Post BEPCII and Super Tau Charm Factory

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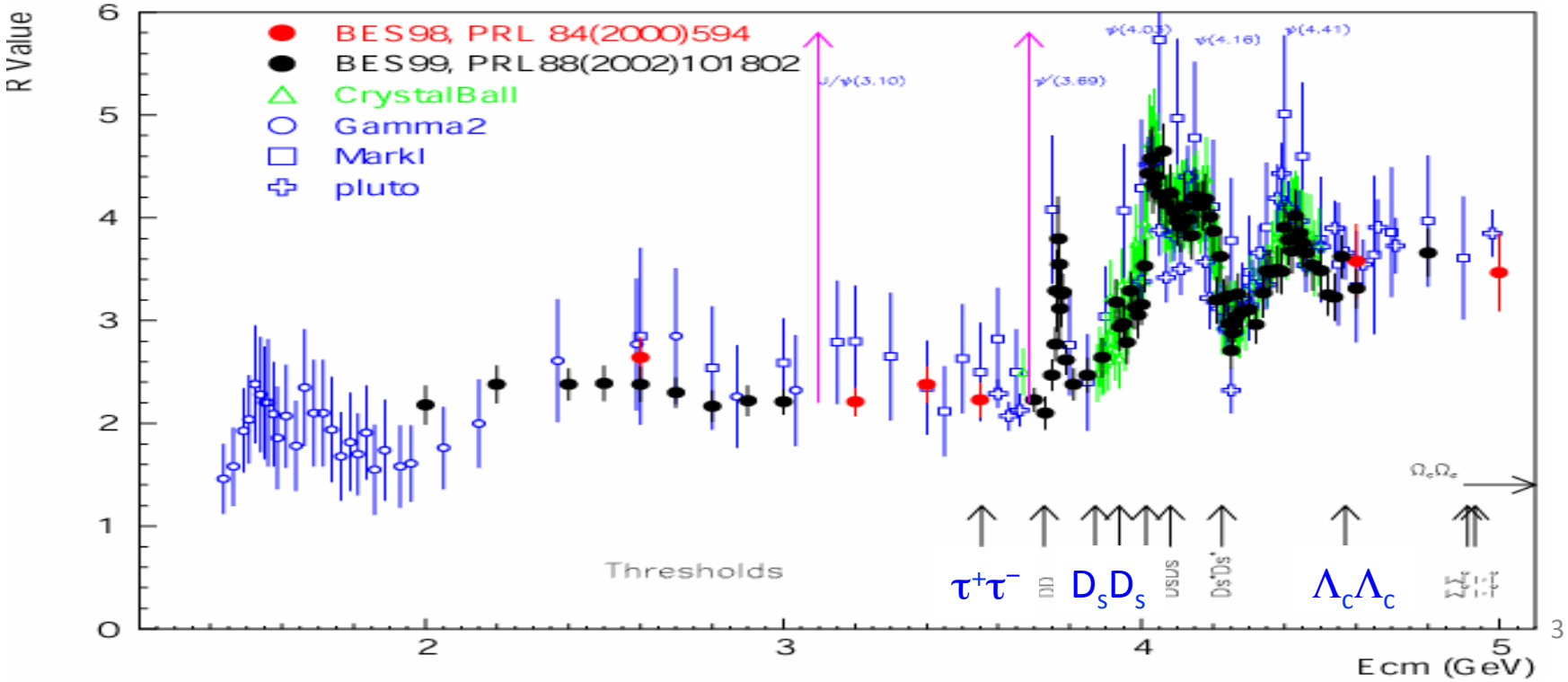
Outline

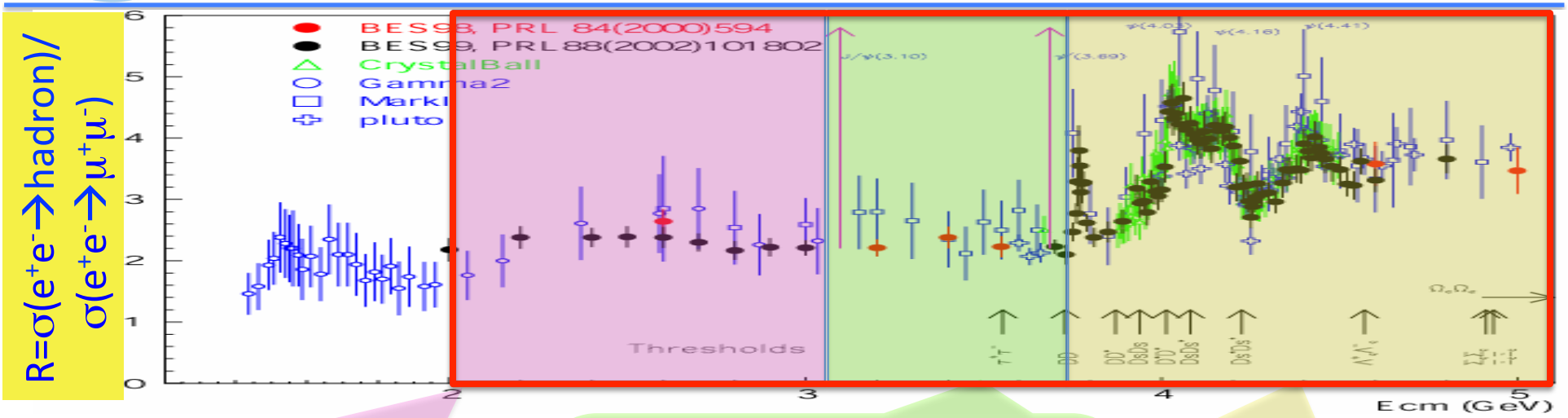
- Features of tau-charm energy region
- BEijing Spectrometer (BESIII) at Beijing Electron Positron Collider (BEPCII)
- Super Tau-charm Factory (STCF)
- Summary

Features of the 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.
- Energy location of the gluonic and exotic states.



