High Intensity Electron Positron Accelerator (HIEPA) Facility in China

Hai-ping Peng (彭海平)

penghp@ustc.edu.cn

(On behalf HIEPA Steering Committee)

University of Science and Technology of China (USTC)

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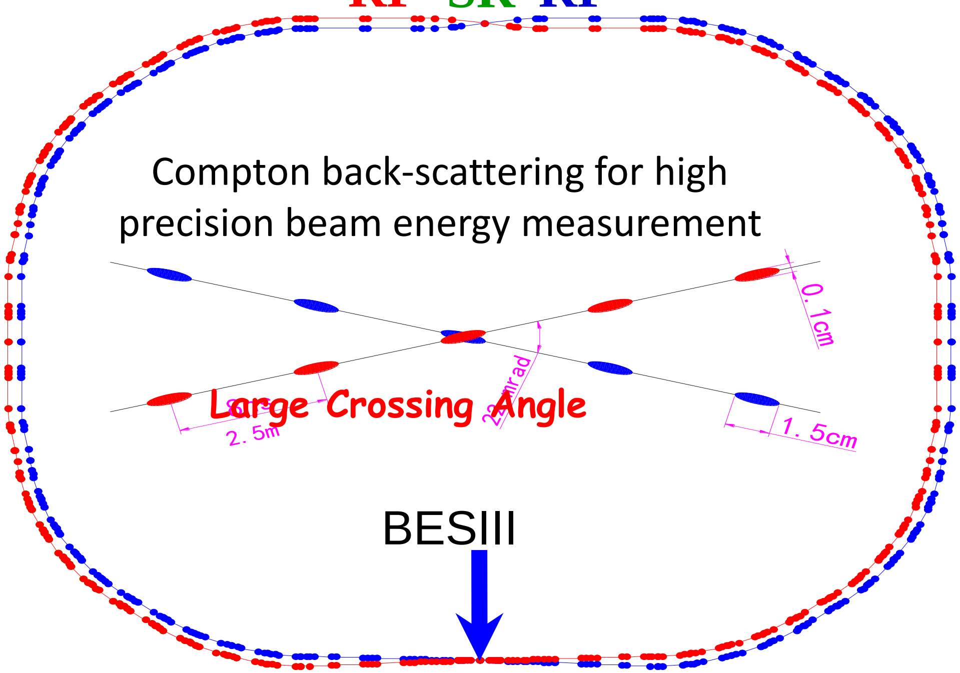
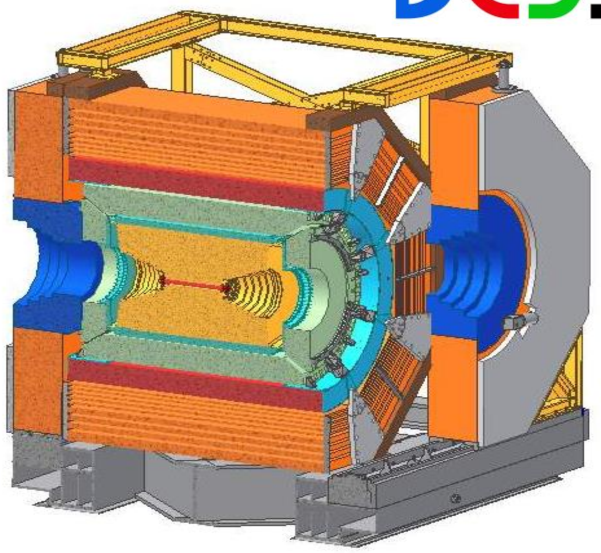
Status of BEPCII/BESIII





Sub-detectors			Performance
MDC	Momentum resolution		0.5%@1GeV
	dE/dx resolution		6%
EMC	Energy resolution		2.5%@1GeV
	Spatial resolution		6 mm
TOF	Time resolution	Barrel	80 ps (Bhabha)
		Endcap	110 ps (Di-muon)
MUC	9 layers RPC, 8 layers for endcap		

- Beam energy : 1.0-2.3 GeV
- Energy spread : 5.16×10^{-4}
- Optimum ene. : 1.89 GeV
- Luminosity : 1×10^{33} cm^{-2}s^{-1}
  Achieved 0.7×10^{33}cm^{-2}s^{-1}
- No. of bunches : 93
- Bunch length : 1.5 cm
- Total current : 0.91 A
- SR mode : 0.25A@2.5GeV

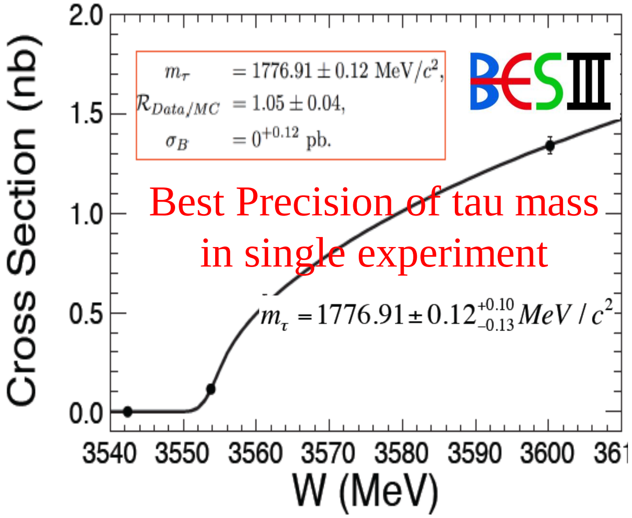
Unique machine running on tau-charm region in the world

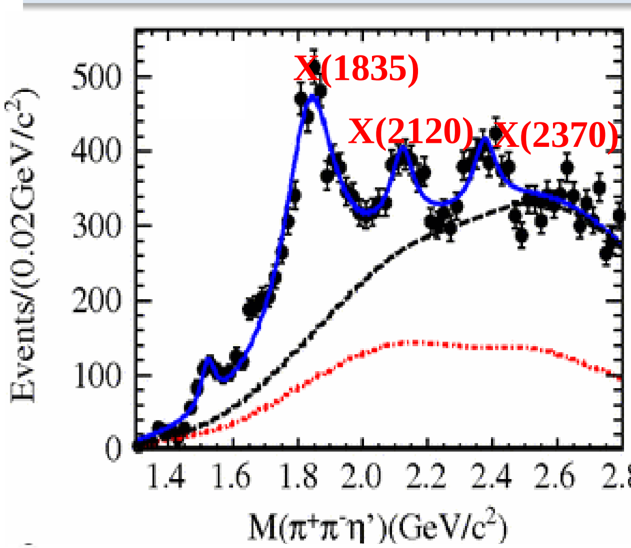
BESIII Data Taking

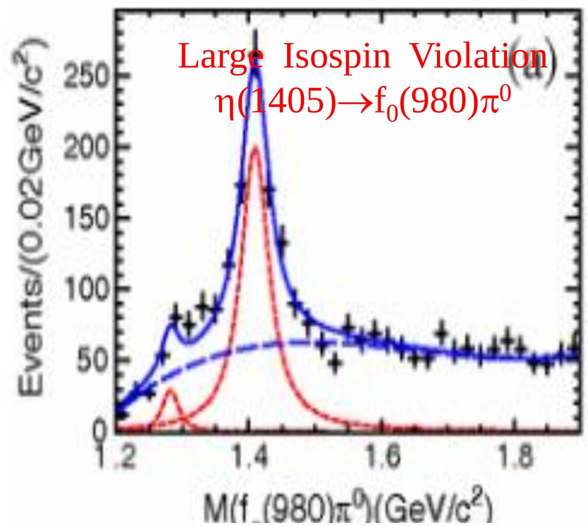
Began taking data from 2009

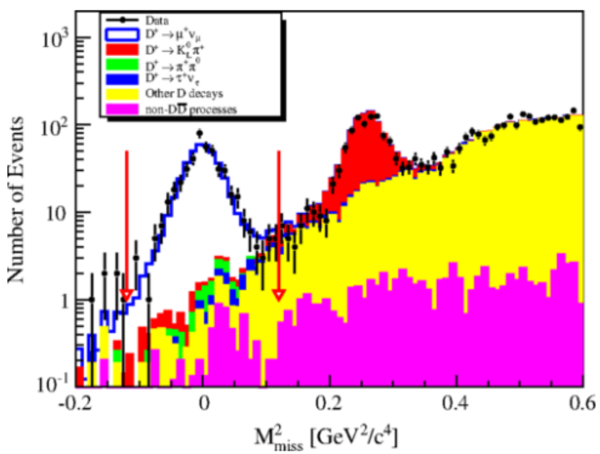
J/ψ	1.3 $\times10^9$ events	world largest sample	10×10^9 proposed
ψ'	0.6 $\times10^9$ events	world largest sample	3×10^9 proposed
$\psi(3770)$	~2.9 fb^{-1}	world data sample X 3	$10fb^{-1}$ proposed
$D_s\bar{D}_s$ @ 4.01 GeV	~0.5 fb^{-1}	unique data	
Y (4260)	~2.2 fb^{-1}	unique data	
Y (4360)	~0.6 fb^{-1}	unique data	
τ mass scan	24 pb^{-1}		
3850 MeV - 4590 MeV	0.8 fb^{-1}	unique data	
4100 MeV - 4400 MeV	0.5 fb^{-1}	unique data	
4420 MeV	1 fb^{-1}	unique data	
4600 MeV	0.5 fb^{-1}	unique data	

BESIII Fruitful Physics Results

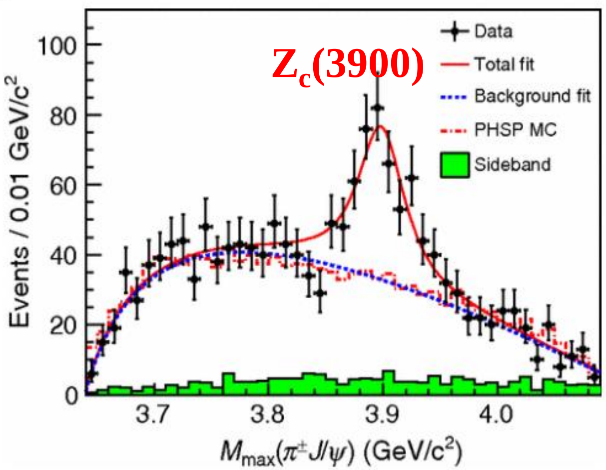


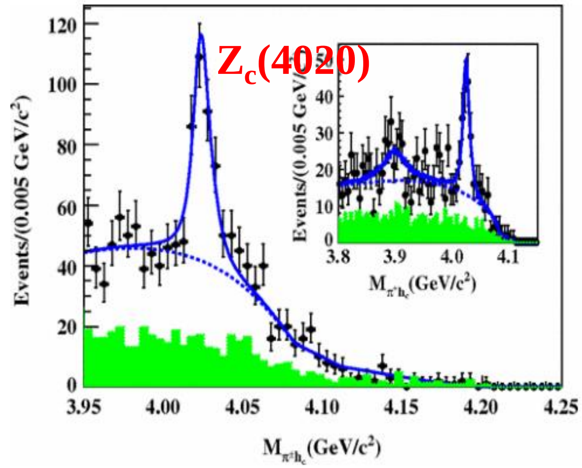






Most precise measurement
for D leptonic decay





BESIII have more than 70 publications

http://bes3.ihep.ac.cn/pub/physics.htm

What Project Are We Proposing?

