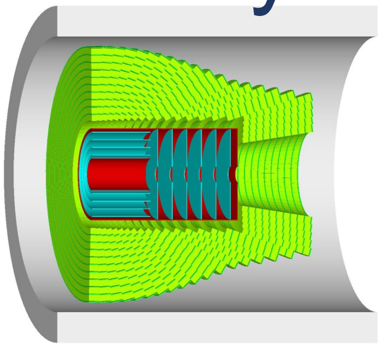
ATLAS: 100 kHz



STAR: 1 kHz



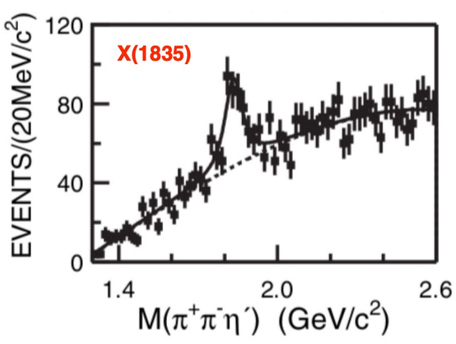
BESIII: 4 kHz



HHaS: 100 MHz

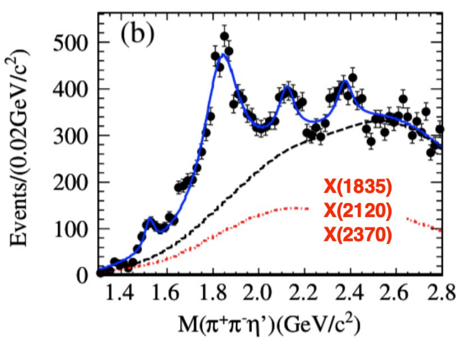
1亿/秒

BESII PRL95 (2005) 262001



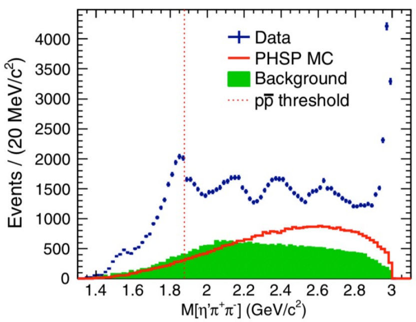
58M J/ψ

BESIII PRL106 (2011) 072002



230M J/ψ

BESIII PRL117 (2016) 042002



1B J/ψ

BESIII PRL 132 (2024) 181901

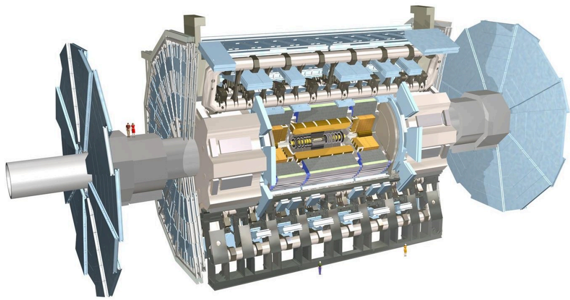
X(2370) $J^{PC} = 0^{-+}$

glueball-like particle

10B J/ψ

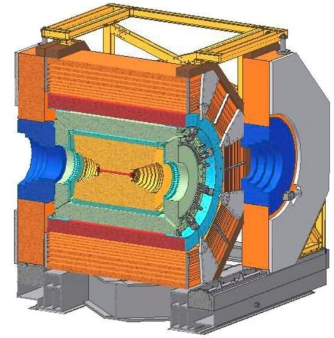
- HHaS is 3-5 orders of magnitude faster than current experiments
- History has repeatedly shown that more statistics and better precision leads to new discoveries

Key feature I: Ultra-high event rate – why?

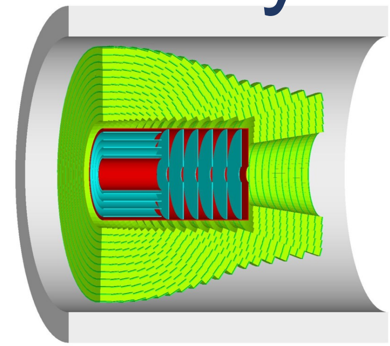


ATLAS: 100 kHz

STAR: 1 kHz



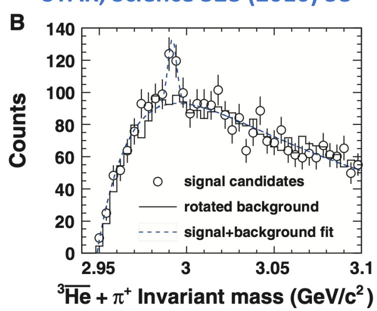
BESIII: 4 kHz



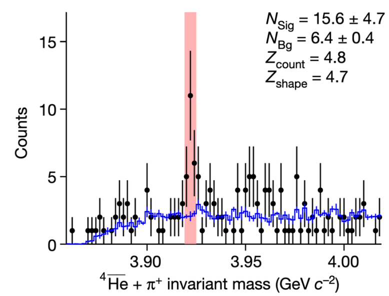
HHaS: 100 MHz

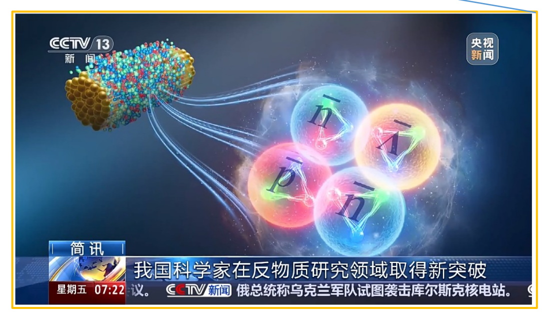
1亿/秒

STAR, Science 328 (2010) 58



STAR, Nature 632 (2024) 1026





1 min

1st observed antihypernucleus

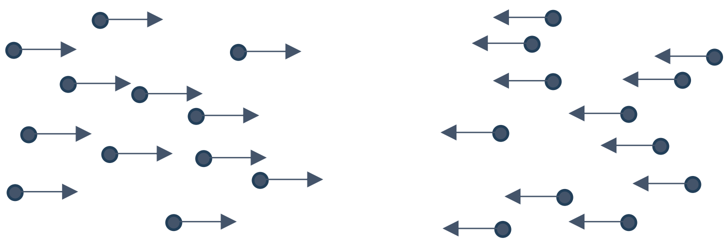
– antihypertriton: 110M events

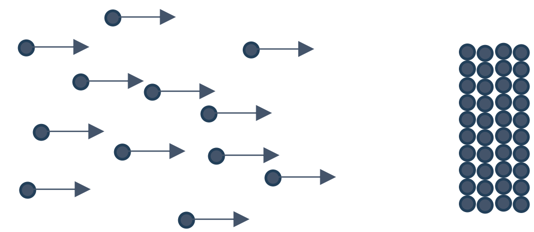
Heaviest observed antihypernucleus

– antihyperH4: 6B events since yr 2010

- HHaS is 3-5 orders of magnitude faster than current experiments
- History has repeatedly shown that more statistics and better precision leads to new discoveries

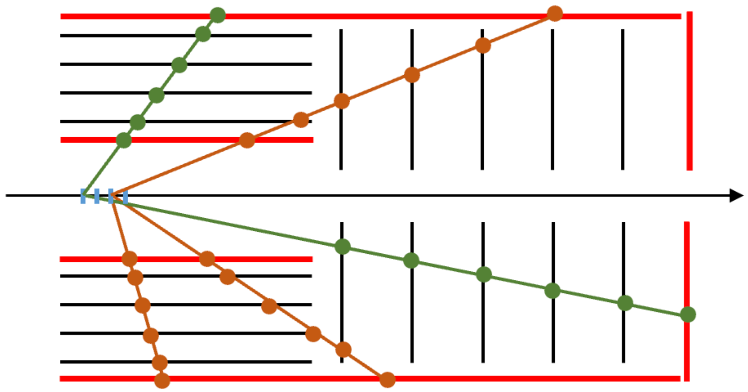
Key feature I: Ultra-high event rate – why?