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
- LFV process
- Rare and forbidden decays
- Physics with τ lepton

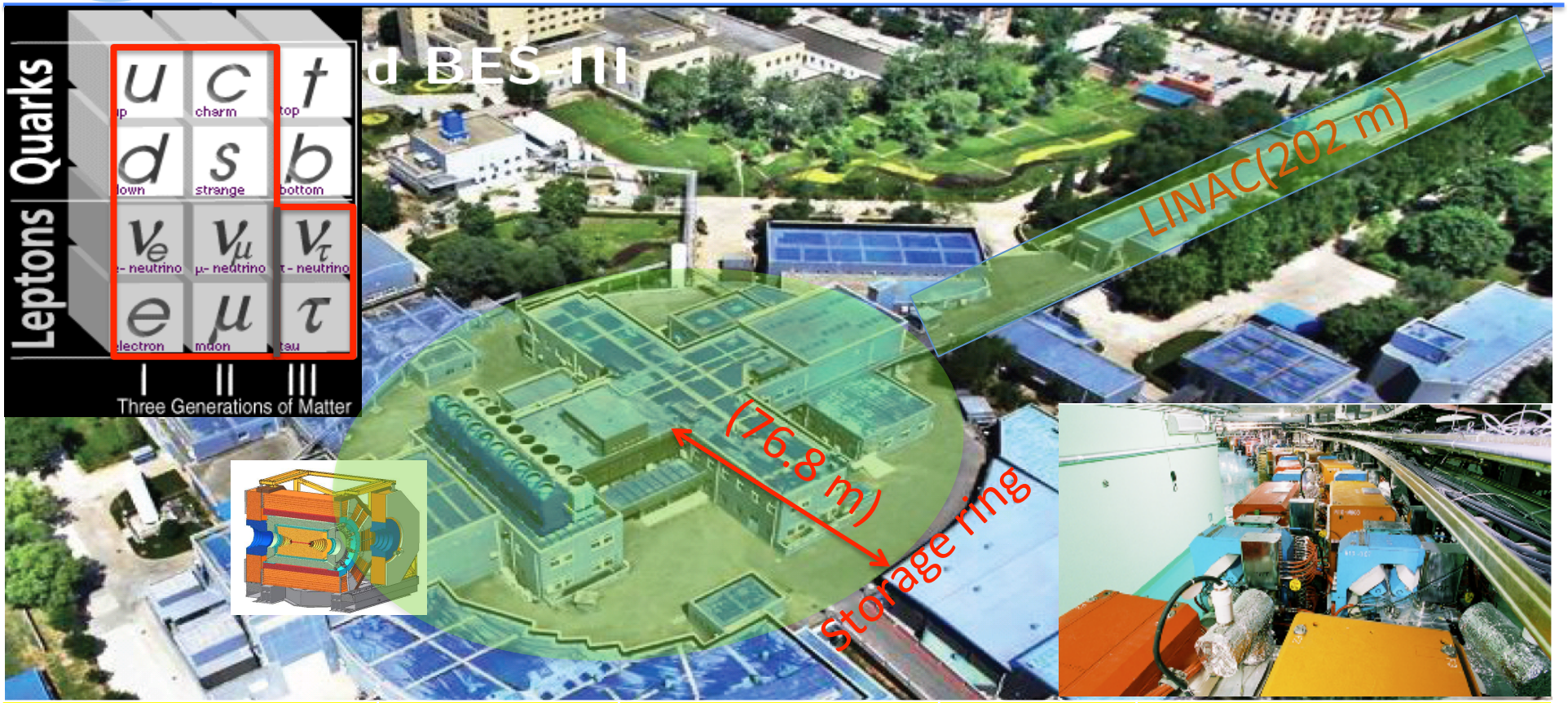
- XYZ particles
- Physics with D mesons
- f_D and f_{Ds}
- D_0-$\bar{D}_0$ mixing
- Charm baryons

R scan

- Precision $\Delta\alpha_{QED}$, a_μ, charm quark mass extraction.
- Hadron form factor(nucleon, Λ, π).
- Possible new resonance which are not yet discovered.

Beijing Electron Positron Collider

(Unique machine that directly operating at tau-charm energy sector)