BEPCII/BESIII will end her mission around 2020

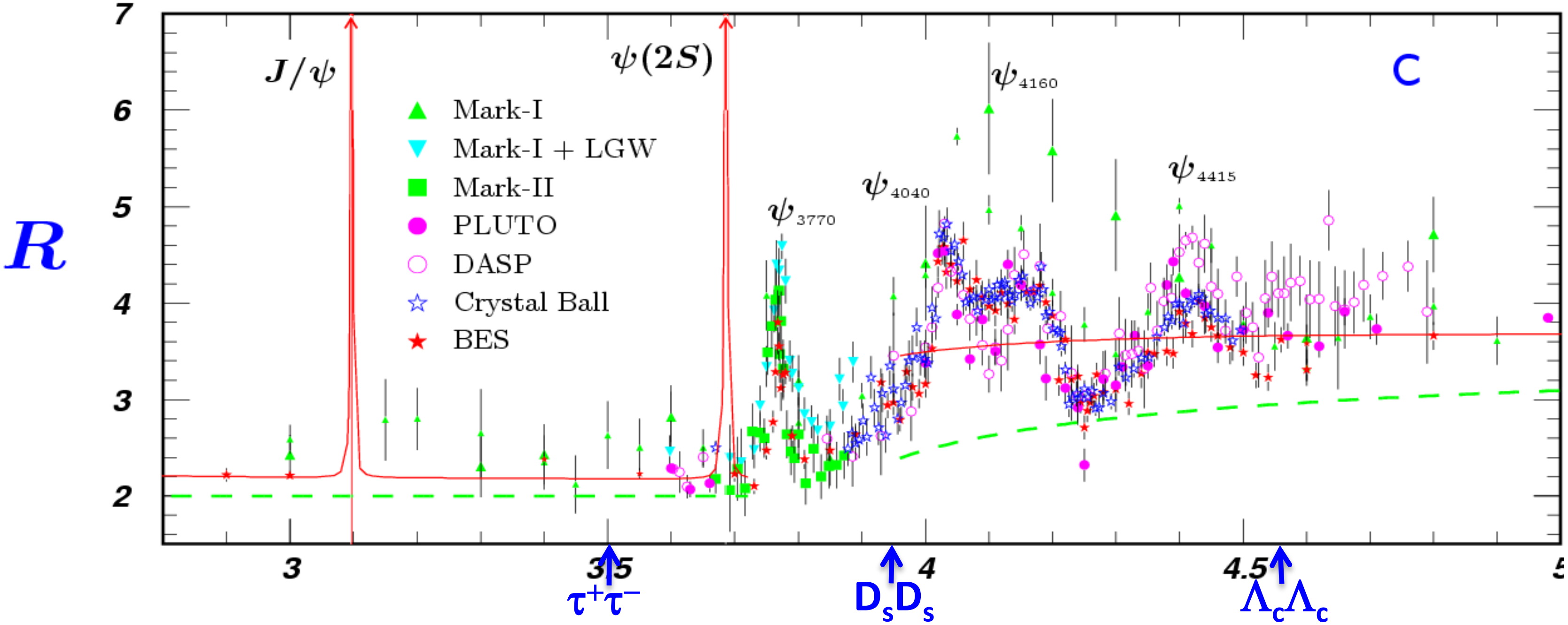
Led by the High Energy Physics Association of China, we are exploring possible future collider project post BEPCII/BESIII

High Intensity Electron Positron Accelerator (HIEPA)

- Collider machine
  - Providing peak luminosity about 1×10^{35} $cm^{-2}s^{-1}$ at 4 GeV for physics
  - Energy range E_{cm} = 2–7GeV
  - Polarization available on one beam
  - Symmetric machine with low currents and crabbed waist solution for the interaction region
- Being a $3^{rd}/4^{th}$ generation SRF (synchrotron radiation facility).
- Reserving the potential for FEL (free electron laser) study with the long LINAC.

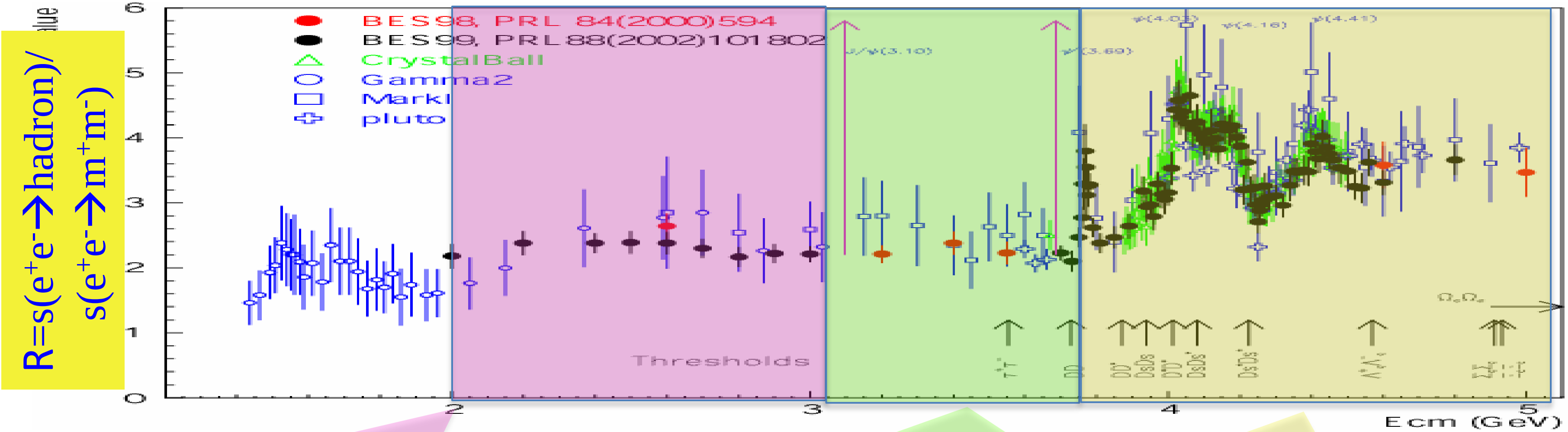
Features of the τ-c Energy Region

Why Physics on τ-c energy region



- Rich of resonances, charmonium and charmed mesons.
- Threshold characteristics (pairs of τ, D, D_s, charmed baryons…).
- Transition between smooth and resonances, perturbative and non-perturbative QCD.
- Mass location of the exotic hadrons, gluonic matter and hybrid.

Physics at τ-c Energy Region



- Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark, Zs
- MLLA/LPHD and QCD sum rule predictions

- Light hadron spectroscopy
- Gluonic and exotic states
- Process of LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

- XYZ particles
- Physics with D mesons
- f_D and f_{Ds}
- D_0-D_0 mixing
- Charm baryons

R scan

- **Precision $\Delta\alpha_{QED}$, a_μ, charm quark mass extraction.**
- **Hadron form factor(nucleon, Λ, p).**

Data Samples / Year

$$10^{35}cm^{-2}s^{-1} \times 86400s \times 180days \times 90\% = 1.4ab^{-1}$$

	CLEO-C		BES-III/ year $10^{33}cm^{-2}s^{-1}(10fb^{-1})$	τ-charm/year $10^{35}cm^{-2}s^{-1}$ $(1ab^{-1})$
J/ψ	–	–	10×10^{9}	10×10^{11}
$\psi(2S)$	54 pb^{-1}	27×10^{6}	3×10^{9}	3×10^{11}
$\psi(3770)$	818 pb^{-1}	5×10^{6} D-pair	3×10^{7}	3×10^{9}
4.17 GeV	586 pb^{-1}	7×10^{5} D_s-pair	2×10^{6}	3×10^{9}
$\tau^{+}\tau^{-}(4.25)$		4×10^{6}	3×10^{7}	3×10^{9}

Highlight physics topic

- Hadron Spectroscopy (charmonium)
- Tau Physics
- Nucleon/hadron electromagnetic form factor
- …..

10^{10} charm @ Υ(4S)

10^{10} τ pairs @ Υ(4S)

BELLE-II/Super KEKB

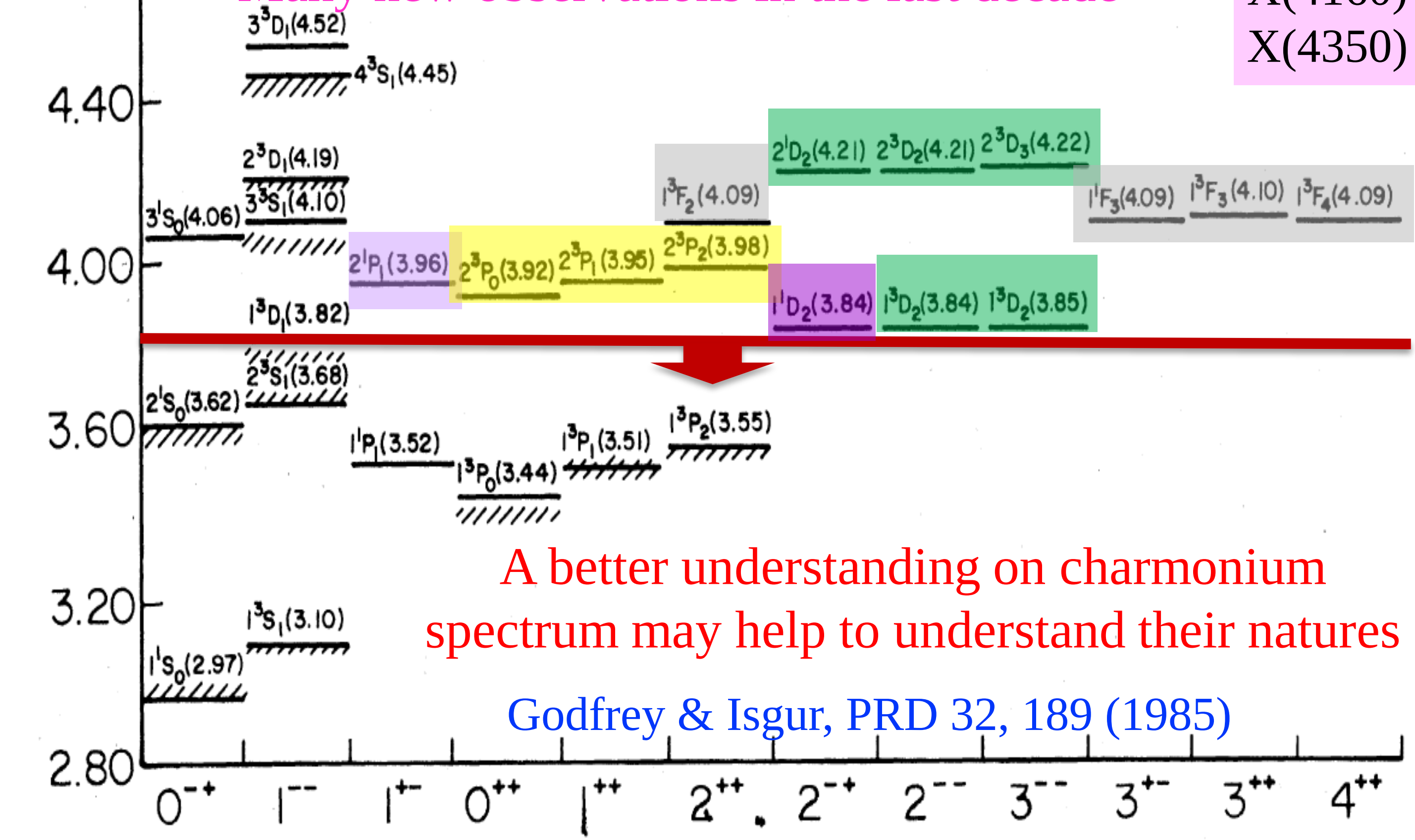
$10^{36}cm^{-2}s^{-1}(10ab^{-1})$

Charmonium (like) Spectroscopy

Key Science question : Is there any exotic hadron exist

- States below charm threshold are all well observed
- Many missing states above charm threshold
- Many new observations in the last decade

X(3872)	Y(3940)	Z(3900)
X(3940)	Y(4008)	Z(4020)
X(4160)	Y(4260)	Z(4050)
X(4350)	Y(4360)	Z(4200)
	Y(4660)	Z(4250)
		Z(4430)



A better understanding on charmonium spectrum may help to understand their natures

Godfrey & Isgur, PRD 32, 189 (1985)

Nature unclear

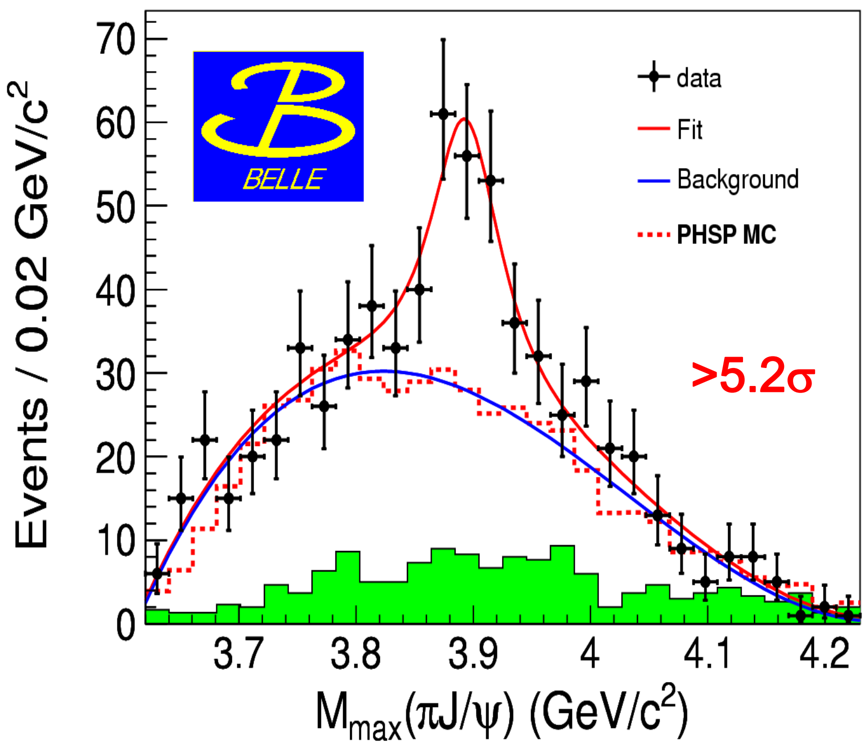
- Charmonium?
- Hybrid?
- Tetraquark?
- Molecule?
- Non-resonance?