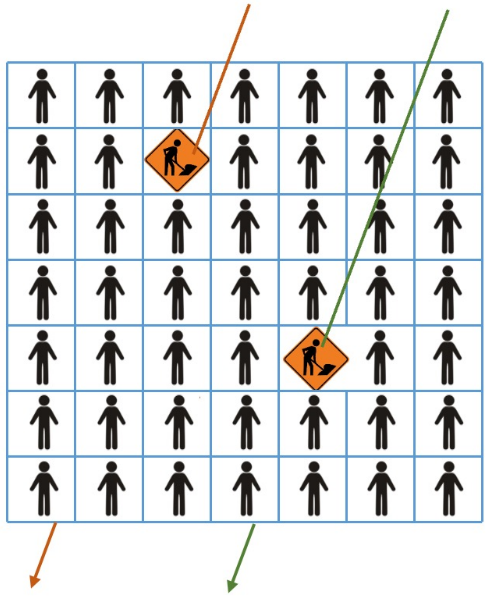




- It's much easier to obtain high luminosity with fixed target experiments than colliders
- High Intensity heavy-ion Accelerator Facility (HIAF)
  - 2×10^{12} protons in 0.3s ⇒ ~10 GHz maximum collision rate, far beyond current experiment's capabilities
- Capability to record events with an ultra-high rate is necessary to exploit HIAF's high luminosity

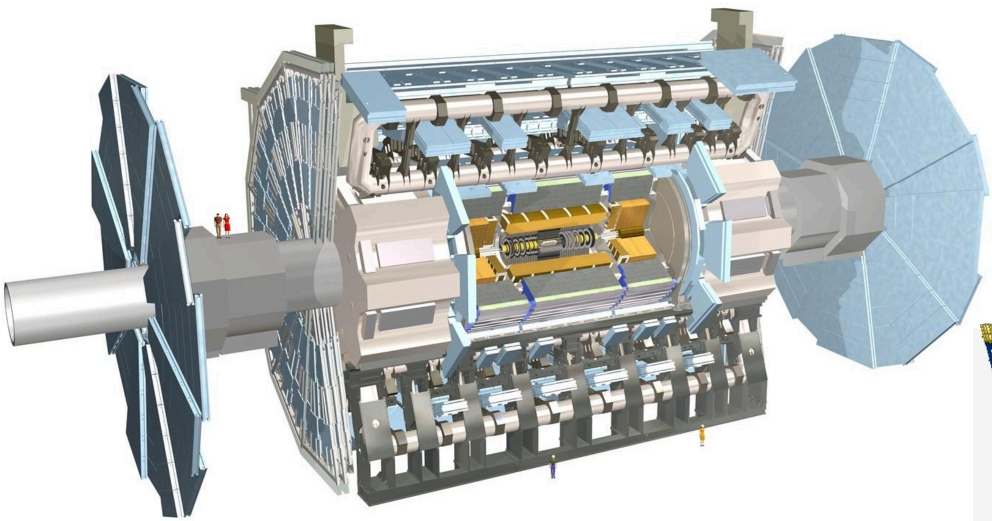
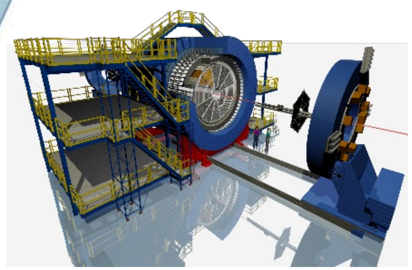
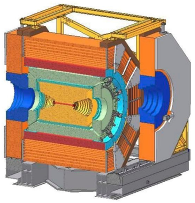
Key feature I: Ultra-high event rate – how?





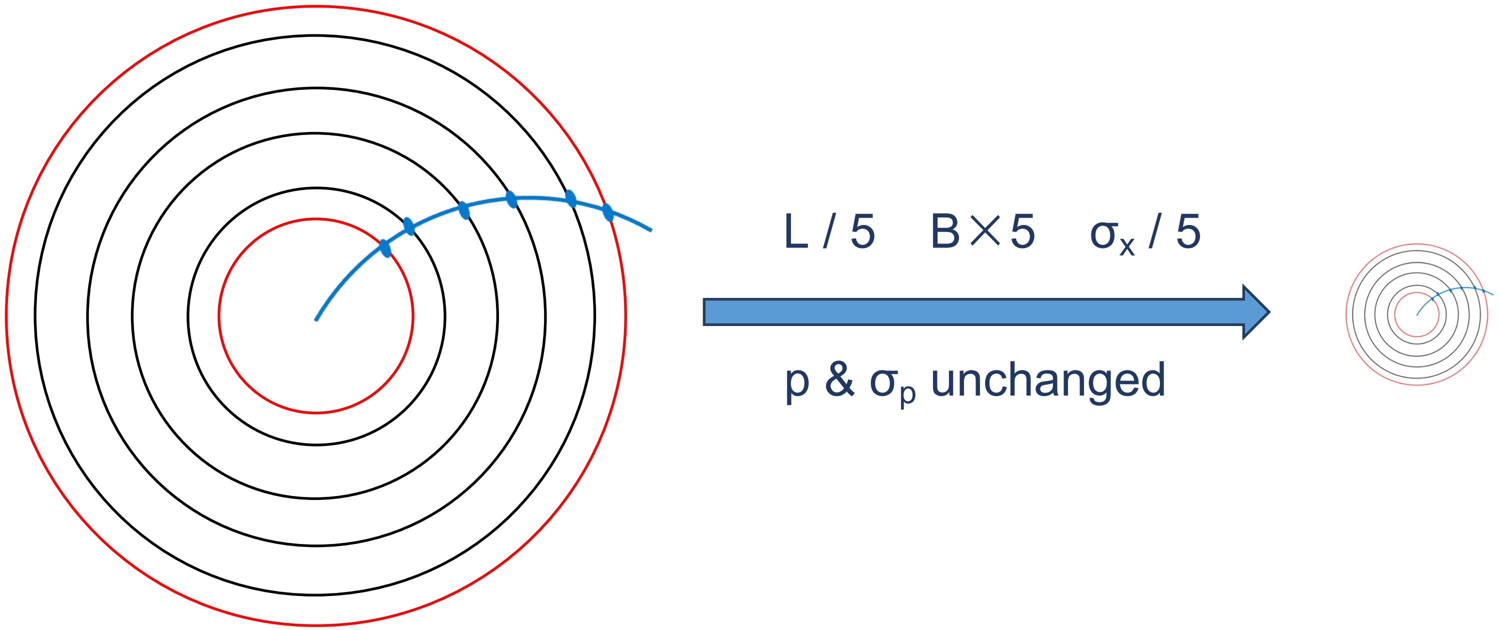
- Each pixel (strip / tower) record hit time information
  - used to distinguish signals from different collisions
- Pixels (strip / tower) work parallelly to record hits from different collisions
  - like GPU: large amount of pixels ⇒ ultra high event rate
  - ~>20M pixels on the innermost layer ⇒ ~0.02% occupancy with 100 MHz event rate

Key feature II: Compact


ATLAS STAR BESIII HHaS

Key feature II: Compact



- Traditional gas tracking detector σ_x ~ mm
- Pixel σ_x ~ tens μm
- ⇒ HHaS pixel tracker with R_{out} = 30cm has similar σ_p as meter scale gas detector trackers

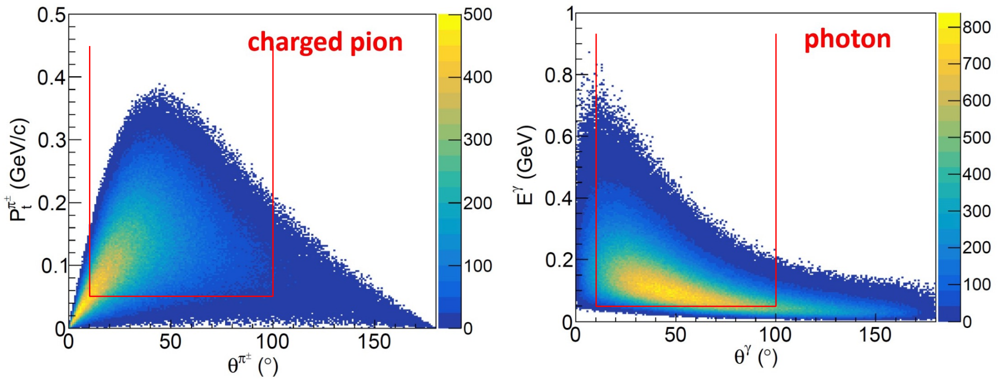
Key feature II: Compact – moderate cost

Sub-system	cost (M Chinese yuan)
Target	0.5
pixel tracker	30
LGAD TOF	33
EMC	22
Solenoid	20
Supporting structure	1
DAQ	24
Total	130.5

- ~1.3亿元

Expected performance – large acceptance

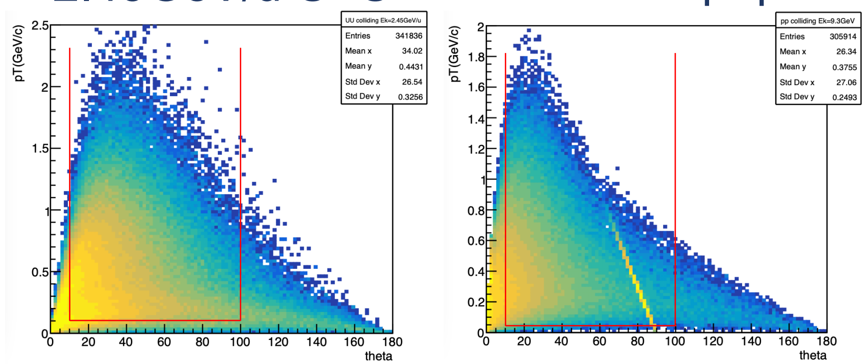
$\eta \rightarrow \pi^+\pi^-\pi^0(\gamma\gamma)$