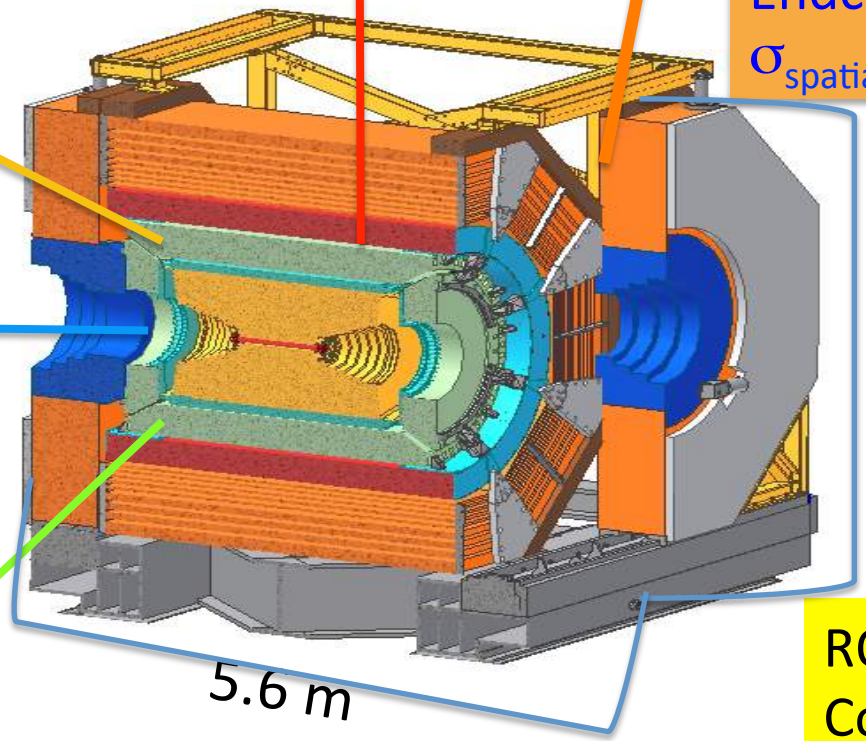
Collider	Detector	Year of running	E(GeV)	L (m^{-2} s^{-1})
BEPC(single ring)	BESI	1988-1995	2-5	2.7×10^{30} @J/ψ
	BESII	1998-2003	2-5	1×10^{31} @ ψ(3668)
BEPCII(double ring)	BESIII(new)	2008-2020	2-4.6	7×10^{32} @ ψ(3770)

BESIII Detector

Drift chamber (MDC)
Small cell, 43 layer
Gas He/C_3H_8=40/60
σ_{xy}=130 mm, dE/dx~6%
σ_p/p = 0.5% at 1 GeV

1 T Super conducting magnet

Muon counter
Resistive plate chamber
Barrel: 9 layers
Endcaps: 8 layers
$\sigma_{spatial}$: 20 mm



Time-of-flight (TOF)
Plastic scintillator
σ_T(barrel): 90 ps
σ_T(endcap): 110 ps

ECAL calorimeter
CsI(Tl): L=28 cm (15X_0)
Energy range: 0.02-2GeV

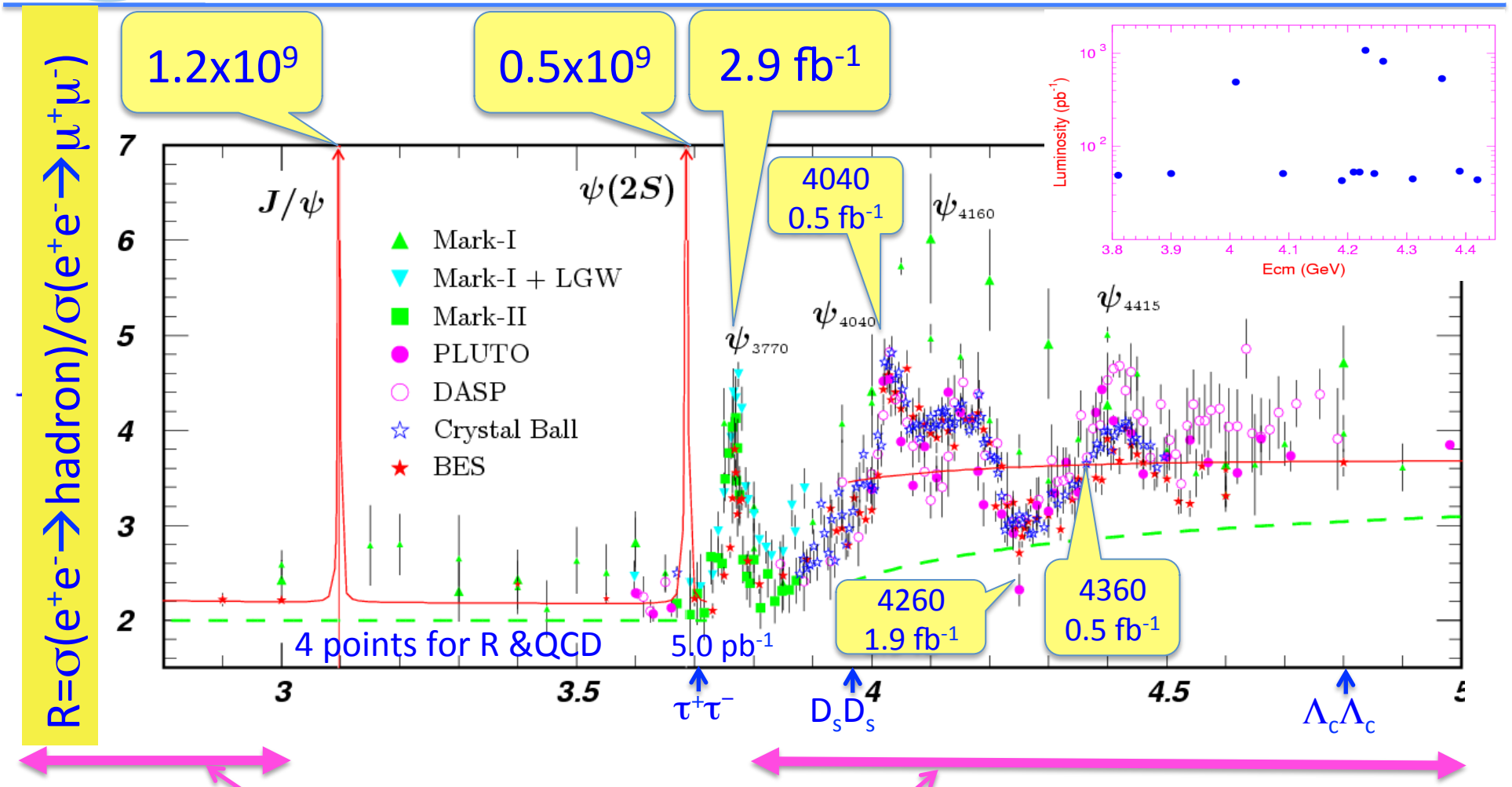
At 1 GeV	σ_E (%)	σ_l(mm)
Barrel:	2.5	6
Endcap:	5	9

