A03班　タウ・レプトンの物理

研究課題

(1) タウ data 解析

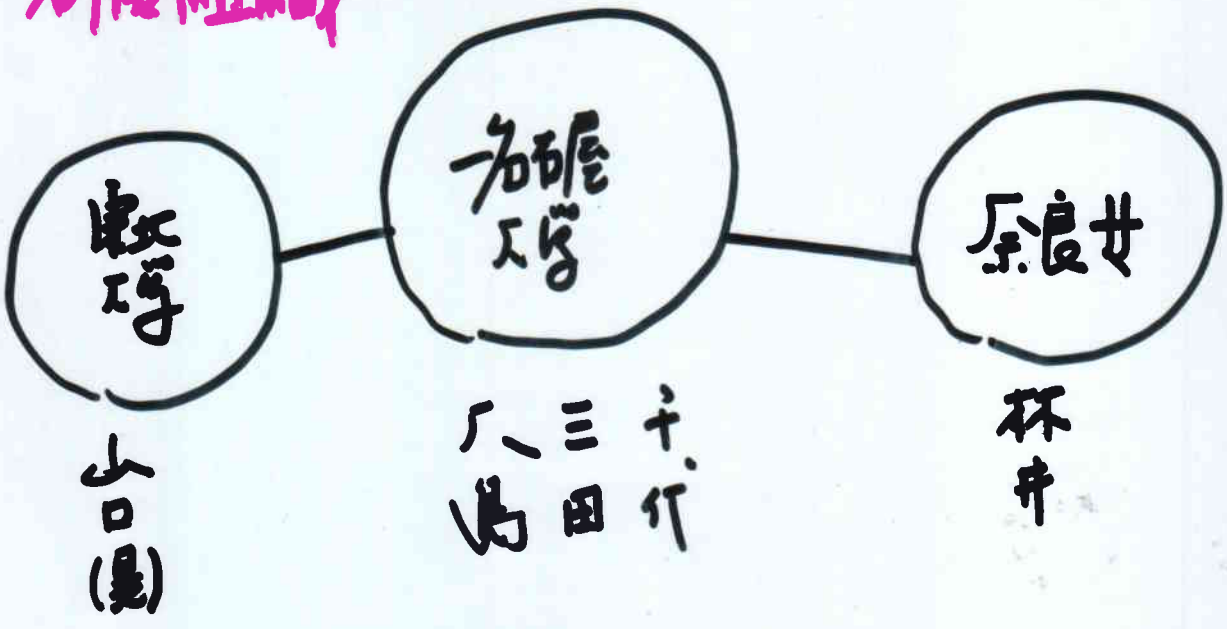
(Belle $\sigma(e^+e^- \to \tau^+\tau^-) = 0.9nb$

$B\bar{B} = 1.05nb$

(2) 新粒子識別装置

TOP counter の R&D

研究組織



τ data 解析中

Belle ~90 fb^{-1} ≒ 80M τ-pairs
世界最大の data 量

(1) τのEDM (CPV in lepton sector) 良い! 名大

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(2) τ→μγ (LFV = BSM search) } 解析終了 論文作成中 名大
(3) τ→μKs, 3leptons (LFV = BSM search) } 解析終了 論文作成中 東北大

(4) τ→μη, μπ^0 (LFV = BSM search) 解析最終段階 名大

(5) τ→ππ^{0}ν (anomalous mag. moment) 解析中 全員共

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(6) τ→Kπ^{0}ν の CPV search ing 全員共