charged particles

2.45GeV/u U+U

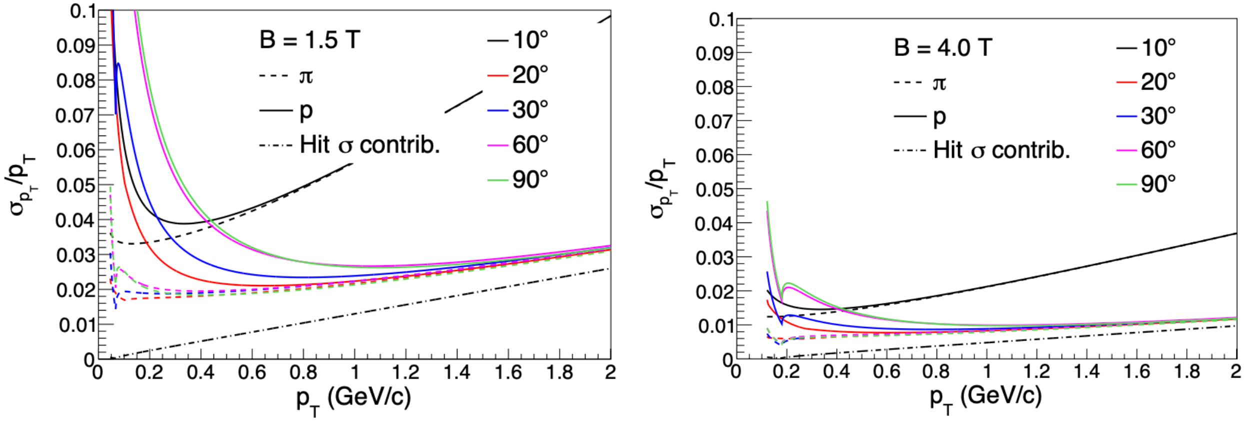
9.3GeV p+p



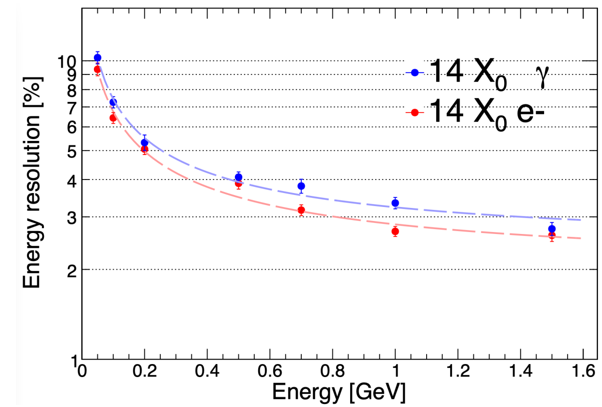
angle, momentum and energy coverage

event rate	~100 MHz (p beam), ~1 MHz (HI beam)
angle coverage	θ: 10˚~100˚; φ: 0~2π
charged particle p_T range	p_T > 50 MeV (B=1.5 T)
γ energy range	E > 50 MeV
typical p_T resolution	~3% (B = 1.5 T); ~1% (B = 4 T)
EM energy resolution	~3% @ 1GeV
typical track pointing resolution	~0.9 mm (p @ 500 MeV/c)
identified particles	e^{+-}, γ, π^{+-}, K^{+-}, p, d, t, ^{3}He, ^{4}He

Expected performance – good resolution



p_T resolution



EM energy resolution

event rate	~100 MHz (p beam), ~1 MHz (HI beam)
angle coverage	θ: 10˚~100˚; φ: 0~2π
charged particle p_T range	p_T > 50 MeV (B=1.5 T)
γ energy range	E > 50 MeV
typical p_T resolution	~3% (B = 1.5 T); ~1% (B = 4 T)
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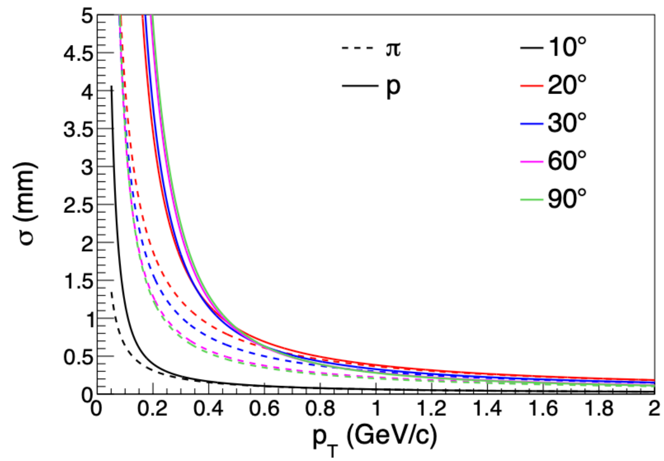

track pointing resolution

event rate	~100 MHz (p beam), ~1 MHz (HI beam)
angle coverage	θ: 10˚~100˚; φ: 0~2π
charged particle p_T range	p_T > 50 MeV (B=1.5 T)
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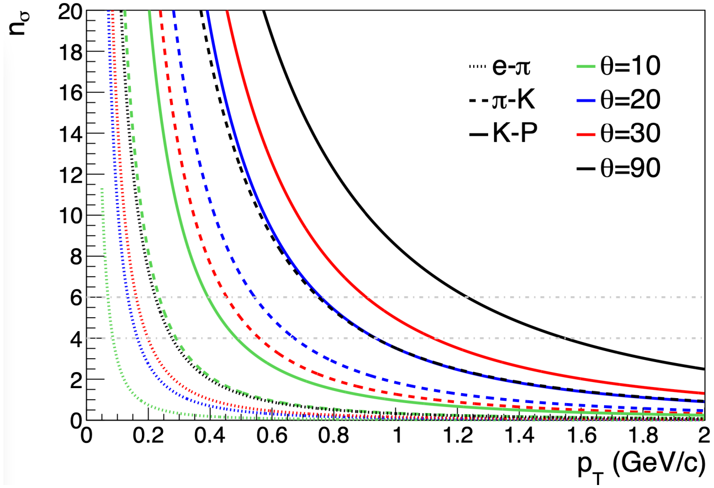
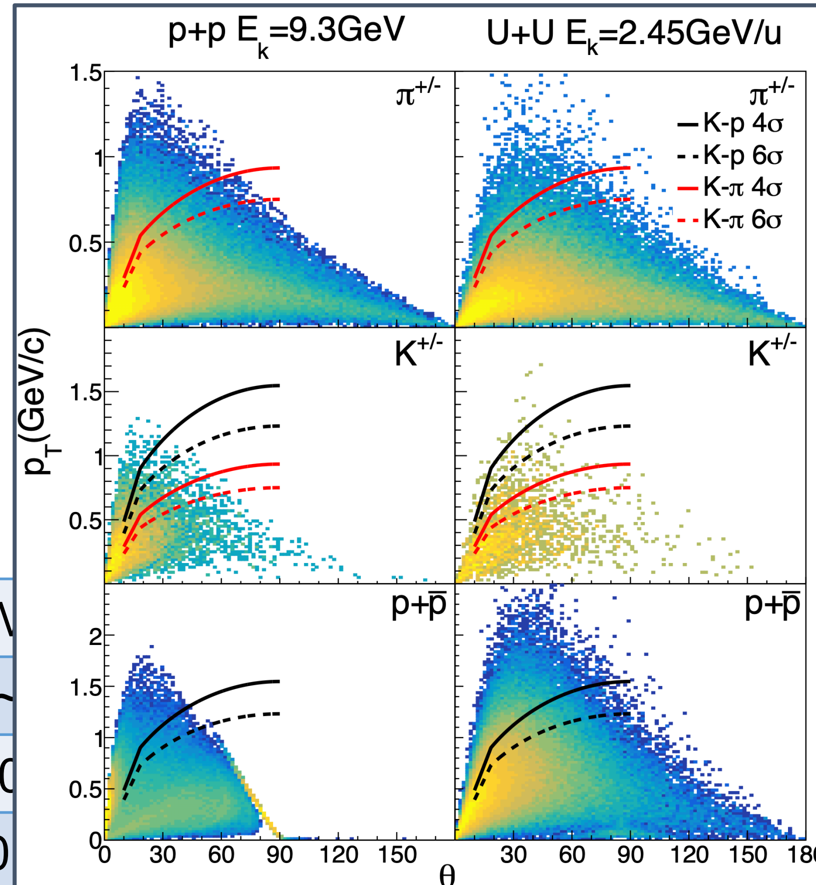
Expected performance – good PID ability