RO channels: 10^4
Cost: 200 M RMB

Data acquisition
Event rate: 4 kHz
Data size: 50 MB/s

Grid computing
CPU: 3200 core
Storage: 2.2 pB

Data Samples Accumulated with BESIII



Not well explored region

Need very high statistical data

Selected Highlights from BES

- Precision measurement of M_τ
  - Lepton universality puzzle
- R scan in 2-5 GeV (average precision ~6%)
  - Precision determination of $\Delta\alpha_{QED}$, M_H from SM fit
  - Contribute to the interpretation of a_μ
  - Extraction of M_C
- Observation of "new states" - X(1835), X(1810), X(1860), $Z_c(3900)$ $Z_c(4020)$, $Z_c(4025)$, N*(2065), N(2570)…..
  - Light hadron spectroscopy
  - Exotic states

Post BEPCII High Energy Physics in China

(Nothing official, purely personal information collection)

- Chinese high energy physicists, led by the Chinese High Energy Association, has been exploring the future project.
- Projects under discussing by four working groups
  - Circular Higgs Factory (CHF, CEPC)
  - Z Factory (ZF)
  - Electron Heavy Ion Collider (EIC)
  - Super Tau Charm Factory (STCF)

Whichever project is going to be chosen, the site won't be in current IHEP campus and a new site needs to be found.

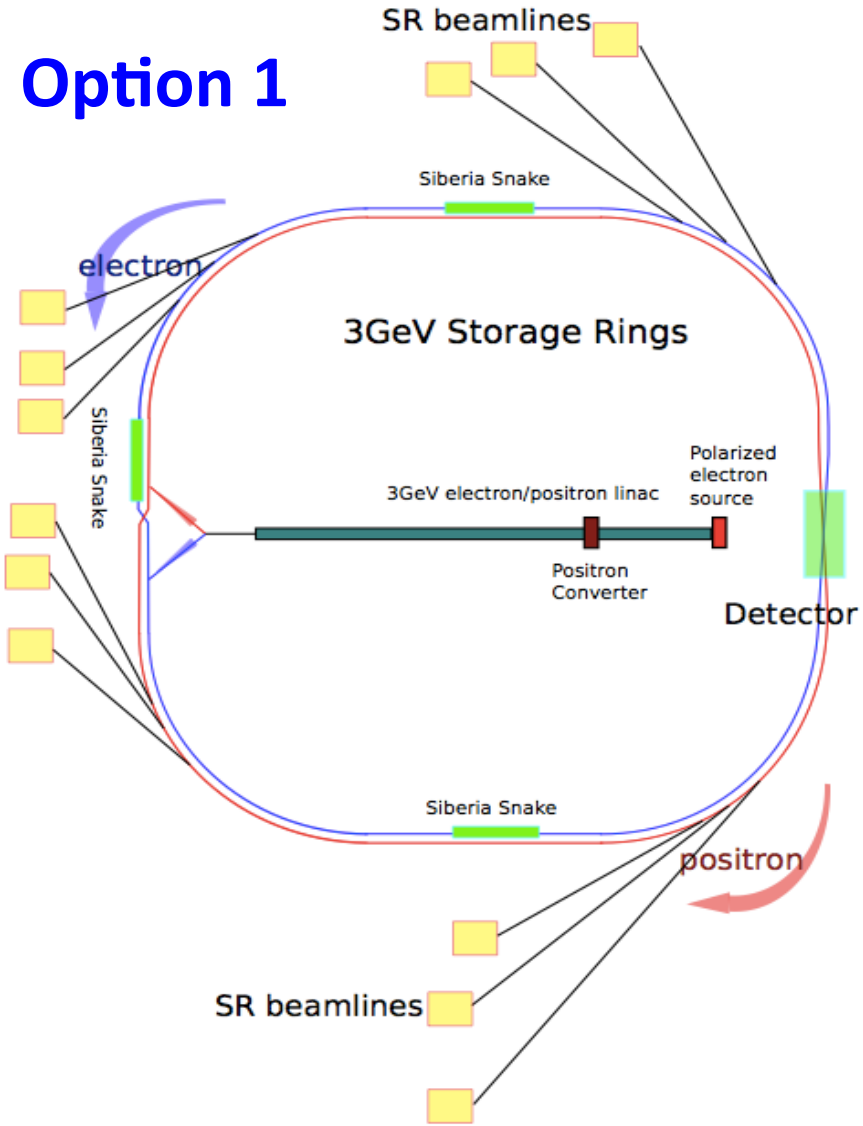
Facilities for Particle Physics in China