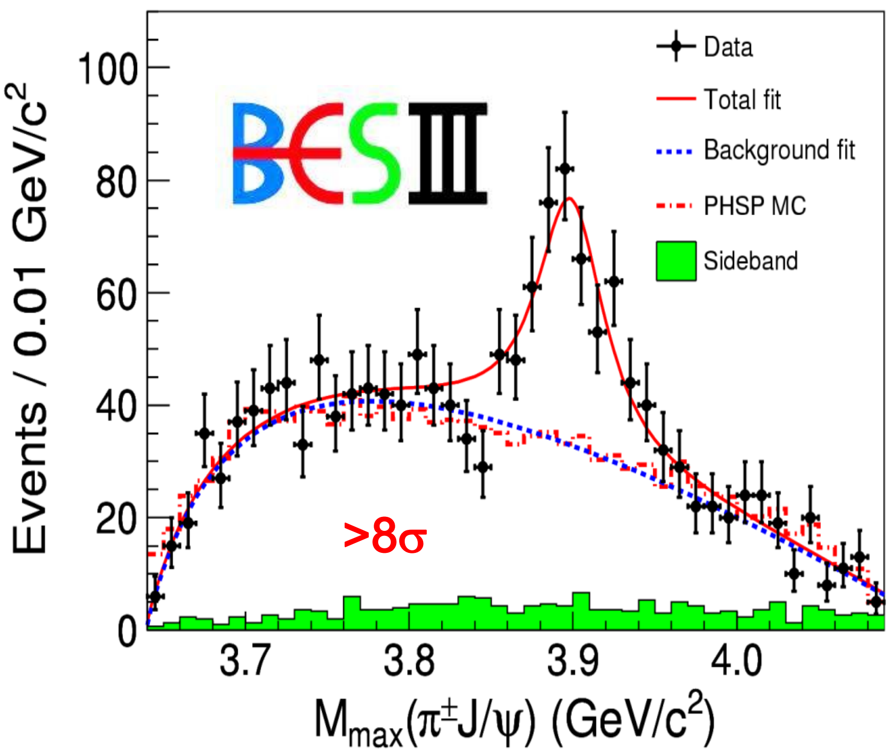
Physics on Charmonium

Incomparable superiority for Hadron Spectroscopy (charmonium)

Belle with ISR: PRL110, 252002
967 fb^{-1} in 10 years running time

BESIII at 4.260 GeV: PRL110, 252001
0.525 fb^{-1} in one month running time





Production mechanism

- **ψ/Y particles are directly produced :**
  - Measure the production cross section precisely,
  - Extract the excited ψ or Y states resonance parameters via fitting data.
- **Study states with C=+1 via radiative transition :**
  - $B(\psi(3S)\to\gamma\chi'_{cJ}) = (7,3,1)\times10^{-4}$ for J=2, 1, 0 [E. Eichten et al. Rev. Mod. Phys. 80, 1161 (2008)]
  - $\psi(nS/nD)\to\gamma XYZ$ [X(3872) ,Y(4140) et al.], no theoretical prediction on transition rate, BESIII : $\sigma(Y(4260)\to\gamma X(3872))\sim6$pb [PRL 112, 092001 (2013)]
- **Search for states in ψ/Y particles hadron decay :**
  - $Y(4260)\to\pi Z_c(3900)$, $\psi\to\pi h_c(1P/2P)$ …..

Topics at HIEPA

- **Where are the missing states above the charm threshold**
  - $^1D_2(2^{-+})$: M~3830MeV, narrow, may be produced in $h_c(2P)$ E1 transition
  - P-wave spin-triplets from S-wave E1 transition
  - P-wave spin-singlets from S-wave hadron transition
- **Can we identify F-wave states?**
- **Can we find the Z_{cs}?**
- **Are there hybrids (1^{--}, others J^{PC})**

Search for $\eta_{c2}(1^1D_2)$ and $\chi_{c1}(2^3P_1)$

Simple estimations

$L_{peak} = 10^{35}cm^{-1}s^{-1}$, 1 year running = $10^6 pb^{-1}$ = $1ab^{-1}$

A BESIII-Like detector

Detail MC studies are ongoing

$\eta_{c2}(1^1D_2)$

- $\sigma(e^+e^- \to \pi^+\pi^- h_c(2P)) \sim 20$ pb @ Ecm=??GeV
- $B(h_c(2P) \to \gamma\eta_{c2}) \sim 3\times10^{-4}$ [E1 trans., Barnes' 05]
- $B(\eta_{c2} \to \gamma h_c) \sim (44\text{–}54)\%$ [E1 trans., Fan' 09]
- $B(h_c \to \gamma\eta_c) \sim 54\%$ [E1 trans., BESIII'10]
- $\varepsilon B(\eta_c \to \text{hadrons}) \sim 1.5\%$ at BESIII
- $N^{obs}=2\times10^{-5}\times L$ (L is int. lumi. in pb^{-1})
- N^{obs}=20 events /year,
- Bkg is low for narrow h_c and η_c

$\chi_{c1}(2^3P_1)$

- $\sigma(e^+e^- \to \psi(nS)/\psi(mD)) \sim (3\text{-}7)$ nb @ for n>1, m>2
- $B(\psi \to \gamma\chi'_{c1}) \sim 3\times10^{-4}$ [E1 trans., Barnes' 05]
- $B(\chi'_{c1} \to \gamma\psi') \sim 1\times10^{-3}$ [E1 trans., Barnes' 05]
- $B(\chi'_{c1} \to \gamma J/\psi) \sim 1\times10^{-4}$ [E1 trans., Barnes' 05]
- $\varepsilon B \sim (1\text{–}5)\%$ at BESIII
- $N^{obs} = (1\text{–}10)\times10^{-5}\times L$ (L is int. lumi. in pb^{-1})
- N^{obs} = (10–100) events /year,
- Bkg is low for narrow ψ' and J/ψ

Search for 1^{--} Hybrid $H_{ccg} \to \gamma\eta_c$ & $\gamma\chi_{c0}$

- Assume $\sigma(e^+e^- \to H_{ccg}) \sim O(10\text{–}100)$ pb [???]
- $B(H_{ccg} \to \gamma\eta_c) \sim 2 \times B(\eta_{c2} \to \gamma\chi_{c0}) \sim 4\times10^{-4}$

  [in Hybrid, ccbar in spin-singlet, LQCD by Dudek′09]
- Scan $e^+e^- \to \gamma\eta_c$ and $\gamma\chi_{c0}$ for exotic structure
- If $\varepsilon B \sim 10\%$ for $\to\gamma\eta_c$ and $\gamma\chi_{c0}$ decay to γ+hadrons
- $L_{peak} = 10^{35}\text{cm}^{-1}\text{s}^{-1}$, 1 year running $= 10^6\text{pb}^{-1} = 1\text{ab}^{-1}$
- At 100 energy points above DDbar threshold
- $N^{obs}(\gamma\eta_c) = O(4\text{-}40)$ events/point/year at peak
- $N^{obs}(\gamma\chi_{c0}) = O(2\text{-}20)$ events/point/year at peak

Detail MC studies needed to understand the background, and to improve the sensitivity

New Physics

W. Altmannshofer et al. arXiv : 0909.1333

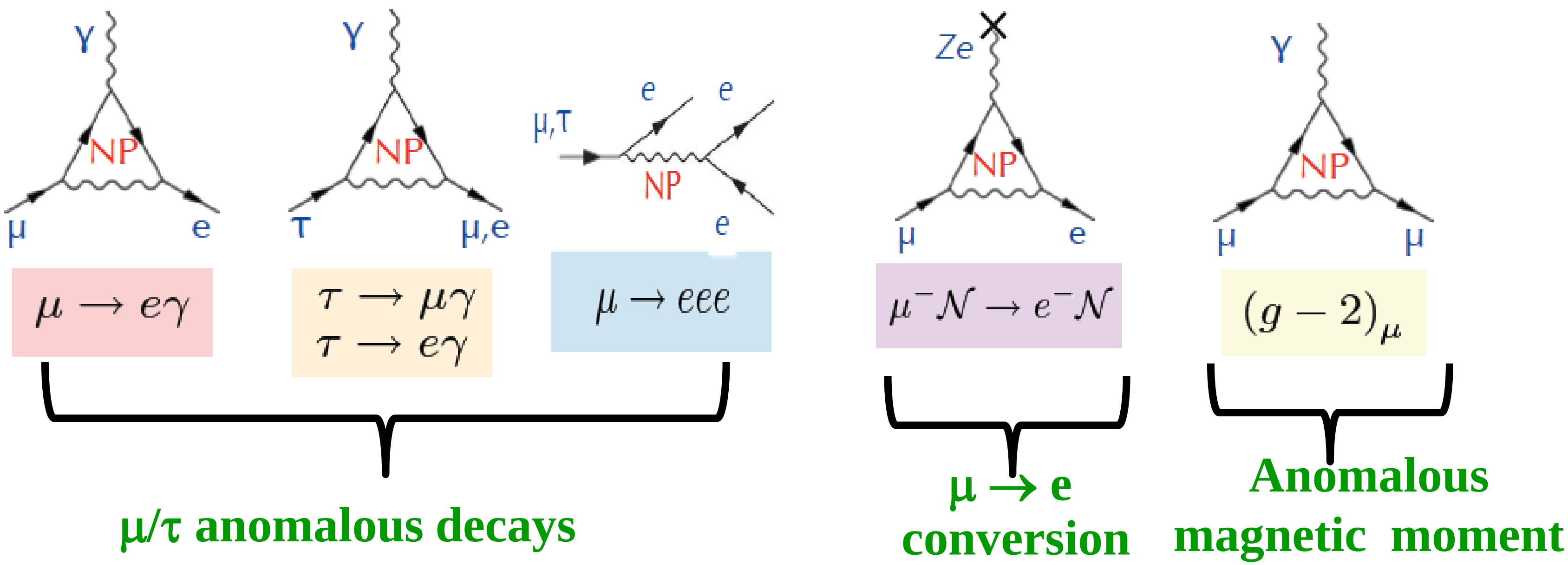
- The discovery of the Higgs completes the list of the particles in the SM.
- Physics beyond the SM due to phenomena that cannot be explained within SM framework:
  - SM does not explain gravity
  - SM does not supply any fundamental particles that are good dark matter candidates, nor be able to explain dark energy
  - No mechanism in the SM sufficient to explain asymmetry of matter and anti-matter.
- No evidence of new physics been found at high energy frontier.
- important and complementary to directly search for new physics in the precision frontier.

	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
$D^0-\bar{D}^0$	★★★	★	★	★	★	★★★	?
ϵ_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
$A_{CP}(B\to X_s\gamma)$	★	★	★	★★★	★★★	★	?
$A_{7,8}(B\to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?
$A_9(B\to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
$B\to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s\to\mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+\to\pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$K_L\to\pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu\to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
$\tau\to\mu\gamma$	★★★	★★★	★	★★★	★★★	★★★	★★★
$\mu+N\to e+N$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	?

Table 8: "DNA" of flavour physics effects for the most interesting observables in a selection of SUSY and non-SUSY models ★★★ signals large effects, ★★ visible but small effects and ★ implies that the given model does not predict sizable effects in that observable.