TOF particle identification performance



event rate	~100 M
angle coverage	θ: 10°~
charged particle p_T range	p_T > 50
γ energy range	E > 50
typical p_T resolution	~3% (B = 1.5 T); ~1% (B = 4 T)
EM energy resolution	~3% @ 1GeV
typical track pointing resolution	~0.9 mm (p @ 500 MeV/c)
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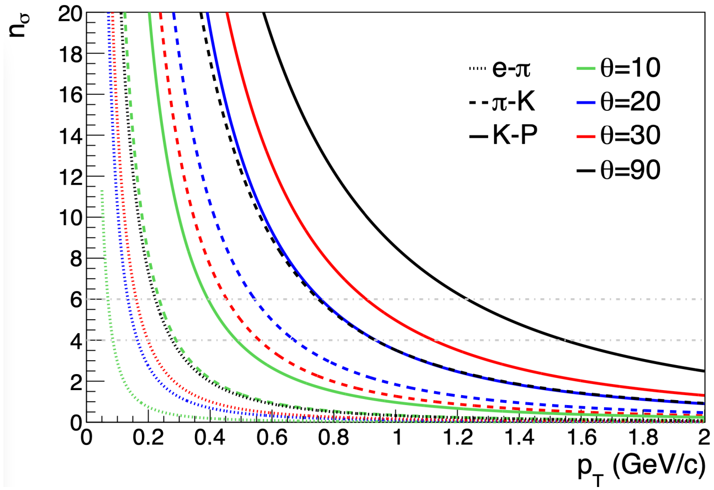
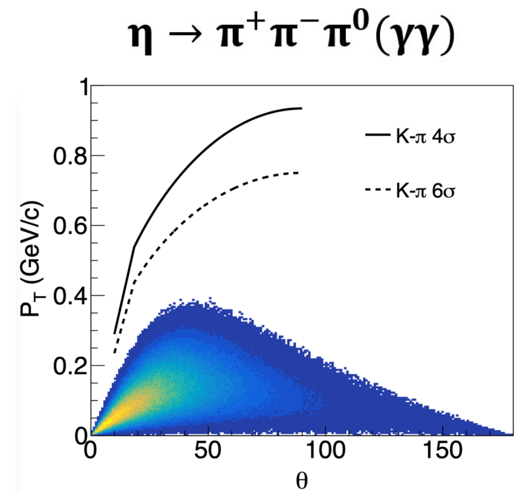


TOF particle identification performance



event rate	~100 MHz (p beam), ~1 MHz (HI beam)
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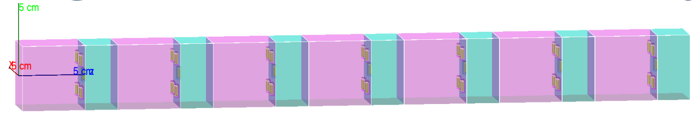
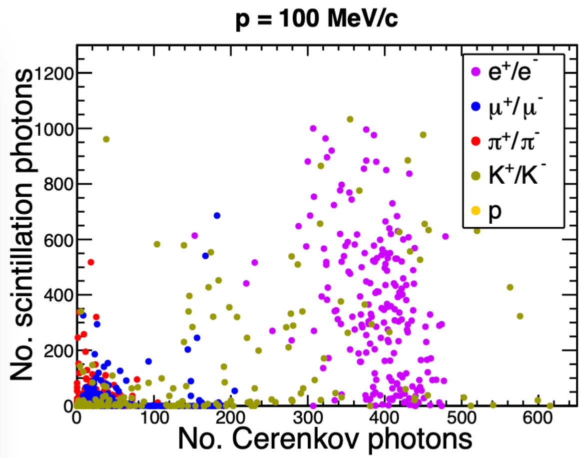
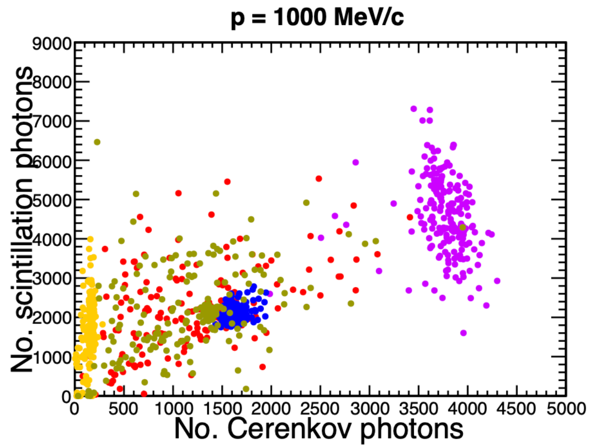
identified particles	e^{+-}, γ, π^{+-}, K^{+-}, p, d, t, ^3He, ^4He

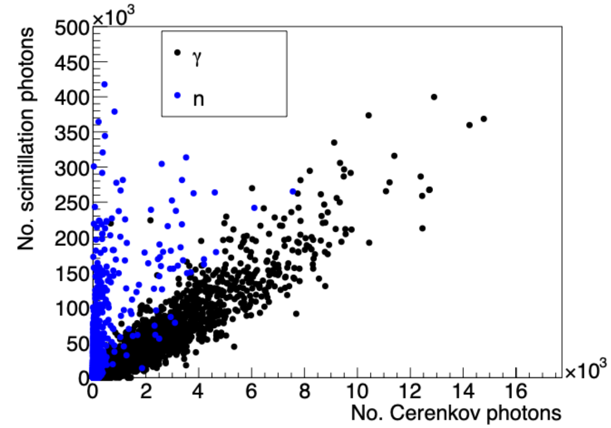
Expected performance – good PID ability

EM vs. hadron shower identification









event rate	~100 MHz (p beam), ~1 MHz (HI beam)
angle coverage	θ: 10˚~100˚; φ: 0~2π
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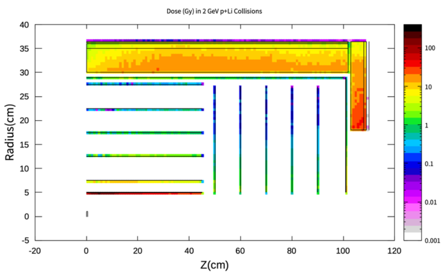
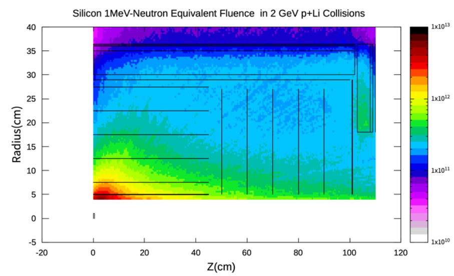
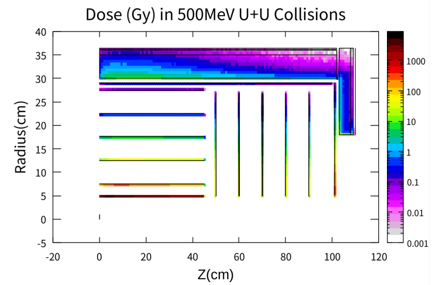
Radiation hardness

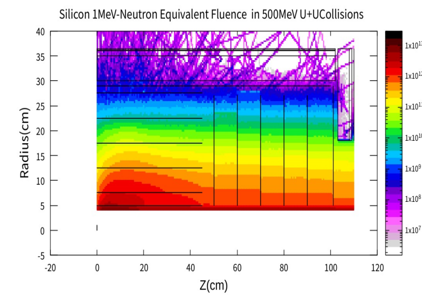
2 GeV p+Li





500 MeV U+U





	simulation with FLUKA		reference radiation hardness		
	Dose (Gy)	Si1MeV fluence (neq/cm2)	detector/material	Dose (Gy)	Si1MeV fluence (neq/cm2)
innermost Si	3000	3×10^{12}	pixel	2×10^{4}	1.7×10^{13}
			LGAD		1×10^{15}
innermost EMC	50	3×10^{11}	lead glass	20	
			SiPM		1×10^{14}

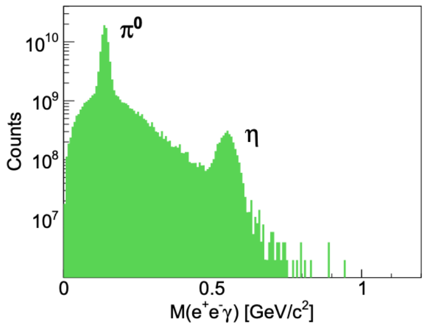
- Most detector components can sustain the radiation
- Lead glass will receive a dose that is close to its limit (TF101: 1% transmittance loss after 20-Gy radiation dose) ⇒ Need to test and select a good type of lead glass

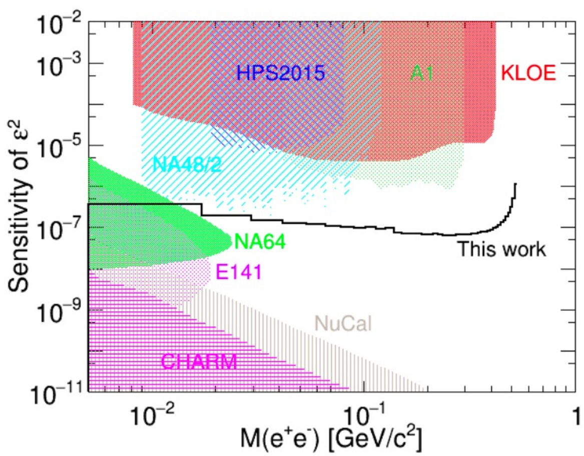
Data rate

- pixel tracker:
    - 100 MHz * 4 track / event * 4 hits / track * 2 pixel / hit * 8 Byte / pixel = 26 GB/s
- LGAD TOF:
    - 100 MHz * 4 track / event * 2 hits / track * 2 strip / hit * 6 Byte / strip = 10 GB/s
- EMC:
    - 100 MHz * 0.4 γ / event * 9 towers / γ * 8 Byte / tower = 3 GB/s
- 39 GB/s in total
- For reference, CEE design data bandwidth 5 GB/s