STCF: Accelerator

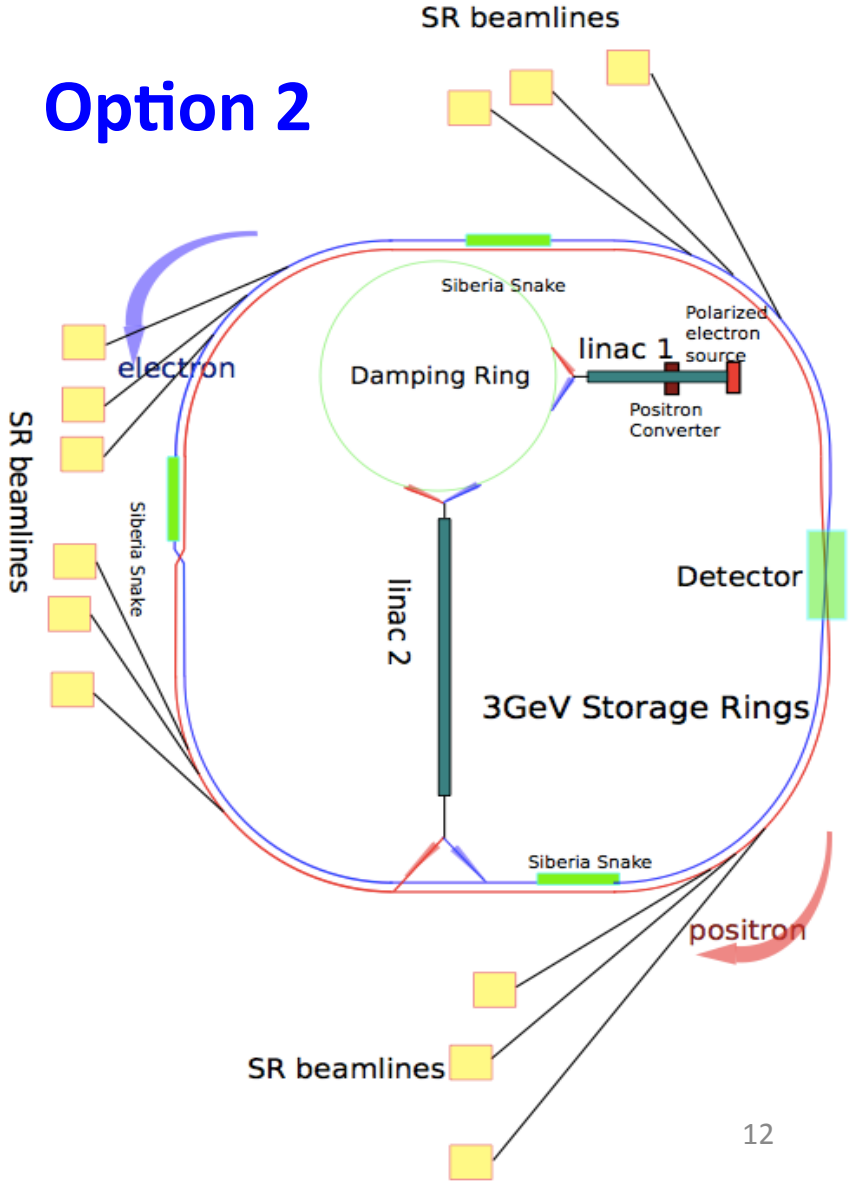
- Peak luminosity: 1 x 10^{35} $cm^{-2}s^{-1}$ at E_{cm}=4 GeV
- Energy region: E_{cm}=2–7 GeV
- Polarization available on one beam
- Symmetric machine with low currents and crab waist solution for the interaction region
- Interdisciplinary mode for
  - ring: compatible with synchrotron radiation facility (SRF)
  - linac: free electron laser (FEL)

Possible Schematic Layout
(Qin Qing, IHEP)

Option 1



Option 2



Beam Parameters (Qin Qing)

(Lattice and other related AP studies are under way)

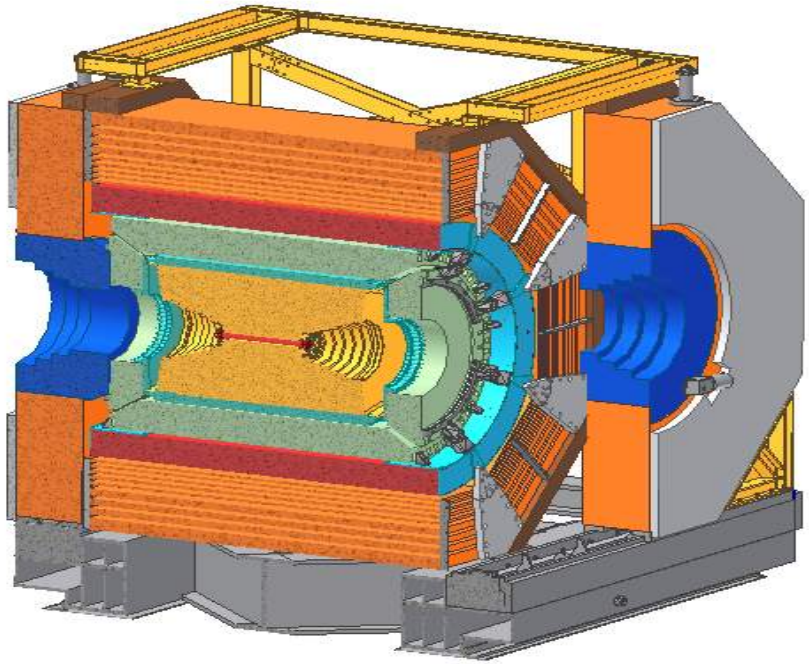
Beam energy (GeV)	3.0	Revolution frequency (MHz)	0.302
Circumference (m)	992.8	Harmonic number	1656
Coupling factor	0.005	$\beta_{x,\,y}$ @ IP (mm)	1000, 1.0
Emittance (nm.rad)	10	Beam-beam parameter	0.06
Bunch length (mm)	10	Number of bunch	540
Momentum compaction	0.001	Bunch current (mA)	5.0
SR energy 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