(7) τ→2πν (2nd class current) ing 名大

(8) ρのMDM 理論計算 名大

(9) e$^+$e$^-$→μτ 解析中 名大

2002

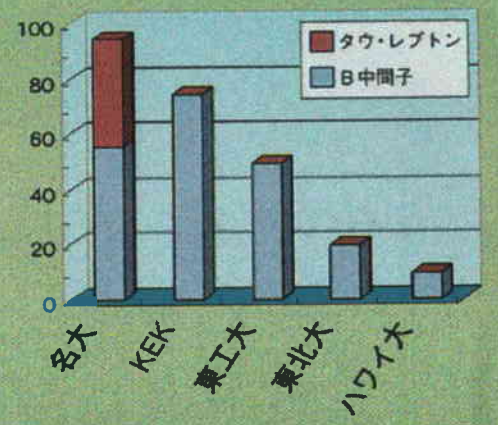
能の推移

に凄く膨大な量であ
のでは早期に物理成
ク網を用いたSINET
トワーク；最大性能
実上不可能であった。
の登場によりデータ
扱うのと同等の高速

り、最初にギガビッ
有用性を確認した。

共に増大する
増え続けてい

比べ100分の
による輸送を
、一部の緊急
たが、SINET
ため主力は磁
線の開通以来、
なり、データ
った。
有をおこない
Belle実験の



●シミュレーション事象の生成

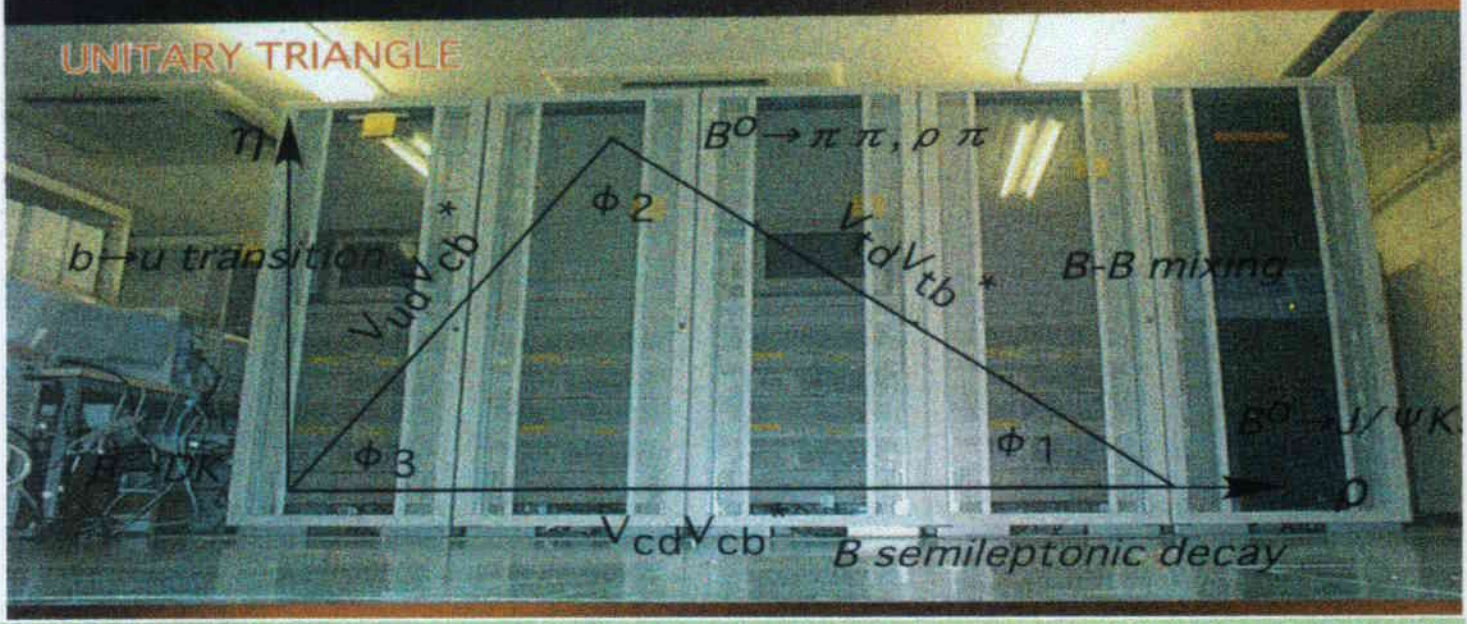
物理解析のためのモンテカルロ・シミュレーション事象をKEKおよび協同研究機関で協力して生成する。本施設は、また、タウ事象のデータ/解析環境を整備するBelleグループ内唯一の機関でもある。B中間子反応とあわせると、最多の事象数を生成している研究機関である。