η meson physics

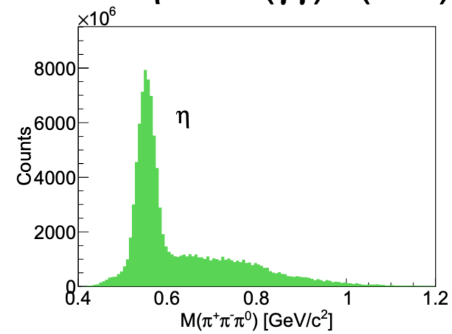
$\eta \to e^+e^-\gamma$

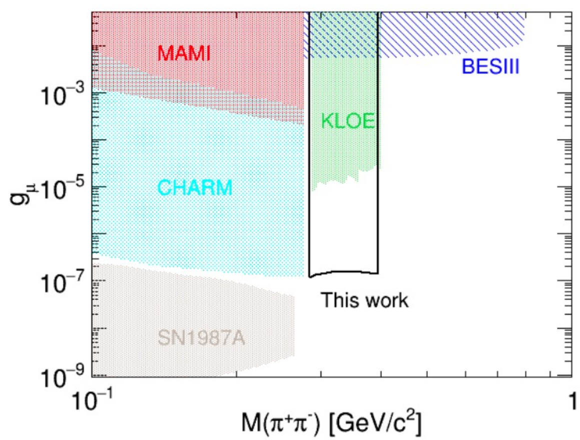




search for dark photon

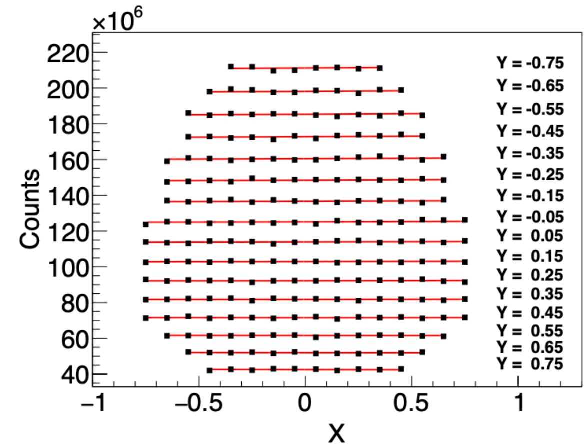
$\eta \to \pi^0(\gamma\gamma)\ h(\pi^+\pi^-)$





search for dark Higgs

$\eta \to \pi^+\pi^-\pi^0$

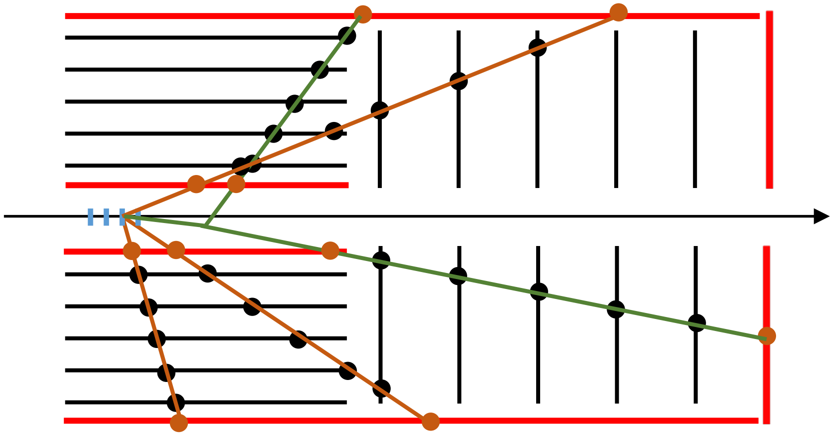


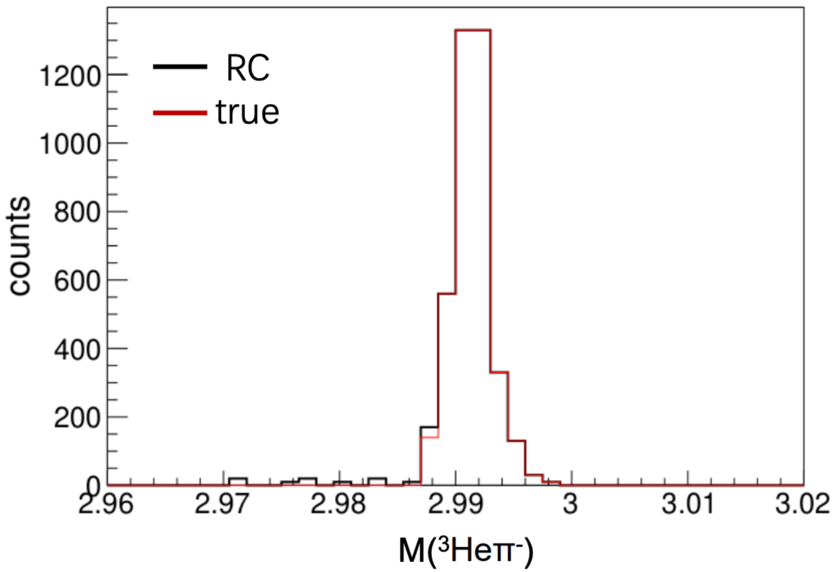
- CP symmetry test
- $\Delta c \sim 5 \times 10^{-5}$
- ~2 orders of magnitude more precise than COSY & KLOE-II results

Nuclear Science and Techniques (2025) 36:137

- 1.8 GeV p + ^{7}Li, 1 month, 100MHz, average / peak beam intensity = 30%
- 6×10^{11} η produced 1000 times of current world η meson data

Hypernucleus reconstruction



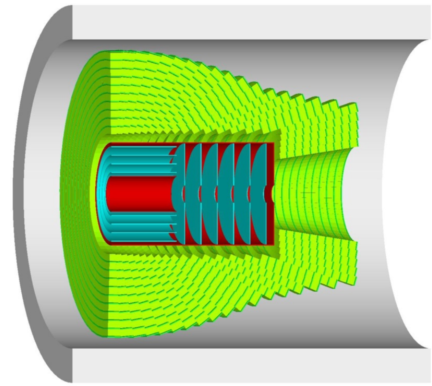


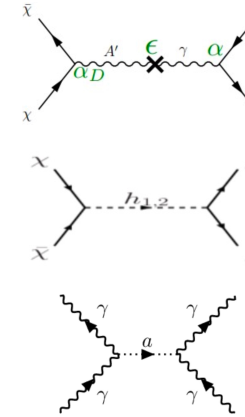
- ~mm level pointing resolution

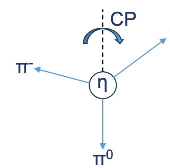
  ⇒ background-free hypernucleus reconstruction with decay topology information

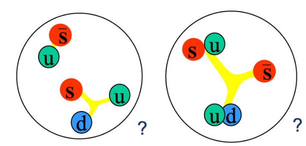
Summary

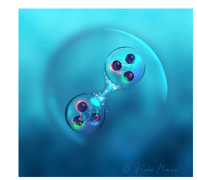
- Huizhou Hadron Spectrometer (HHaS)
  - sate-of-the-art detectors
    - 5-D pixel tracking
    - LGAD TOF detector
    - ADRIANO-II type calorimeter
  - good expected performance
    - event rate > 100 MHz (p beam)
    - large acceptance
    - comprehensive PID
      - e^{+-}, γ, π^{+-}, K^{+-}, p, d, t, ^{3}He, ^{4}He
  - Compact size ⇒ moderate cost
  - Wide range of physics

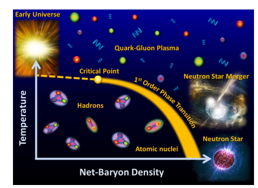


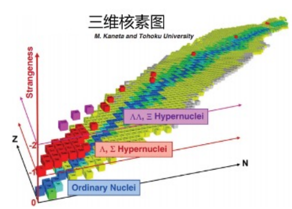












群聊：惠州强子谱仪HHaS

Thanks ☺ Welcome to join!