Requirement To The Detector

Efficient event triggering, exclusive state reconstruction and tagging – high efficiency and resolutions for charged and neutral particles

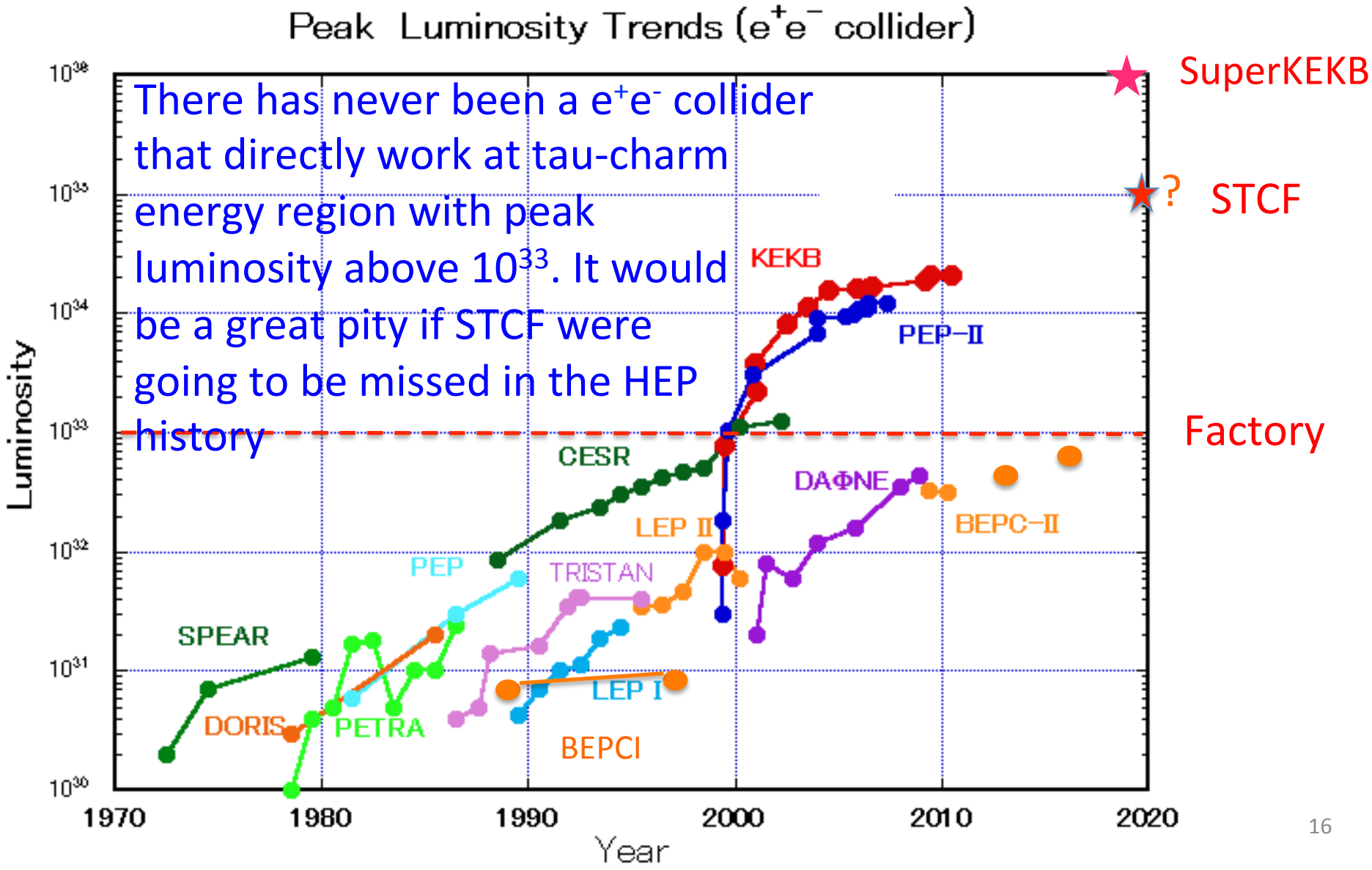
- Best possible solid angle coverage
- High resolution for charged particles: [0.05, 1.6] GeV
- Good PID: [0.05, 1.6] GeV
- Good e, γ detection eff. and energy resolution: [0.02, 2.5] GeV
- Good secondary vertex detection? – depend on the physics

Detector – BESIII As Reference



- BESIII Super conducting magnet (SCM) can be used (B = 0.7- 1 T ?)
- Better design for IP region
- Vertex: GEM/TPC/small gas chamber
- EMC: CsI crystal for barrel, LYSO or pure Cs for endcaps

Luminosity Trend of e^+e^- Collider



Highlights of the Physics Program

- Hadron form factor (nucleon, π, Λ)
- Search for gluonic and exotic states
- Search for new physics beyond the SM, e.g

  - process of LFV, rare and forbidden decays

  - dark force (GeV scale hidden dark photons)