Charged Lepton Flavor Violation (cLFV)

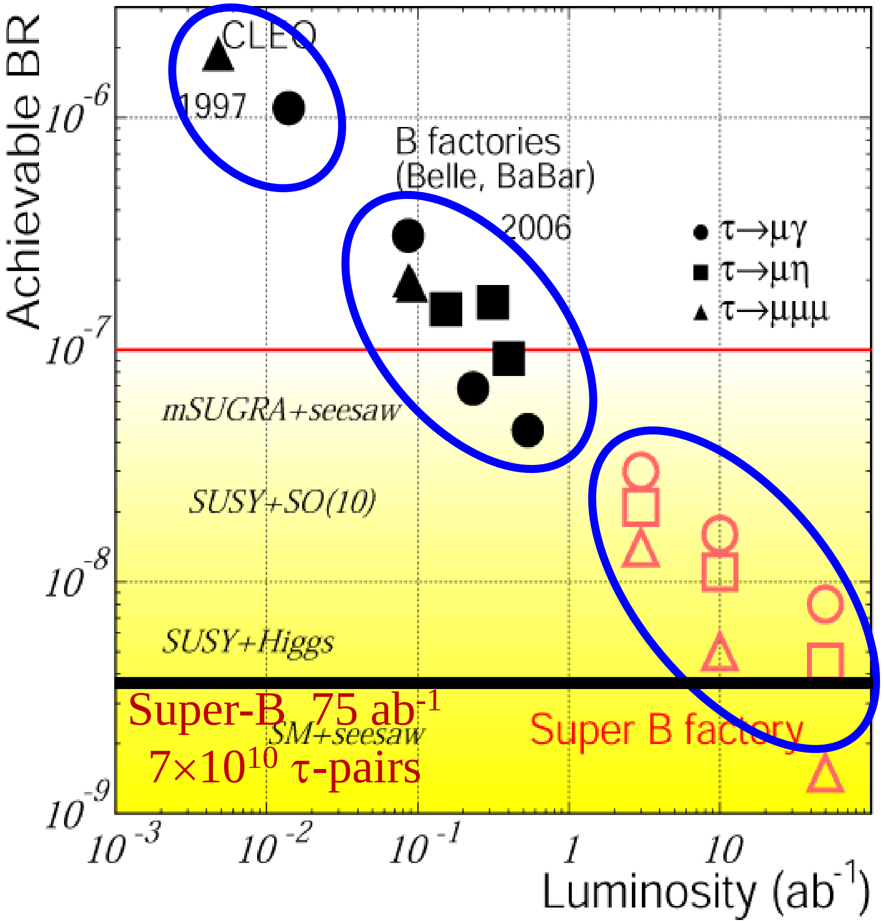
- In SM, cLFV is negligibly even taking into account neutrino mass
- Several cLFV process, sensitive to NP through “new” lepton-lepton coupling



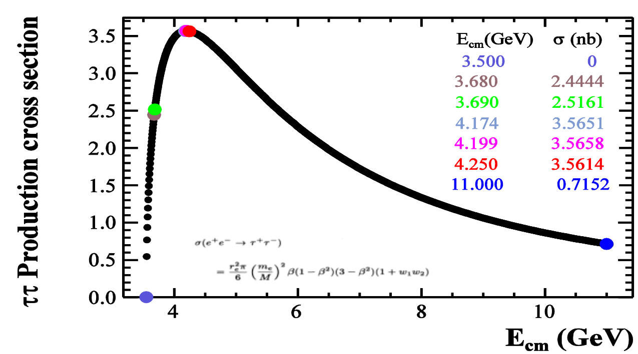
In tau-charm factory, τ→μγ decay is golden mode to search for NP

cLFV Decay τ→μγ @ B Factory

From A. Bondar, Charm2010



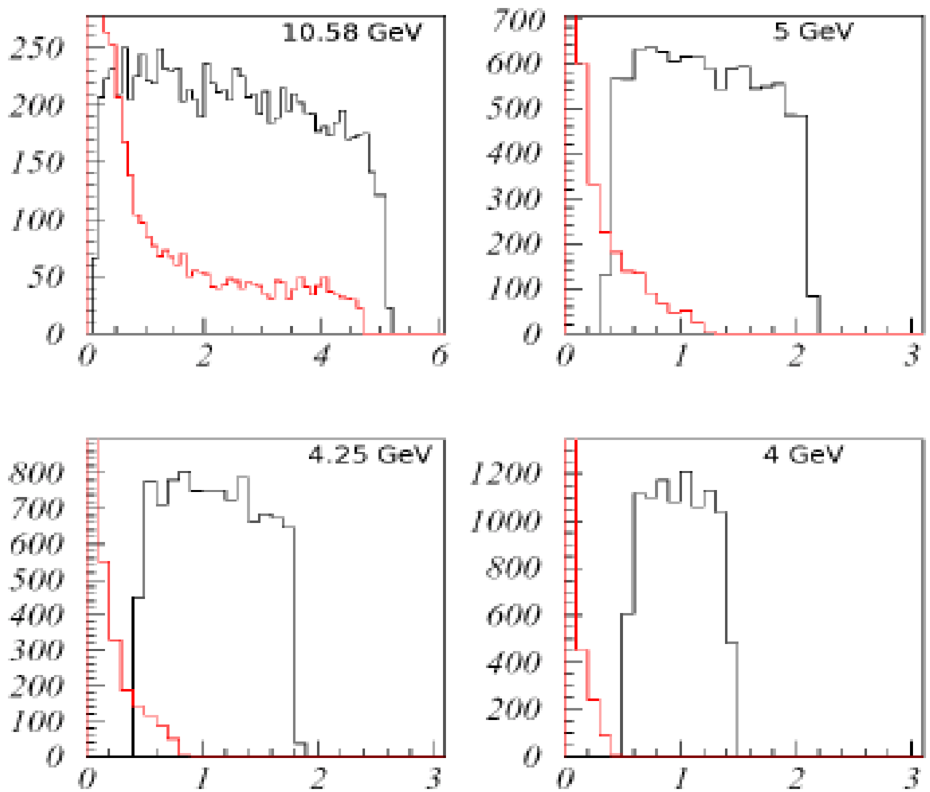
- **Current limit : ~ 4×10^{-8} (5×10^{8} τ-pairs)**
  - BABAR : $516fb^{-1}$ [PRL, 104, 021802]
  - BELLE : $545fb^{-1}$
- **At Υ(4S) :**
  - ISR background $e+e- \to \tau^+\tau^-\gamma$
  - Upper Limit $\propto 1/\sqrt{L}$
  - Expected limit : $3\text{x}10^{-9}$@$75ab^{-1}$ (7×10^{10} τ-pairs)
- **Belle-II Factory with $L=10^{36}cm^{-2}s^{-1}$**
  - 10^{10} tau pairs per year (x-sec=1nb)
- **HIEPAF with $L=10^{35}cm^{-2}s^{-1}$**
  - 10^{8} tau pairs per year at threshold (x-sec=0.1nb)
  - 3.5×10^{9} tau pairs/year at 4.25GeV (x-sec = 3.5nb)



What can HIEPA have with $3\text{x}10^{9}$ ττ pairs / year?

$\tau \to \mu\gamma$:background

Background $e^+e^- \to \tau^+\tau^-\gamma$



Dominant background

- τ decays, direct ($\tau^+ \to \pi^+\pi^0\nu_\tau$) and combinatorial [arXiv:1206.1909]
- QED processes: $e^+e^- \to \mu^+\mu^-\gamma\gamma$, $e^+e^- \to e^+e^- \mu^+\mu^-\gamma$
- Continuum hadron production $e^+e^- \to qq$
- $\psi(2S)$ and D-meson decays

- Dominant source at Υ(4S),
- Does not contribute below $\sqrt{s} \approx 4m_\tau/\sqrt{3} \approx 4.1$ GeV.

Expected $\tau\to\mu\gamma$ Br upper limit

E(GeV)	σ(nb)	L(ab^{-1})	$N_{\tau\tau}(10^{10})$
3.686	5.0	1.5	0.75
3.77	2.9	3.5	1.03
4.17	3.6	2.0	0.71
Total		7.0	2.49

Results from Vladimir Druzhinin, (BINP, Novosibirsk) at Workshop on Tau Charm at High Luminosity 26-31 May, 2013, La Biodola, Italy

Fast simulation for NP sensitivity and detector optimization is ongoing

	σ_E/E=1.5%	σ_E/E=2.5%
Signal (Br=10^{-9})	17	15
Muon background	7	11
Pion background	83	271
Expected 90% CL upper limit for Br	1.1×10^{-9}	3.0×10^{-9}
Expected 90% CL upper limit for Br with pion suppression by a factor of 30	3.3×10^{-10}	5.1×10^{-10}

Supper-B Expected limit : $3\text{x}10^{-9}$@$75ab^{-1}$ (7×10^{10} τ-pairs)

CP Violation in τ Decay

- CP violation is observed in B, D and K systems to date
- No CPV has been observed in the lepton sector
- The discovery of CPV in the tau sector would be a clean signature of NP
- One of the most promising CPV channels is $\tau^- \to K_S \pi^- \nu$
  - SM CP asymmetry from K_S-K_L mixing is expected to be : [Bigi & Sanda, PLB 625, 2005, Grossman &Nir JHEP 1204 (2012) 002]

$$|K_S\rangle = p|K^0\rangle + q|\overline{K}^0\rangle$$
$$|K_L\rangle = p|K^0\rangle - q|\overline{K}^0\rangle$$

$$\frac{\Gamma(K_L \to \pi^- l^+ \nu) - \Gamma(K_L \to \pi^+ l^- \overline{\nu})}{\Gamma(K_L \to \pi^- l^+ \nu) + \Gamma(K_L \to \pi^+ l^- \overline{\nu})} = |p|^2 - |q|^2 \simeq (3.27 \pm 0.12) \times 10^{-3}$$

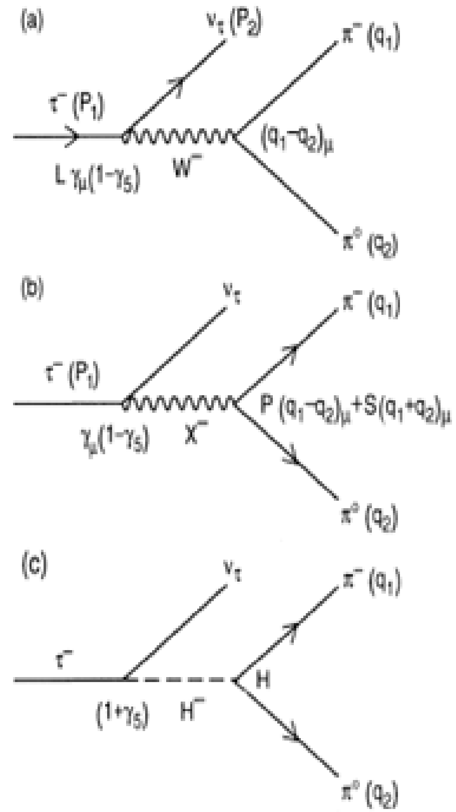
  - BaBar measurement [PRD 85, 031102]

$$A_\tau \equiv \frac{\Gamma(\tau^+ \to \pi^+ K_S \bar{\nu}_\tau) - \Gamma(\tau^- \to \pi^- K_S \nu_\tau)}{\Gamma(\tau^+ \to \pi^+ K_S \bar{\nu}_\tau) + \Gamma(\tau^- \to \pi^- K_S \nu_\tau)} = (-4.5 \pm 2.4 \pm 1.1) \times 10^{-3}.$$

  - Belle measurement [PRL 107, 131801]

$$|\mathrm{Im}(\eta_S)| < 0.026 \text{ or better}$$

A_{cp} = (1.8±2.1± 1.4) ×10^{-3} @ W ~ [0.89-1.11] GeV



Charge Higgs, new Scalar, W_L-W_R Mixings, LeptonQuarks?

τ CPV in Angle Distribution

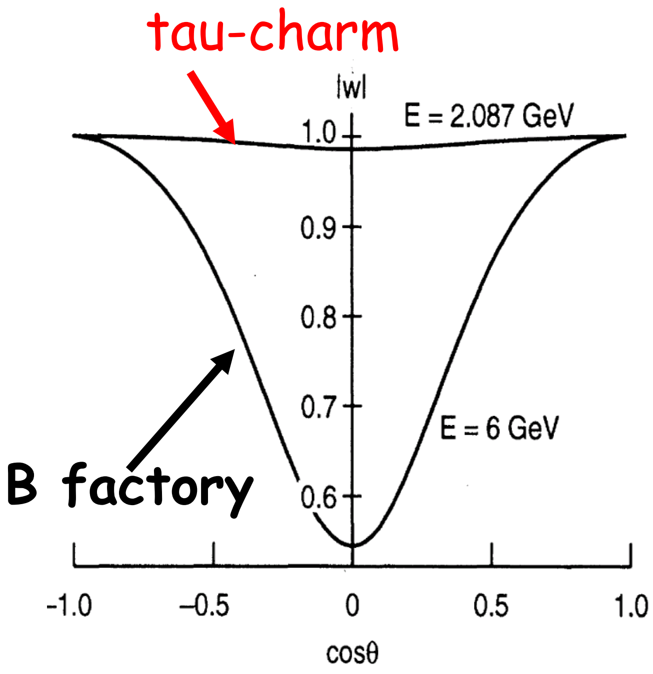
Need new measurement on the angular CPV asymmetry

Use T-odd rotationally invariant products : e.g.

$$P_2^T \cdot (\vec{P}_{\pi^+} \times \vec{P}_{\pi^0})$$

in τ^+ and τ^- decays to >=2 hadrons such as :
$\tau^- \to \pi^-\pi^0\nu_\tau / k^-\pi^0\nu_\tau$, $\tau^- \to \pi^-\pi^+\pi^-\nu_\tau / K^-\pi^+\pi^-\nu_\tau$,

Need polarized beam



"**Figure Of Merits**" -- **Y. S. TSAI**

$$\text{merit} = \text{luminosity} \times \bar{w}_Z \times \text{ total cross section}$$
$$\propto \text{luminosity} \times (w_1 + w_2)$$
$$\times \sqrt{1 - a^2}a^2(1 + 2a) ,$$