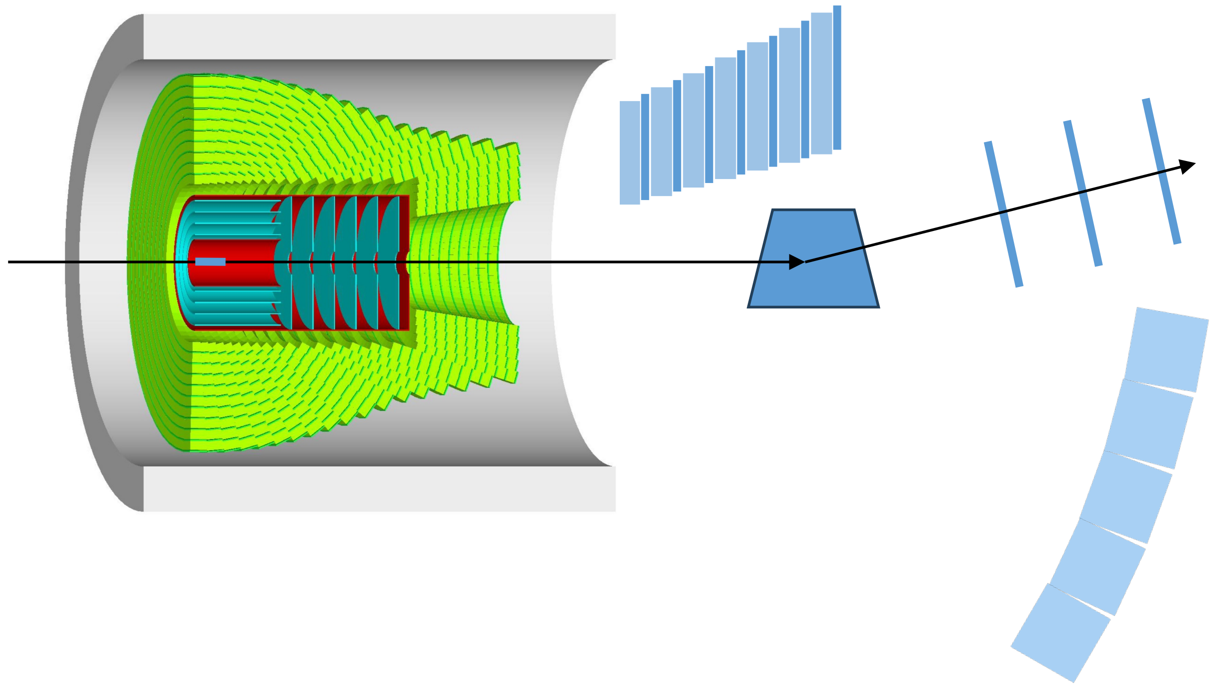
P.S.: future's future

polarized beam & target?

- spin physics

muon detector: plastic dead layer + MRPC?

- +2 times of decay channels for η meson physics



projectile endoscope?

- projectile-like hypernuclei
- short-range correlation

π & K beam?

- cleaner η meson physics
- light hadron & hypernuclear physics

neutron wall: liquid scintillator?

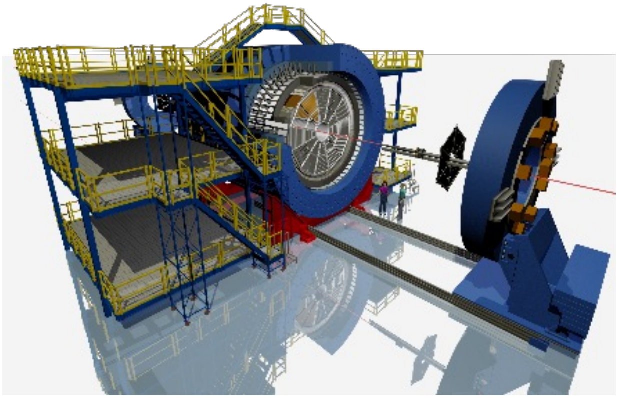
- light hadron physics
- short-range correlation

- ideas welcome

Thanks ☺

Back-up

P.S. I: versatile, too good to be true?

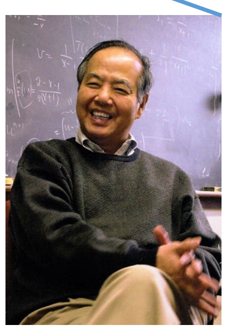


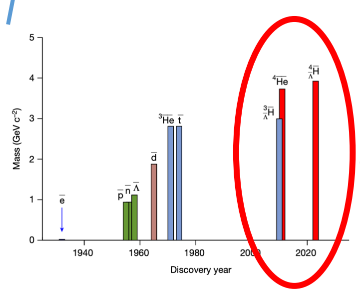
- STAR – glowing for 25 years

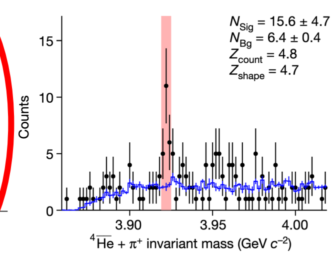
+ vertex detector

good tracking with large acceptance + EM calorimeter + TOF + muon detector + inner TPC + forward tracking & calorimeter

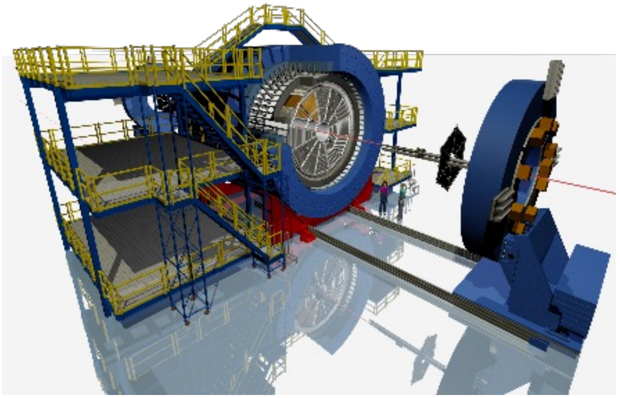
discovery & properties of QGP + proton spin + antimatter + phase transition & critical point + ultra-peripheral collisions







P.S. I: versatile, too good to be true?



- STAR – glowing for 25 years

+ vertex detector

good tracking with large acceptance + EM calorimeter + TOF + muon detector + inner TPC + forward tracking & calorimeter

discovery & properties of QGP + proton spin + antimatter + phase transition & critical point + ultra-peripheral collisions

- A specific experiment for one goal may work; a versatile experiment may also work
- Serious considerations, simulations, discussions & hardware R+D are needed
    - ideas & contributions always welcome
- When considering HIAF's 1st high-energy experiment, it does not hurt to be open-minded at first – if some goals do conflict, we can discuss and give up some aspects

e & muon

C, T, CP-violation

- CP Violation via Dalitz plot mirror asymmetry: $\eta \to \pi^o \pi^+ \pi^-$
- CP Violation (Type I – P and T odd , C even): $\eta \to 4\pi^o \to 8\gamma$
- CP Violation (Type II - C and T odd , P even): $\eta \to \pi^o \ell^+\ell^-$ **and** $\eta \to 3\gamma$
- Test of CP invariance via μ longitudinal polarization: $\eta \to \mu^+\mu^-$
- CP inv. via γ^* polarization studies: $\eta \to \pi^+\pi^- e^+e^-$ & $\eta \to \pi^+\pi^-\mu^+\mu^-$
- CP invariance in angular correlation studies: $\eta \to \mu^+\mu^- e^+e^-$
- CP invariance in angular correlation studies: $\eta \to \mu^+\mu^-\pi^+\pi^-$
- CP invariance in μ polar. in studies: $\eta \to \pi^o \mu^+\mu^-$
- T invar. via μ transverse polarization: $\eta \to \pi^o\mu^+\mu^-$ and $\eta \to \gamma\mu^+\mu^-$
- CPT violation: μ polar. in $\eta \to \pi^+\mu^-\nu$ vs $\eta \to \pi^-\mu^+\nu$ - γ polar. in $\eta \to \gamma\gamma$

Other discrete symmetry violations

- Lepton Flavor Violation: $\eta \to \mu^+e^- +$ c.c.
- Radiative Lepton Flavor Violation: $\eta \to \gamma(\mu^+e^- +$ c.c.
- Double lepton Flavor Violation: $\eta \to \mu^+\mu^+e^-e^- +$ c.c.

Non-η/η′ based BSM Physics

- Neutral pion decay: $\pi^o \to \gamma A' \to \gamma e^+e^-$
- ALP's searches in Primakoff processes: $p\,Z \to p\,Z\,a \to l^+l^-$ (F. Kahlhoefer)
- Charged pion and kaon decays: $\pi+ \to \mu^+\nu A' \to \mu^+\nu e^+e^-$ and $K+ \to \mu^+\nu A' \to \mu^+\nu e^+e^-$
- Dark photon and ALP searches in Drell-Yan processes: qqbar $\to A'/a \to l^+l^-$

New particles and forces searches

- Scalar meson searches (charged channel): $\eta \to \pi^o H$ with $H \to e^+e^-$ and $H \to \mu^+\mu^-$
- Dark photon searches: $\eta \to \gamma A'$ with $A' \to \ell^+\ell^-$
- Protophobic fifth force searches : $\eta \to \gamma X_{17}$ with $X_{17} \to \pi^+\pi^-$
- QCD axion searches : $\eta \to \pi\pi \mathbf{a}_{17}$ with $\mathbf{a}_{17} \to e^+e^-$
- New leptophobic baryonic force searches : $\eta \to \gamma B$ with $B \to e^+e^-$ or $B \to \gamma\pi^o$
- Indirect searches for dark photons new gauge bosons and leptoquark: $\eta \to \mu^+\mu^-$ and $\eta \to e^+e^-$
- Search for true muonium: $\eta \to \gamma(\mu^+\mu^-)|_{2M_\mu} \to \gamma e^+e^-$
- Lepton Universality
- $\eta \to \pi^o H$ with $H \to \nu N_2$, $N_2 \to h'N_1$, $h' \to e^+e^-$

Other Precision Physics measurements

- Proton radius anomaly: $\eta \to \gamma\mu^+\mu^-$ vs $\eta \to \gamma e^+e^-$
- All unseen leptonic decay mode of η / η′ (SM predicts 10^{-6} -10^{-9})