Comment to new physics searches

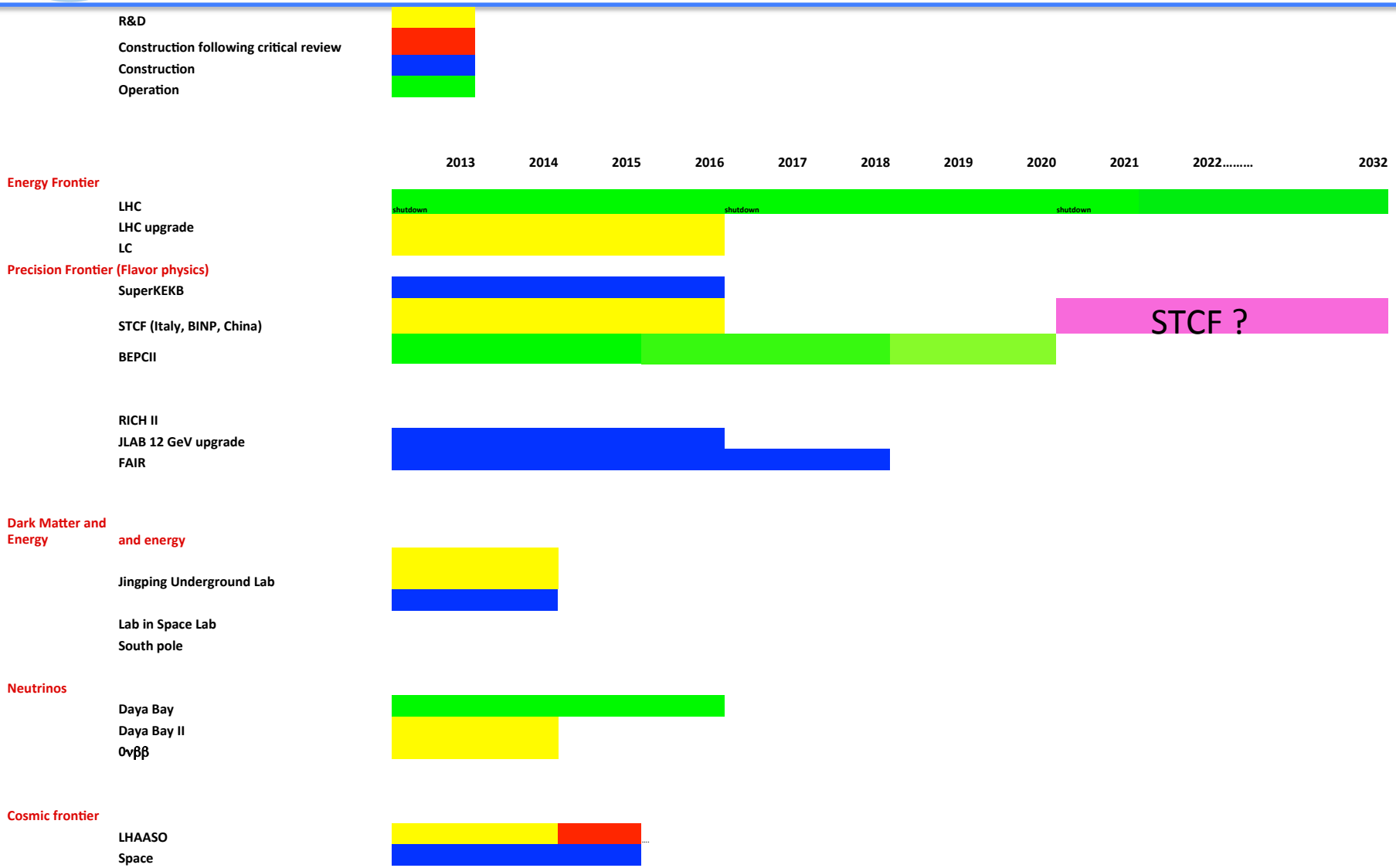
- No new physics has been found at the LHC so far.
- Important to search for NP from the precision frontier, e.g. directly look LFV from indirect searches, even provide data for constraining models.

Summary

- Rich physics program with broad spectrum for STCF
  - Hadron structure (form factor)
  - Search for and understand exotic states
  - New physics beyond SM (LFV, rare and forbidden decays)
- STCF with interdisciplinary mode (SRF, FEL) may be a way to go.
- BES/BEPC has been playing crucial role on physics in the tau-charm sector for over two decades, we have experts for machine/detector/physics) – STCF may still be one of the possible choice for HEP in China.

Extra Slides

Major Facilities for Particle Physics

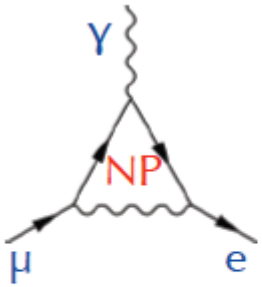


Lepton Flavour Violating (LFV)

cLFV processes sensitive to **New Physics (NP)**

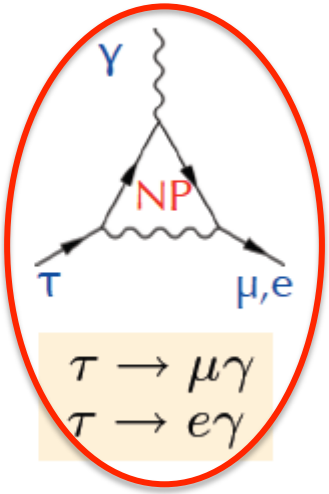
through lepton-lepton coupling $y_{ij}\bar{\ell}_i F^{\mu\nu}\ell_j\sigma_{\mu\nu}$