BESIII @ 4.25 ($10^{33}cm^{-2}s^{-1}$) FOM=1

HIEPA @ 4.25 ($10^{35}cm^{-2}s^{-1}$) FOM=100

Super B @ ($10^{36}cm^{-2}s^{-1}$) FOM=65

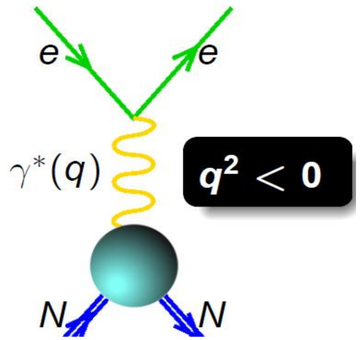
Y. S. Tsai, PRD 51.3172

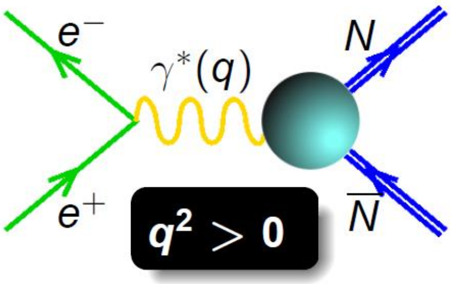
Nucleon Electromagnetic Form Factors (NEFFs)

Spatial distributions of electric charge and current inside the nucleon

$eN \rightarrow eN$ $\qquad$ $e^+e^- \leftrightarrow N\overline{N}, \Lambda\overline{\Lambda}$

Space-like: FF real





Time-like: FF complex

Vector current, **two form factors** (F_1 and F_2)

$$\Gamma_\mu = e\bar{u}(p')[F_1(q^2)\gamma_\mu + \frac{\kappa}{2M_N}F_2(q^2)i\sigma_{\mu\nu}q^\nu]u(p)e^{iqx}$$

Dirac	**Pauli**
$F_1^p(q^2=0)=1$	$F_2^p(q^2)=1$
$F_1^n(q^2=0)=0$	$F_2^n(q^2)=1$

Sachs

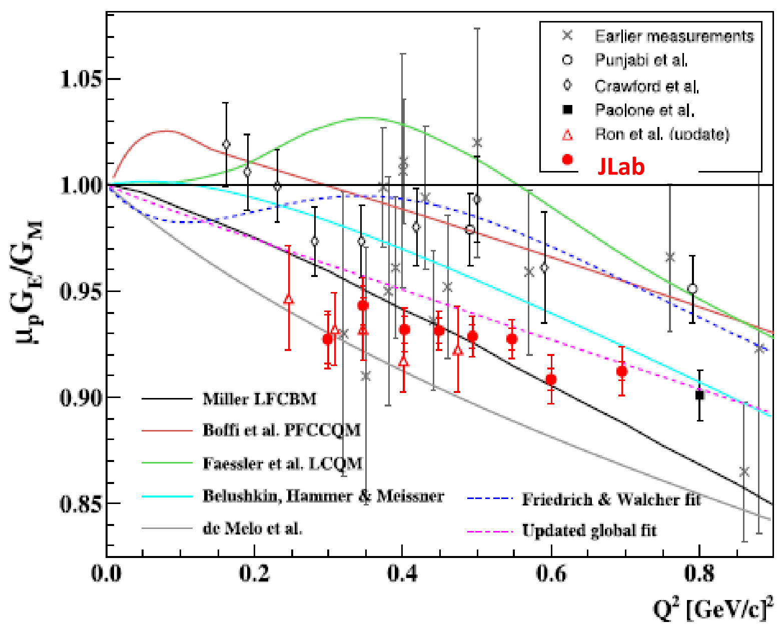
$$G_E = F_1 + \frac{\kappa q^2}{4M^2}F_2 \qquad G_M = F_1 + \kappa F_2$$

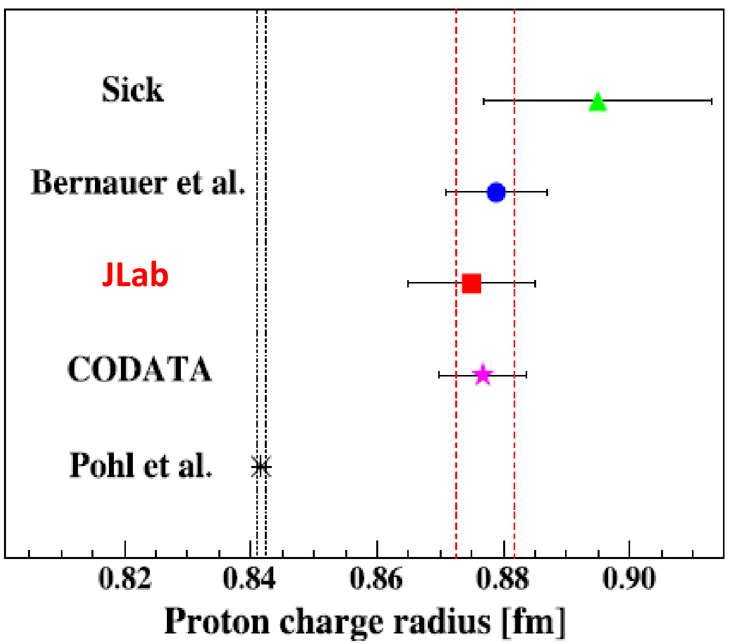
$$G_E(4M_p^2) = G_M(4M_p^2)$$

Complete picture of the nucleon structure requires space-like and time-like FF measurements!

Proton FF : Space-Like

- Many measurements of the proton form factors in the space-like region.
- At Jlab, the proton factor ratio was measured precisely with an uncertainty of ~1%, based on which the proton electronic and magnetic radii could be extracted.



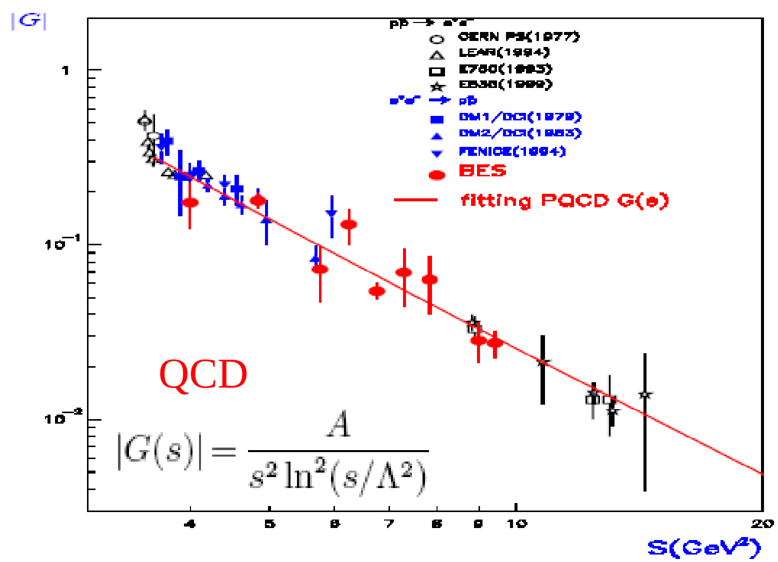


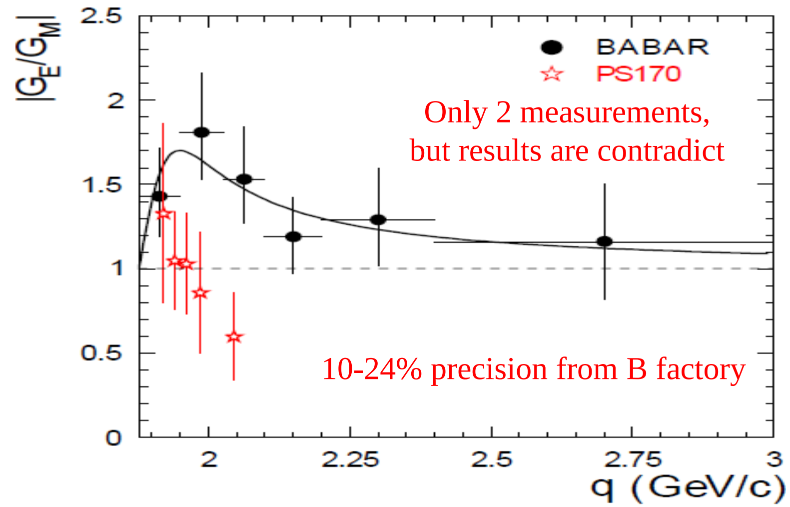
Proton FF : Time-Like

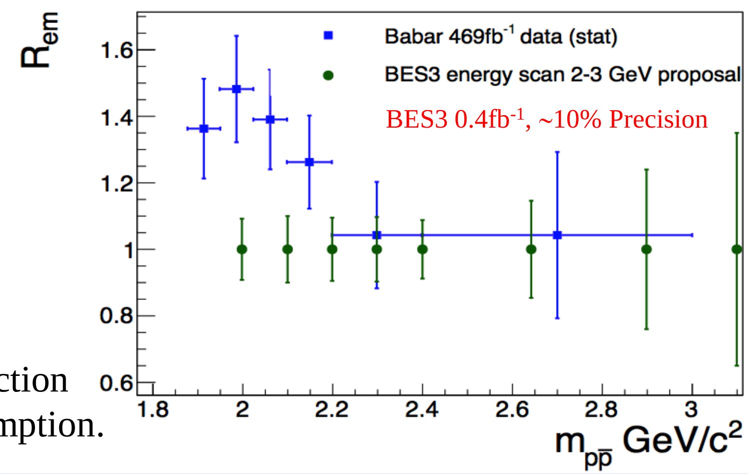
$$\sigma_{e^+e^-\to N\bar{N}} = \frac{4\pi\alpha^2\beta}{3s} C_N(s) \left[\left|G_M^N(q^2)\right|^2 + \frac{2M_N^2}{s}\left|G_E^N(q^2)\right|^2 \right]$$

$$|G_M(q^2)| = [1 + (q^2 - 4M_p^2)/q_2^2]^{-2}$$
$$|G_E(q^2)| = |G_M(q^2)|[1 + (q^2 - 4M_p^2)/q_1^2]^{-1}$$

Assume $G_M=G_E$ $\quad \sigma_0 = \frac{4\pi\alpha^2\beta}{3s}(1+\frac{2M^2}{s})|G(s)|^2$







$\delta|R_{EM}|/|R_{EM}| \sim 9\% - 35\%$

$\delta|G_M|/|G_M| \sim 3\% - 9\%$

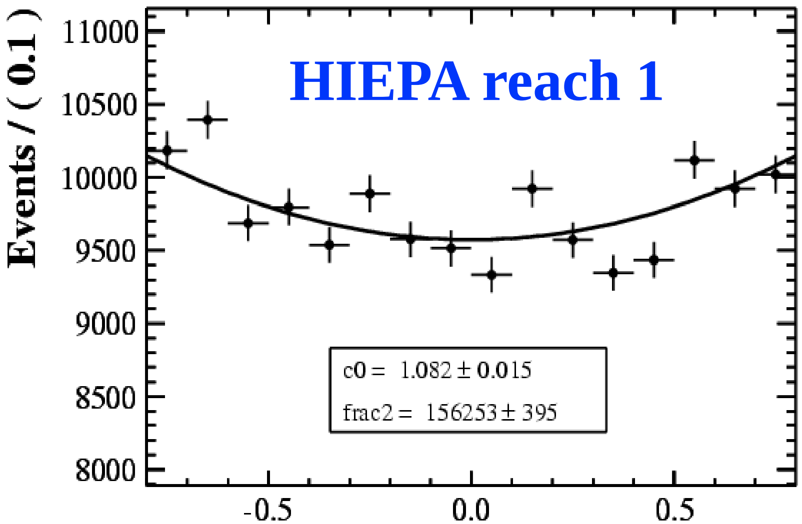
$\delta|G_E|/|G_E| \sim 9\% - 35\%$

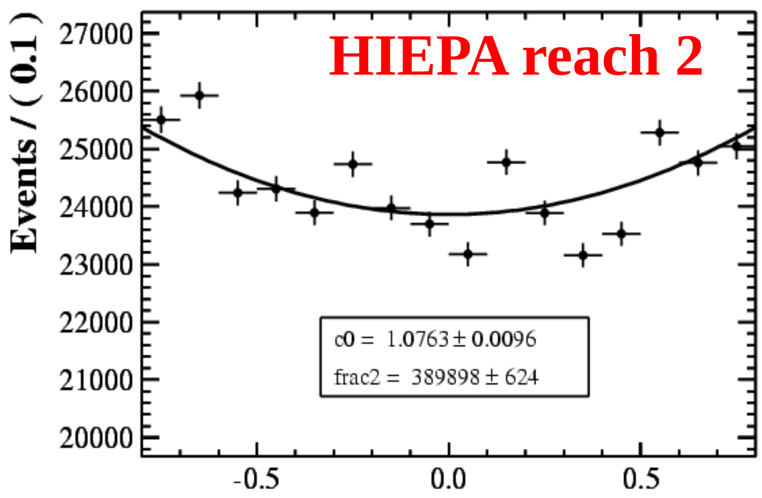
first time extraction without any assumption.