High precision studies on medium energy physics

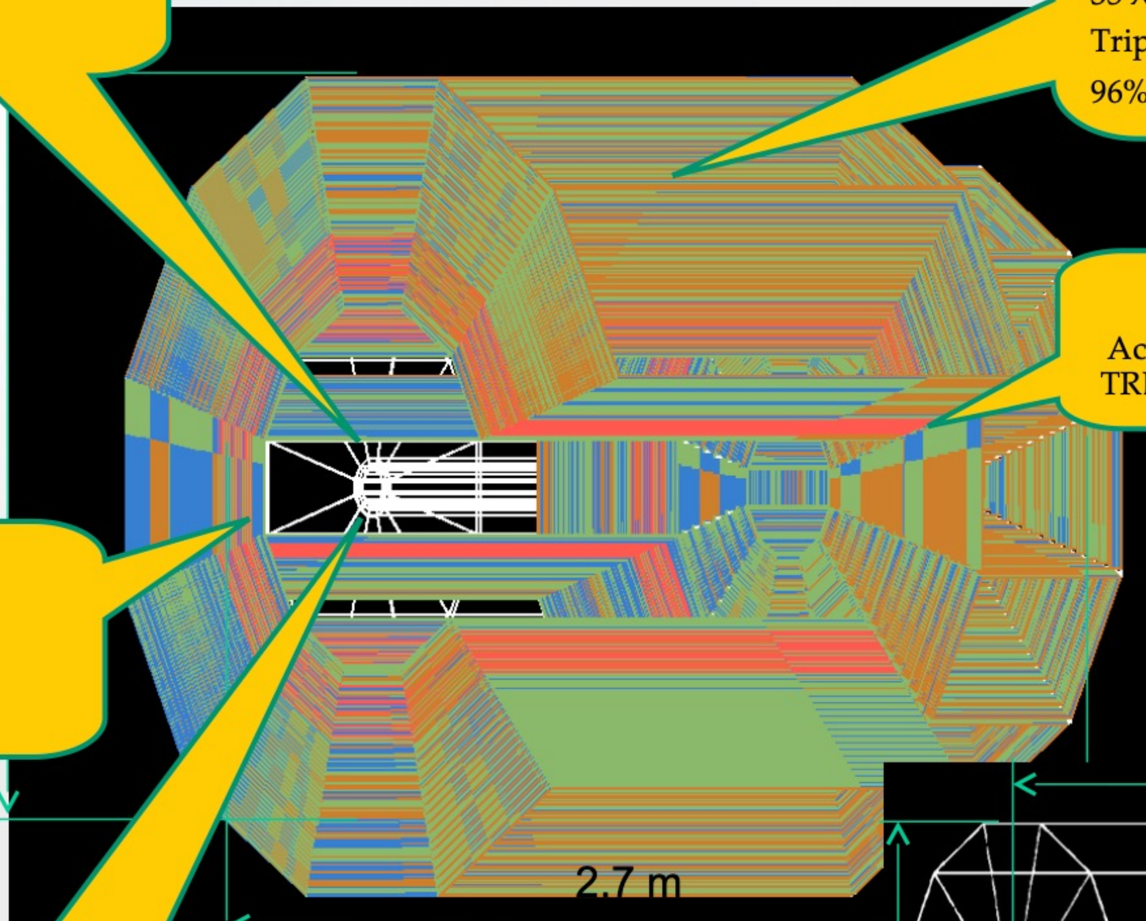
- Nuclear models
- Chiral perturbation theory
- Non-perturbative QCD
- Isospin breaking due to the u-d quark mass difference
- Octet-singlet mixing angle
- Electromagnetic transition form-factors (important input for g-2)

- 绝大部分eta衰变道研究需要电子 & / 缪子

REDTOP detector

Central Tracker
~ 1m x 1.5 m
Thin LGAD
98% coverage

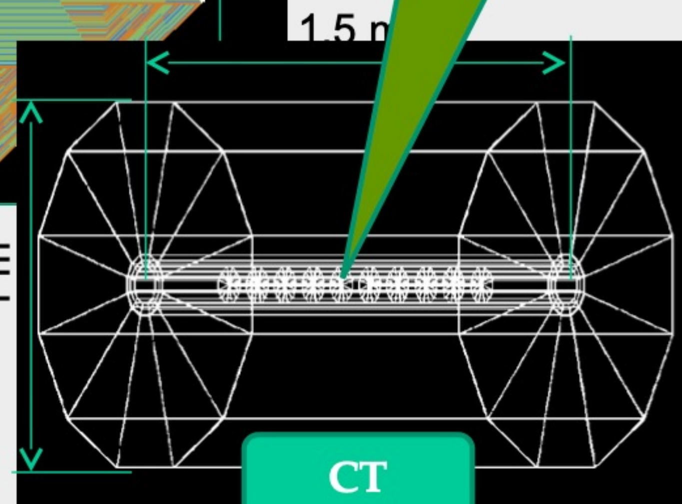
ADRIANO2 Calorimeter (tiles)
Scint. + heavy glass sandwich
35 X_0, 2.9λ_I (~ 64 cm deep)
Triple-readout +PFA
96% coverage



μ-polarizer
Active version (from TREK exp.) - optional

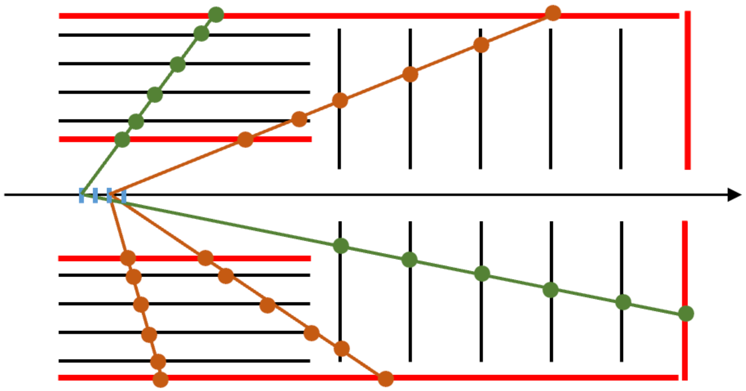
CTOF
~ 1m x 1.5 m
Lead-glass tiles
98% coverage

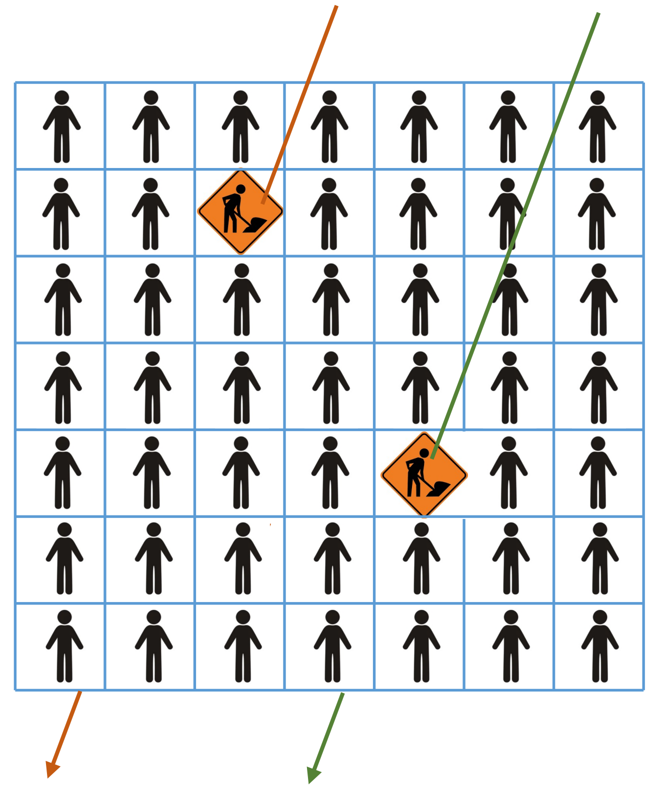
10x Be or Li targets
•0.33 mm thin
•Spaced 10 cm



Fiber tracker or ITS3
for rejection of γ-conversion and vertexing

Ultra-high event rate – how?