PSI



$\mu \to e\gamma$

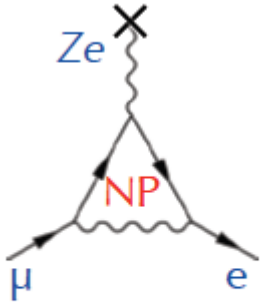
STCF



$\tau \to \mu\gamma$
$\tau \to e\gamma$

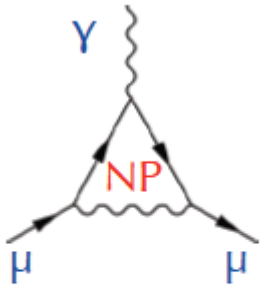
$\mu \to eee$

Mu2e



$\mu^- \mathcal{N} \to e^- \mathcal{N}$

BNL



$(g-2)_\mu$

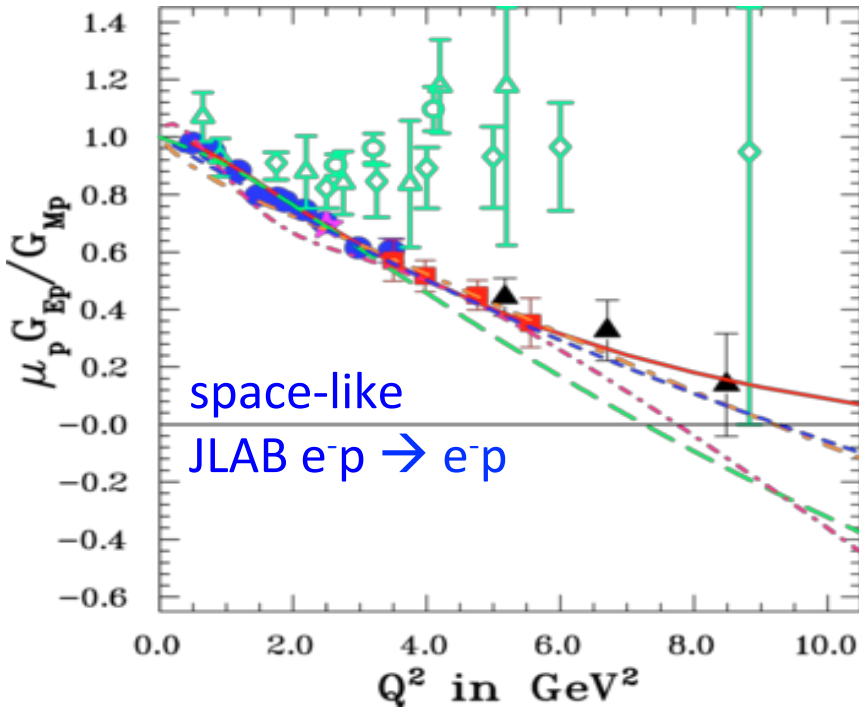
μ, τ anomalous decays

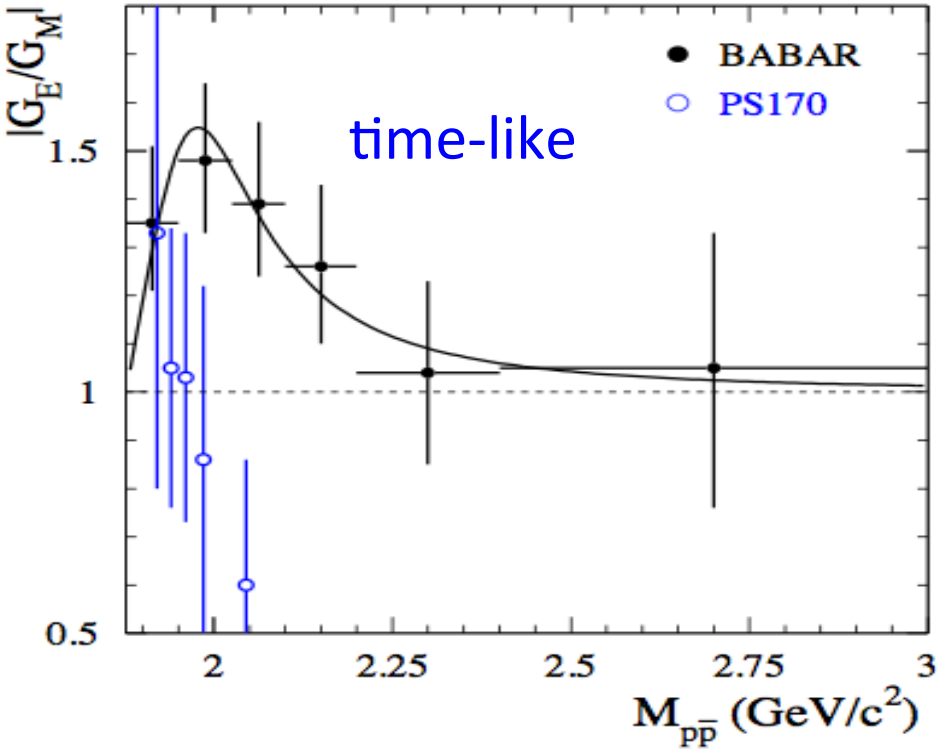
μ → e conversion

Anomalous magnetic moment

Proton Form Factor: $|G_E|/|G_M|$

$|G_E|/|G_M|$





Complete picture of the nucleon structure requires spacelike and timelike measurements!

XYZ Particles

(How many more and what are they?)