Proton FF @ HIEPA

$\sqrt{s}$=2.23 GeV

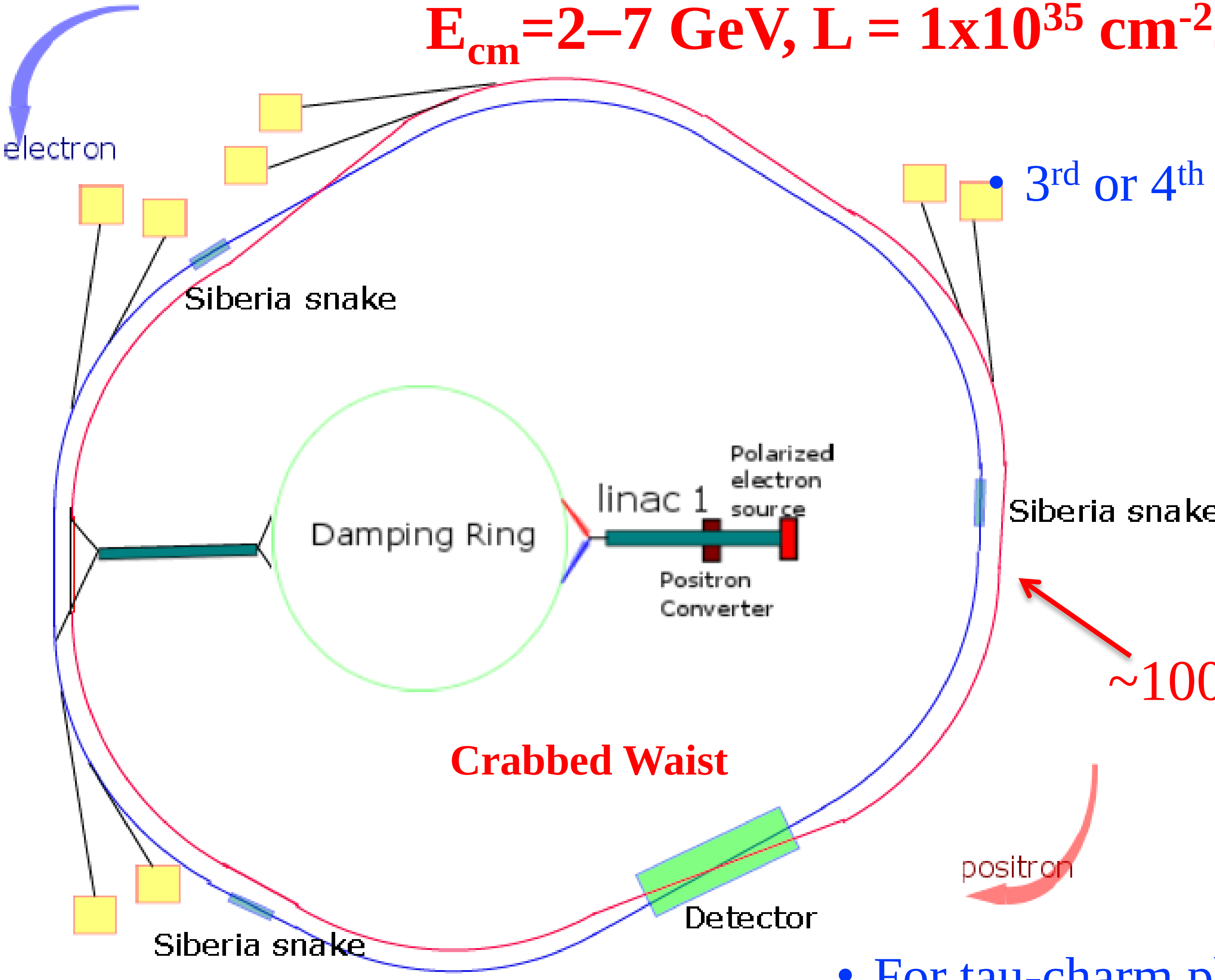
Nsig	$\delta R_{EM}/R_{EM}$	$\delta\sigma/\sigma$	Luminosity (pb^{-1})	comment	
614±24	24%	3.9%	2.631	BESIII test run	
3881±62	9.5%	1.6%	16.630	BESIII expected	
156253±395	1.5%	0.25%	669.533	HIEPAF reach 1	1 day
389898±624	0.96%	0.16%	1670.69	HIEPA reach 2	2 days





High Intensity Electron Positron Accelerator

E_{cm}=2–7 GeV, L = 1x10^{35} $cm^{-2}s^{-1}$ at 4 GeV



- 3rd or 4th generation **SRF**

~1000M double ring

Crabbed Waist

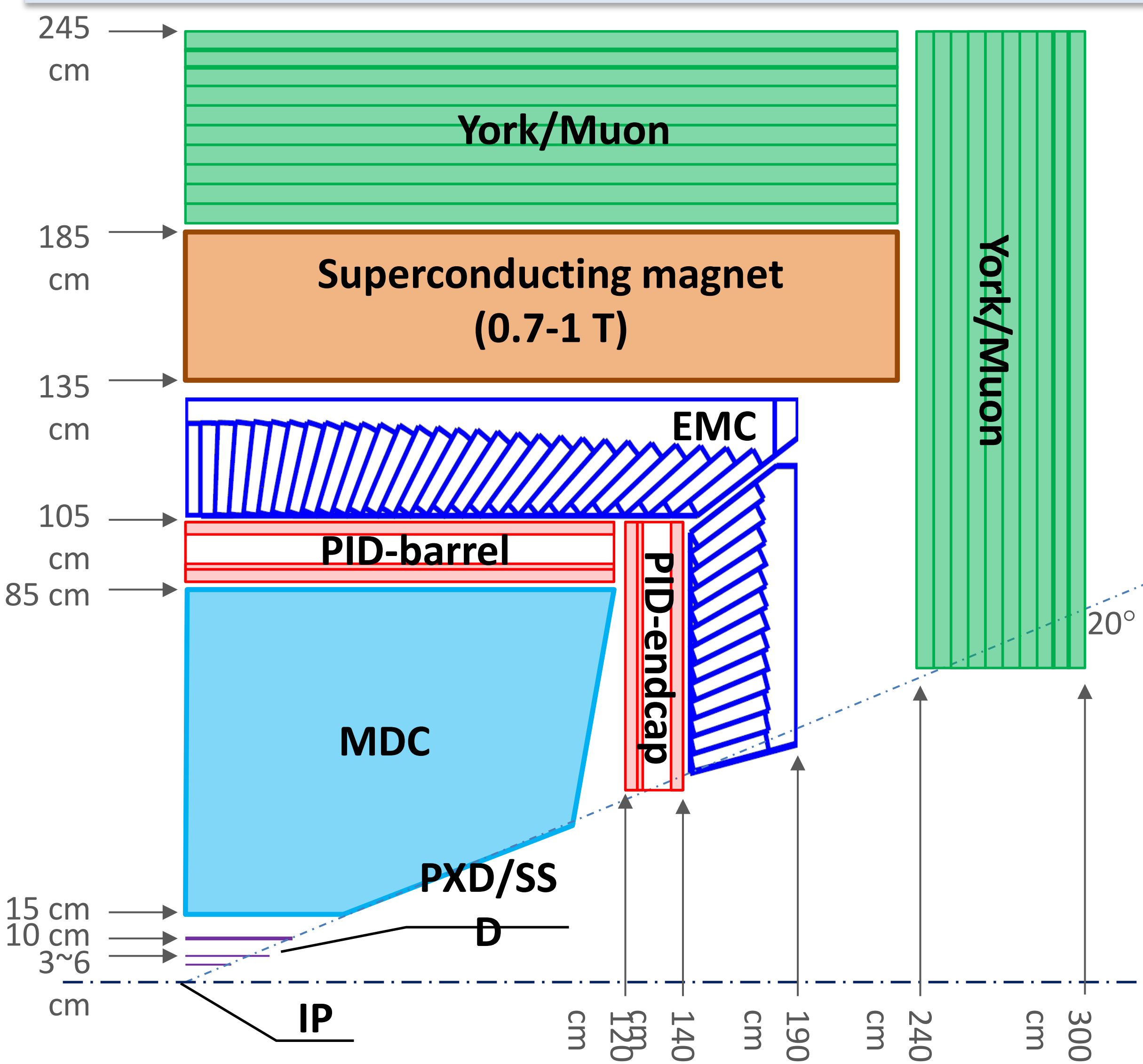
- For tau-charm physics

Beam Parameters

(Lattice and other related AP studies are under way)

Beam energy (GeV)	3.0	Revolution frequency (MHz)	0.302
Circumference (m)	992.8	Harmonic number	1656
Coupling factor	0.005	$\beta_{x,\,y}$ @ IP (mm)	1000, 1.0
Emittance (nm.rad)	10	Beam-beam parameter	0.06
Bunch length (mm)	10	Number of bunch	540
Momentum compaction	0.001	Bunch current (mA)	5.0
SR energy loss/turn (MeV)	0.716	Beam current (A)	2.7
Synchrotron tune	0.0128	SR power (MW)	1.93
RF voltage (MV)	2.0	Energy spread	8.12E-4
RF frequency (MHz)	500.06	Luminosity ($cm^{-2}s^{-1}$)	1.05E35

Detector



MUD

- μ/π suppression power >10/30

EMC

- Energy range: 0.02-2.5 GeV
- At 1 GeV σ_E (%)
  - Barrel(Cs(I): 2
  - Endcap (Cs): 4

PID

- π/K (and K/p) 3-4σ separation up to 2GeV/c

MDC (Low mass)

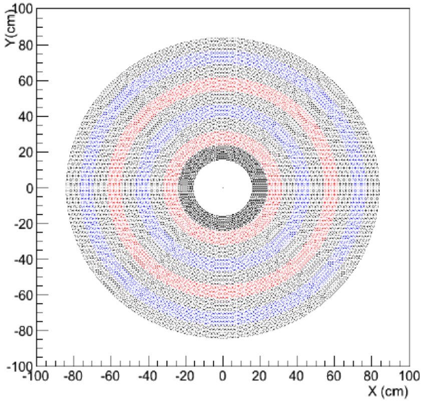
- σ_{xy}=130 mm
- dE/dx<7%, σ_p/p =0.5% at 1 GeV

PXD

- Material budget ~0.15%X_0/layer
- σ_{xy}=50 mm

Tracking System

A Drift Chamber for HEPAF



Low mass

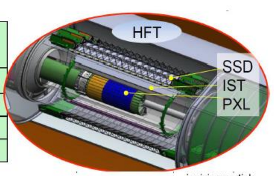
- Rin = 15 cm
- Rout = 85 cm
- L = 2.4 m
- B = 1 T
- He/C2H6 (60/40)
- # of layers = 48
- Cell size =1.0cm(inner),1.5cm(outer)
- Sense wire: 20 um W
- Field wire: 110 um Al
- 0.5%X0 carbon fiber inner wall
- Expected spatial resolution: 130 um
- Expected dE/dx resolution: 7%
- Layer configuration: 8A-5S-5A-5S-5A-5S-5A-5S-5A

Inner Tracker Options

- Silicon detectors
  - Prerequisite for use at HEPAF: low material
  - References
    - STAR heavy flavor tracker
    - BELLE2 pixel detector
- Cylindrical GEM
  - a gaseous detector, low mass intrinsically
  - a reference
    - KLOE inner tracker

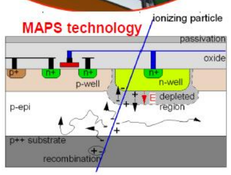
STAR Heavy Flavor Tracker

Detector	Radius (cm)	Hit Resolution R/φ - Z (μm - μm)	Radiation length
SSD	22	30 / 860	1.5 $\%X_0$
IST	14	170 / 1800	1.32 $\%X_0$
PIXEL	8	12 / 12	~0.37 $\%X_0$
	2.6	12 / 12	~0.37 $\%X_0$



- SSD: single-layer double-side strips
- IST: one layer of strips
- PIXEL
  - MASP technique -> low material
  - pixel pitch: 20 μm *20μm
  - 2cm*20cm ladder, 10 ladder in total
  - double layers

MAPS technology



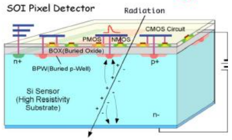
A prototype pixel ladder

BELLE2 Pixel Detector

- Belle II beam pipe radius ~ 1.6 cm.
- Two layers of PXD: 1.8 cm and 2.2 cm in radius, consisting of 8 and 12 modules for innermost layer and the second, respectively.
- In the active pixel matrix region: thickness ~ 75 μm.