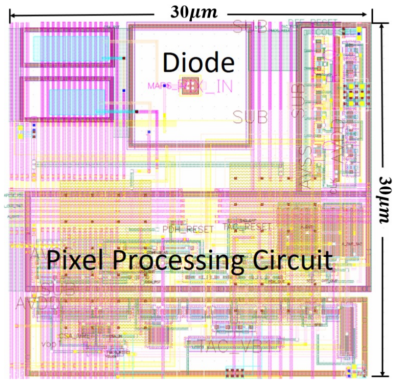


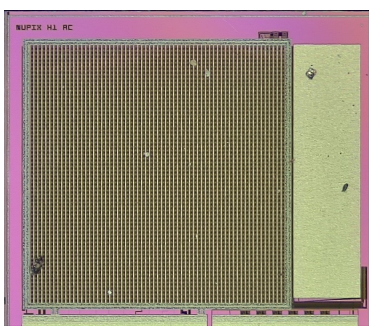
- Each pixel (strip / tower) record time information
  - used to distinguish signals from different collisions
- Pixels work parallelly to record hits from different collisions
  - like GPU: large amount of pixels ⇒ ultra high event rate

5D pixel tracker

Nupix-H1

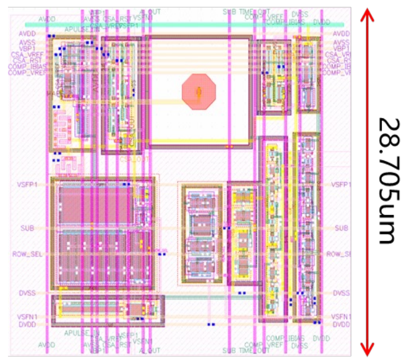
done

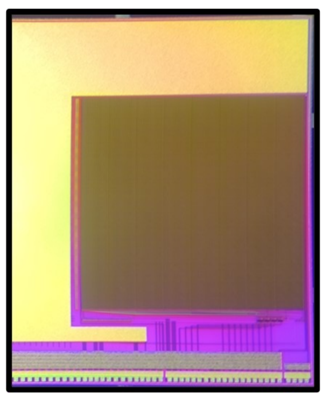




Nupix-H2

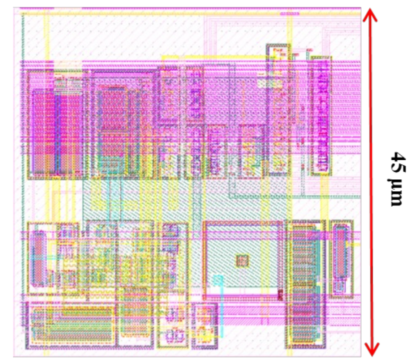
done

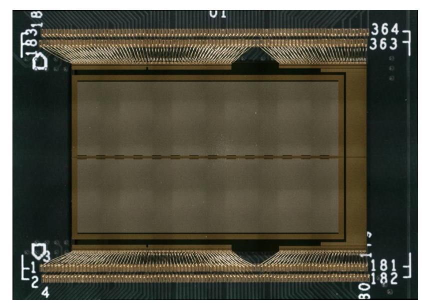




Nupix-H3

being tested





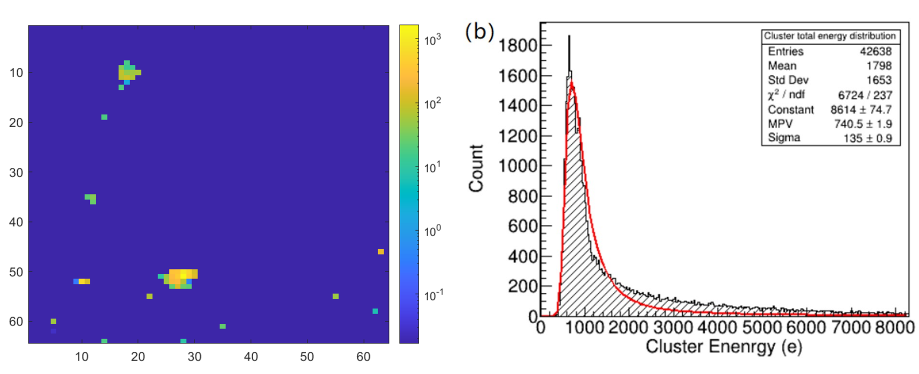
Nupix-H4

being designed

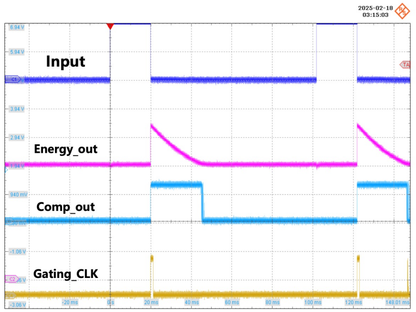
Aiming at HHaS's full requirements

- 3 tape-outs of Nupix-H sensor chips have been designed and produced
- Gradually approaching HHaS's requirements

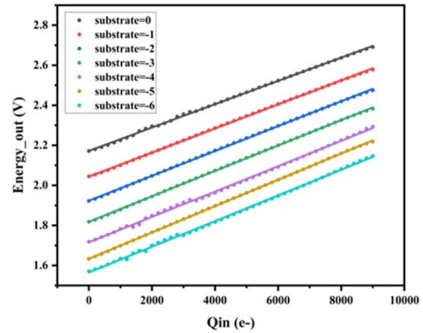
5D pixel tracker



Nupix-H1 ^{90}Sr β cluster and energy spectrum

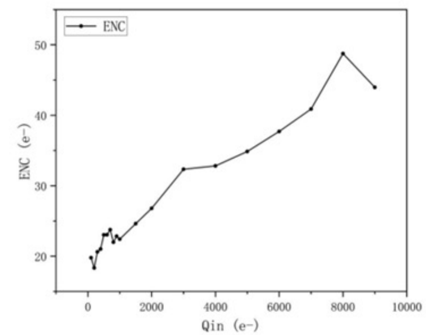


Nupix-H2-test electronics test result



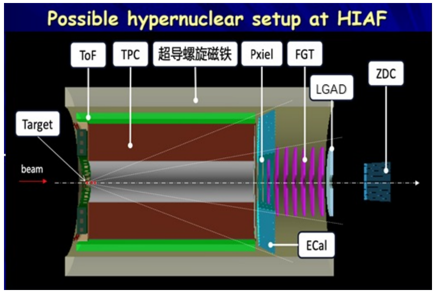
Nupix-H2-test energy dynamic range measurement

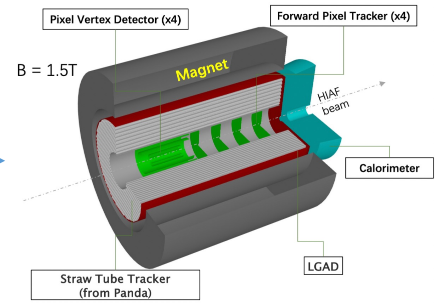
parameter	HHaS requirement	Nupix-H2-test result	status
pixel size	~100 um	28.705 um	meet requirement
energy dynamic range	≥ 16 MIPs (~ 12 ke^-)	9 ke^-	close to requirement
noise	≤1/5 MIPs (~ 150 e^-)	≤ 48.75 e^-	meet requirement
time resolution	≤10 ns	25.88 ns	same order of magnitude as requirement
power consumption	≤ 200 mW/cm2	\	not required for now
dead time	≤ 10 μs	\	not required for now



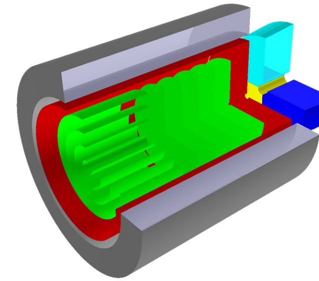
Nupix-H2-test equivalent noise count vs. charge

- Time and energy deposition can be measured on each pixel now

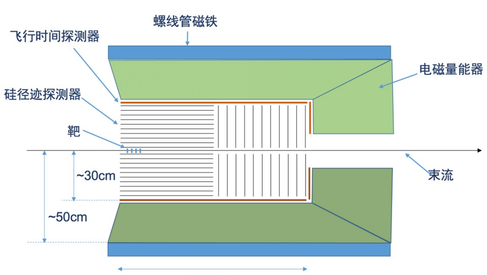




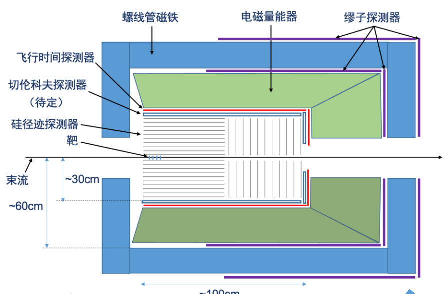
2024.8



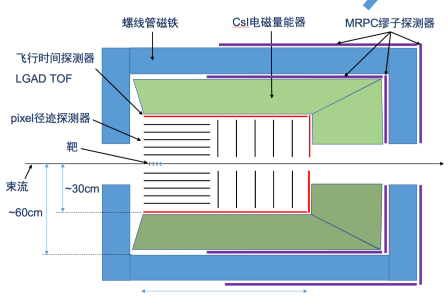
现在



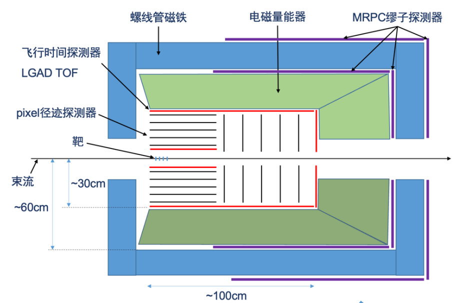
2022.8



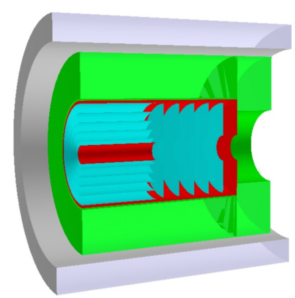
2022.9



2022.12



2023.2



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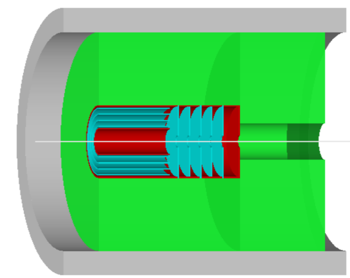

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