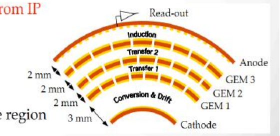
Number of pixels per module	250 x 1536
Pixel size (r-phi, z)	50μm x (60-75) μm
Frame time	20 μs
Material budget per layer	0.15% X_0
Resolution (r-phi, z)	<10μm, < 20μm
Occupancy at 1.8 cm radius	0.2 hits $\mu m^{-2}s^{-1}$
Radiation environment	~1 Mrad/year

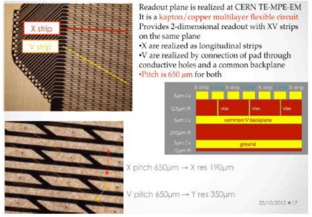
DEPFET Technology

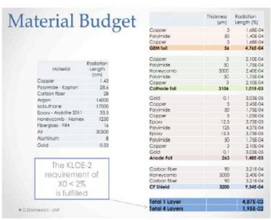


KLOE Inner Tracker

- 4 CGEM layers at 13/15.5/18/20.5 cm from IP inside outer Drift Chamber
- 700 mm active length
- XV strips-pads readout (25°÷30° stereo angle)
- 2% X_0 total radiation length in the active region including Carbon Fiber shield







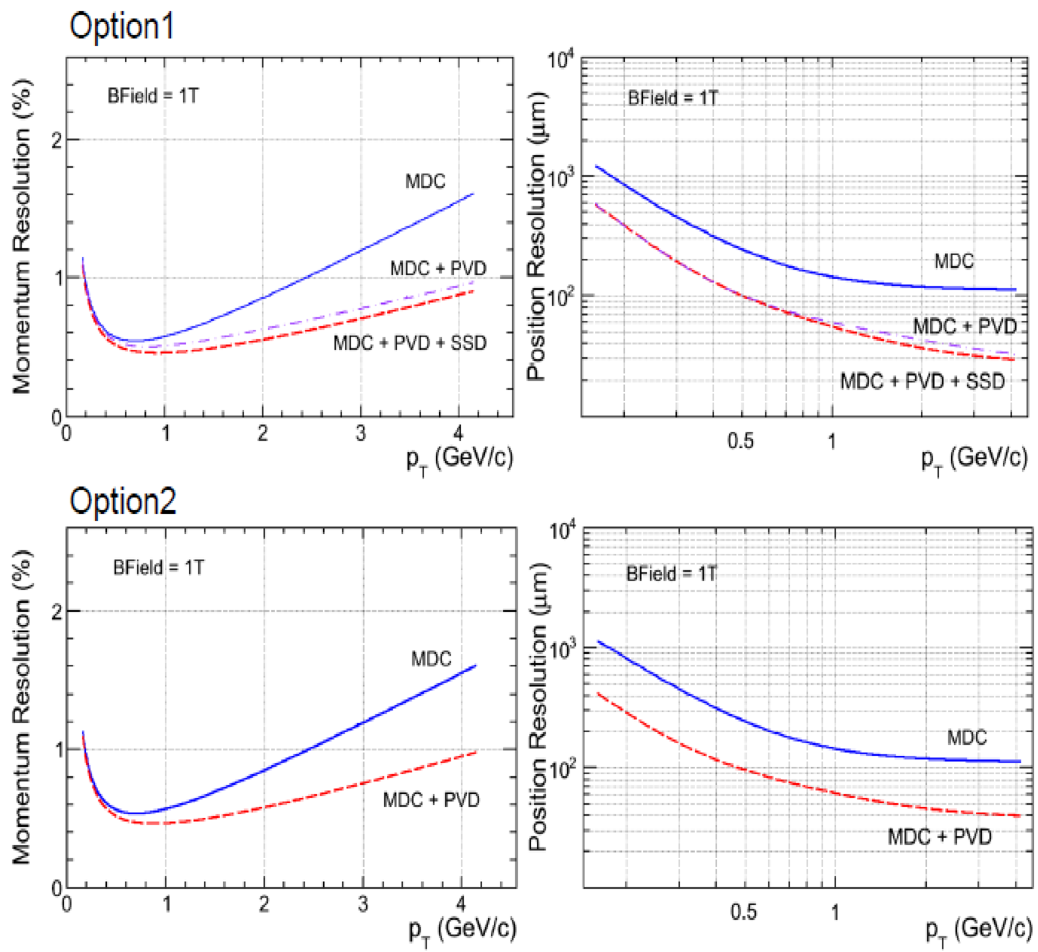
Tracking System

Option I: MDC + STAR HFT (geometry is not optimized)

Detector	radius (cm)	material (%X_0)	resolution (μm)
MDC Outer 9-48	23.5-82	0.0045 /layer	130
MDC Inner 1-8	15-22	0.0051 /layer	130
SSD	10	1.5	250
PXD 2 layers	3/6	0.37 /layer	30
Beam pipe	2	0.15	–

Option II: MDC + Belle-II PXD (geometry is not optimized)

Detector	radius (cm)	material (%X_0)	resolution (μm)
MDC Outer 9-48	23.5-82	0.0045 /layer	130
MDC Inner 1-8	15-22	0.0051 /layer	130
PXD 3rd layer	10	0.15	50
PXD 2 layers	3/6	0.15 /layer	50
Beam pipe	2	0.15	–



PID Detector

Key Features of PID System

- Enable π/K (and K/p) 3-4σ separation up to 2GeV/c
- Suitable for high luminosity run – fast detector
- Radiation hard, especially in the endcap region
- Compact – reduce costs of the outer detectors
- Modest material budget - $<0.5X_0$

Low Momentum PID

- Specific energy loss (dE/dx) in MDC can be used for low momentum PID
- Better dE/dx resolution for longer track length
- BESIII MDC (~6%, track length ~0.7m)
  - clean π/K/p ID for p<0.8/1.1 GeV/c

High Momentum PID

- TOF can not identify π/K to p=2GeV/c
- Cherenkov detector is necessary
- Two catalogs
  - Threshold Cherenkov – simple to build
  - Imaging Cherenkov: RICH (large momentum range)/ DIRC / TOP (most compact)

PID Detector

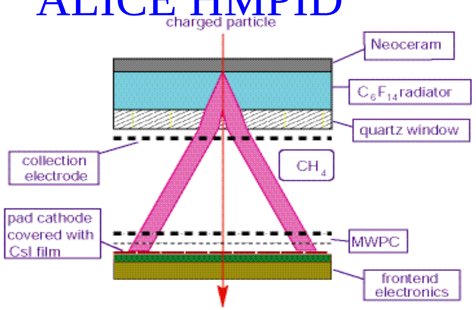
Baseline Design

- PID by RICH at 0.8<p<2GeV/c, no TOF
- Proximity RICH, similar to ALICE HMPID design, but with PHENIX HBD (CsI coated GEM) readout
- n~1.3 (liquid C_6F_{14}), UV detection
- Already proven
- Immune to B field → same structure at both the endcap and the barrel

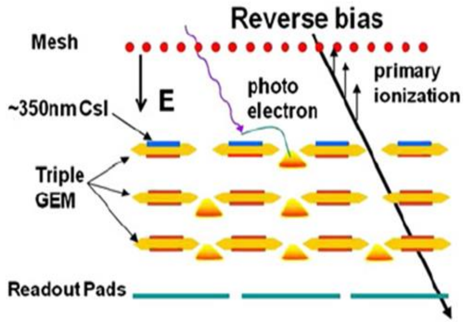
Alternative Design

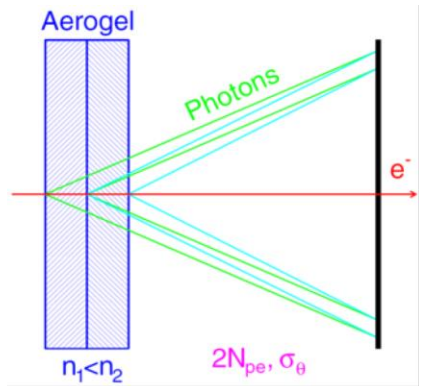
- No TOF, PID by RICH only
- Similar to BELLE-II ARICH design, Aerogel + Position Sensitive Photon Detector
- n~1.13 (Below threshold for proton at p<2GeV/c)
- Already proven at the BELLE-II endcap, how about the barrel part?
- Need R&D

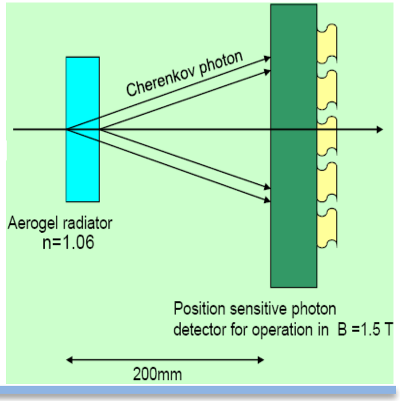
ALICE HMPID



PHENIX HBD







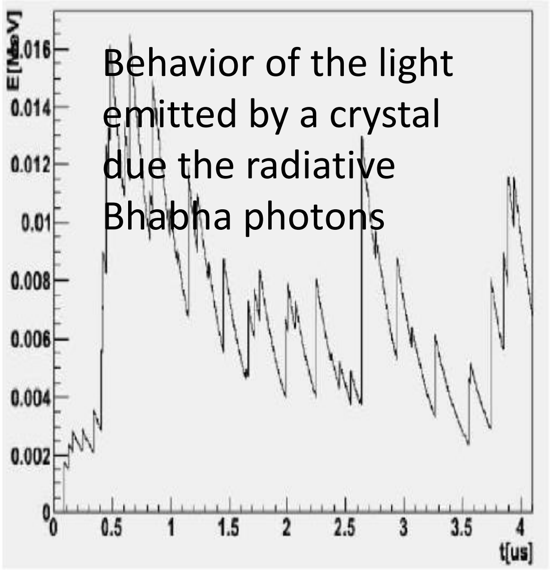
Electromagnetic Calorimeter

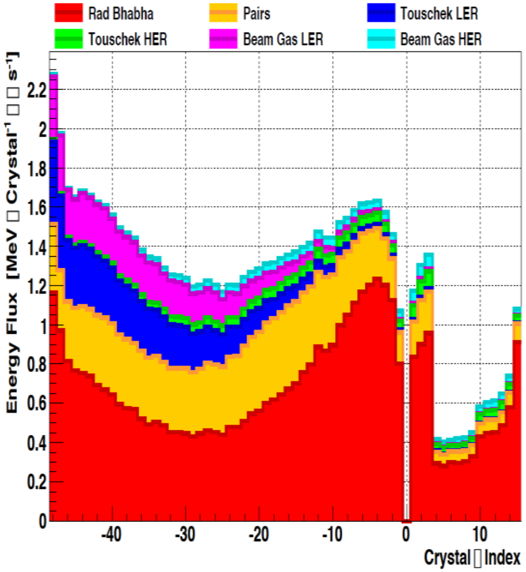
EMC Requirements

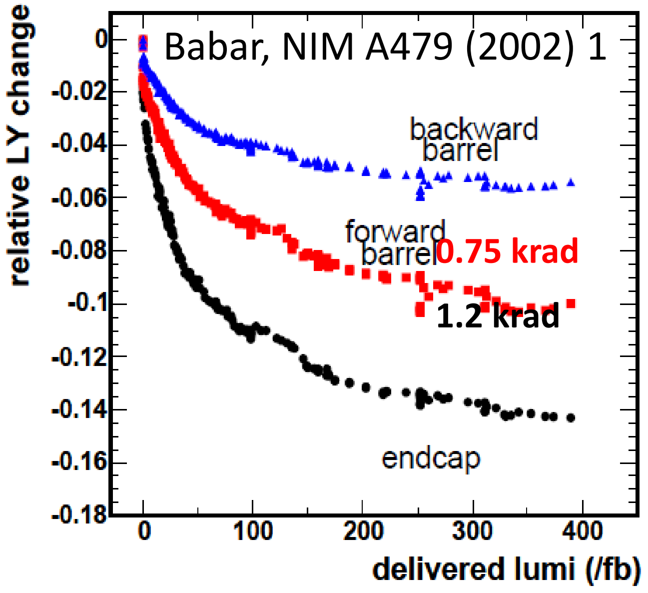
- Good energy resolution
- Good position/angular resolution
- Good timing resolution if possible

Challenging

- Radiation damage
  - Decrease light yield
  - A function of run time
- High photon background rate
  - Produce pile-up
  - Degrade energy and angular resolution







Electromagnetic Calorimeter

BSO Crystal

Pros:

- Relative fast
- Radiation hard
- Emission spectrum peak at 480 nm
- Small X0 (60% CsI) → more compact
- Small Moliere Radius (60% CsI) → finer segmentation
- Low raw material cost (~PWO and 50% BGO, much less than LYSO)

Cons:

- LY smaller than CsI(Tl) and LYSO (however, ~ PWOII at -25 ^{0}C)
- Dose rate dependent LY, fast recovery time → LY Calibration system needed
- Not mature (large size available, mass production not proven)

PhotoSensors

PIN Photodiode

- Mature
- Large noise/signal

Large Area APD

- Relatively Mature
- Large noise/signal

Vacuum photopentode

- New, under developing
- Low noise, low gain (~10-100)
- Sensitive to magnetic field

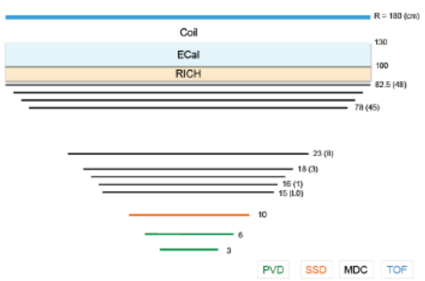
Multi-Pixel Photon Counter (MPPC/SiPM)

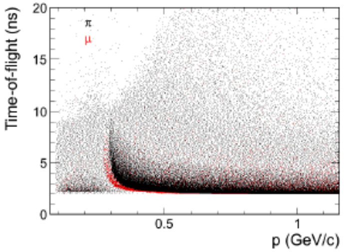
- New, under developing
- High gain (~10^6), low ENE, simplify elec.
- Insensitive to magnetic field
- Good timing resolution

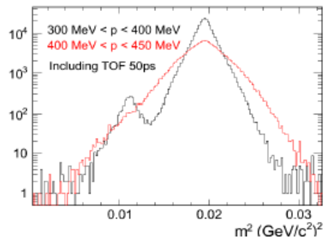
Muon Detector

A “Timing” Muon Detector

- Use a STAR/MTD-like detector to incorporate TOF measurement in muon detection.



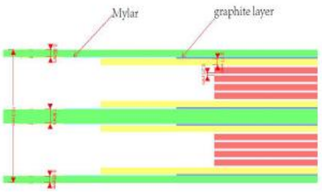




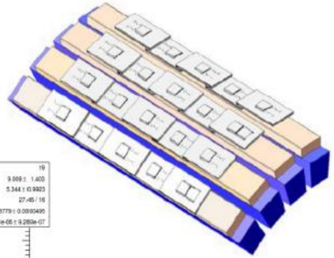
Pions and muons well separated by TOF below 400 MeV

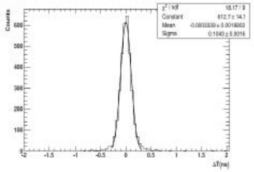
STAR MTD

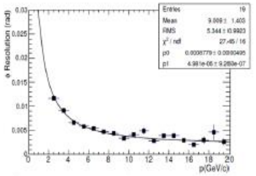
- Muon Telescope Detector (MTD) at STAR
  - based on long-strip MRPC technology
  - 95% F134a + 5% iso-butane
  - Gas gap: 0.25mm, 10 gaps in 2 stacks
  - Read out strip: 2.5 cm wide, 90 cm long



- Performance
  - Time resolution: < 100 ps
  - Spatial resolution: ~ 1 cm
  - High efficiency: ~98%





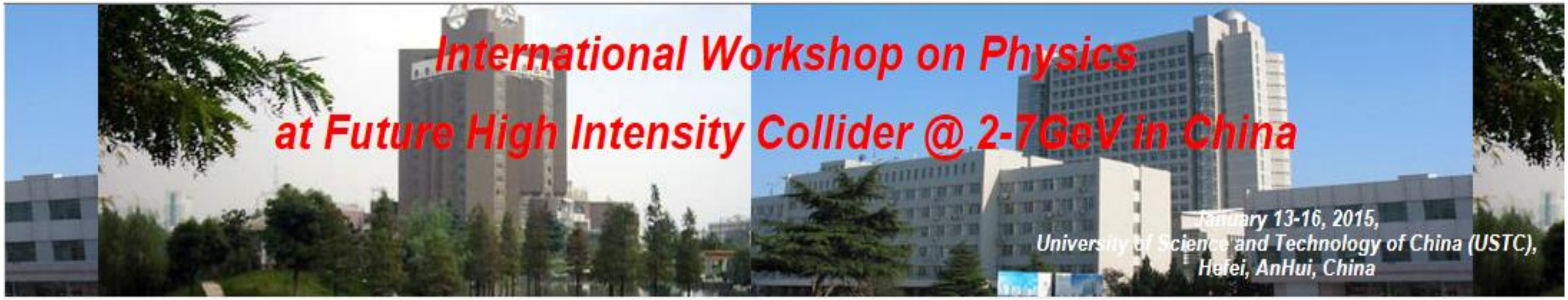


Summary

- HIEPA is one of the possible options for high energy physics in China.
  - Have interesting physics relating to key science questions
  - Have challenges in terms of key technologies
  - Reasonable scale and cost.
  - Interdisciplinary mode (STCF + SRF + FEL?)
- Working groups are formed and are making progress with regular weekly meeting and workshops.
- Tend to have a CDR this winter
- Your ideas, suggestions and inputs are very important for us,

Welcome to join the effort

HIEPA International Workshop



International workshop, Jan 13-16th, 2015, USTC, Hefei, China

The registration was opened

http://cicpi2011.lcg.ustc.edu.cn/hiepa2015/

Thank You!

Backup Slide

Physics @ HIEPA

- ***Precise test of SM***
  - R Scan, Hadron form factor (nucleon, Λ, π), $\Delta\alpha_{QED}$, a_u
  - tau lepton decays, lepton universality test
  - CKM matrix, Decay constants (f_D/f_{Ds}), form factors
  - Neutral D mixing and strong phase
- ***hadron physics***
  - meson, baryon, hyperon spectroscopy
  - threshold effects
  - Glueball: direct test of QCD at low energy
  - Multiquark, exotics, hybrids…..
  - Charmonium(-like) spectroscopy
  - Charmed baryon decays
- ***New physics(tiny/forbidden in SM)***
  - Rare charmonium decays：LFV, LNV, BNV…
  - Rare charm decay : FCNC, LFV, LNV, invisible
  - Rare tau decay : FCNC, LFV, LNV
  - Rare light meson decay : $\eta/\eta'/\omega/\phi$
- ***Exotic phyics***
  - Light dark matter : light Higgs boson(a_0), U boson
  - New interactions
- ***CP Violation***
  - Unexpected large CPV in tau or charm: tiny in SM
  - CP violation in baryon/hyperon/charm baryon

Summary of τ Physics

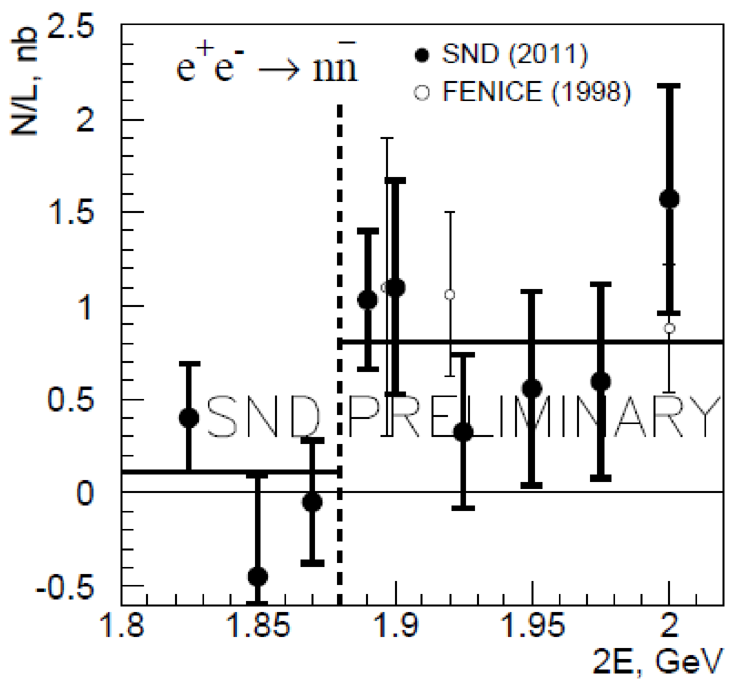
With $1ab^{-1}$ near tau threshold:

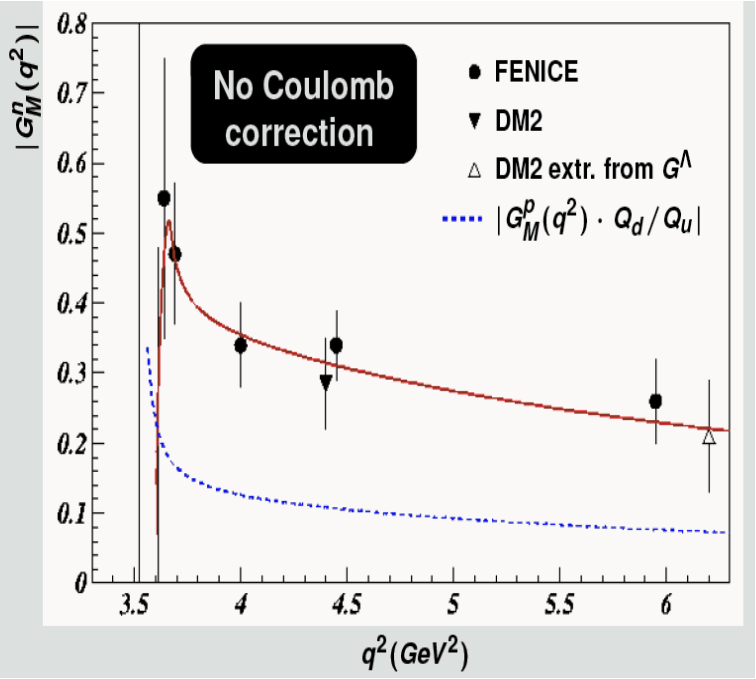
- **LFV: 10^{-9}**
- **Lepton universality: 10^{-4}**
- **CP violation in decay: 10^{-4}**
- **CPT tests: 10^{-4}**
- **Tau mass**
- **Vus: (0.1-0.5)%**

A super-tau-charm and a BELLEII will be complementary machines for tau physics

Nucleons FF

- 中子数据更稀缺，只有Fenice结果(74个$e^+e^- \to n\bar{n}$事例, 0.4 pb^{-1})
- 现有数据表明中子的形状因子是质子的2倍，需要实验验证!



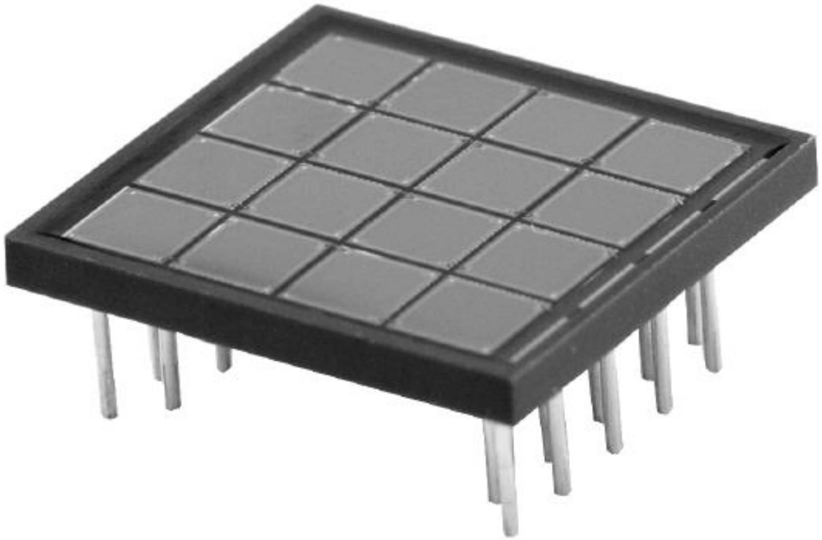


提高中子形状因子的测量精度在实验和理论方面都具有重要意义！

意大利曾计划对**DAΦNE/FINUDA**做重大专门改进来测量核子形状因子

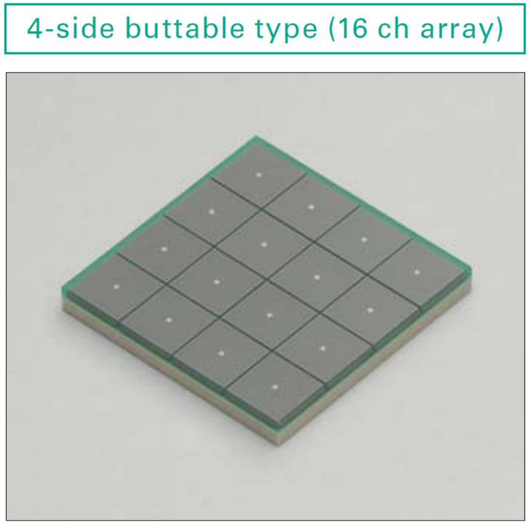
SiPM/MPPC Products

sensL



4 x 4 channel array
3 x 3 mm^2 each channel
4774 cells per channel
~ €120

Hamamatsu



4 x 4 channel array
3 x 3 mm^2 each channel
3600 cells per channel
~ ￥1500