名古屋大学大学院理学研究科
素粒子宇宙物理学専攻

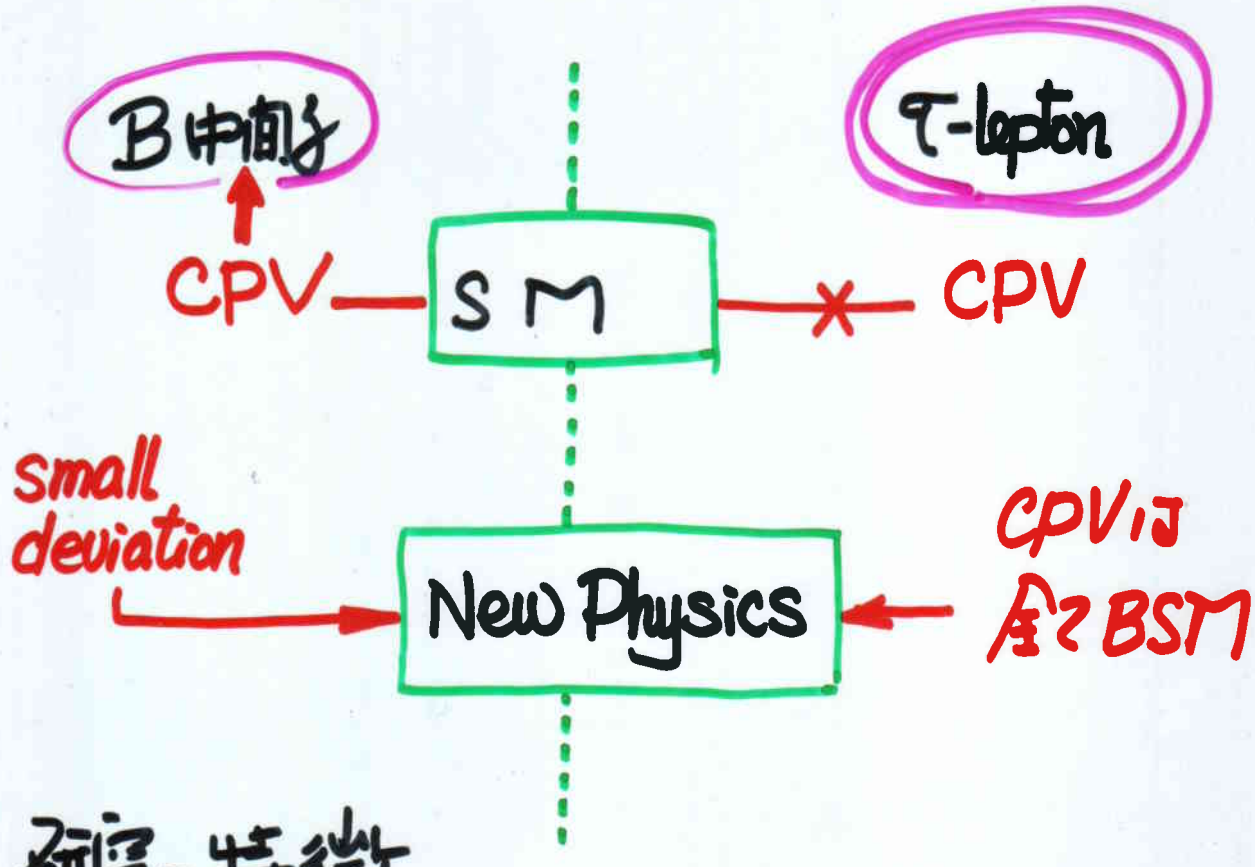
高エネルギー素粒子物理学研究室（N研）

High Energy Physics Lab.（N研）

高エネルギー物理学
データ解析実験施設



(1) CPV in lepton sector



研究の特徴

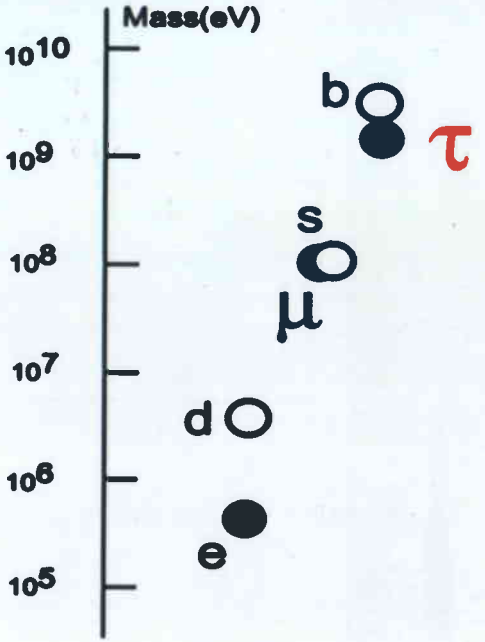
* 高精度のdataの把握

* Systematic errorの理解と減少

1. Tau Physics

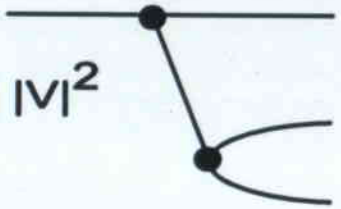
τ-lepton

Heaviest lepton (point=structureless particle)
sensitive to new physics



semileptonic

$$\Gamma_f = \alpha_w^2 \left(\frac{m_f}{m_W}\right)^4 m_f |V|^2$$



- Decay to various modes
- Unstable while e,μ = stable: high precise measurement

τ_K = 12.4 ns, τ_B = 1.7 ps,

τ_μ = 2.2 ns, τ_τ = 0.3 ps,

Beyond the SM

- New Physics ⇒ Rare phenomena ⇒ ***High intensity***

$$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$$

$$\begin{pmatrix} \nu_e \\ e \end{pmatrix} \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}$$

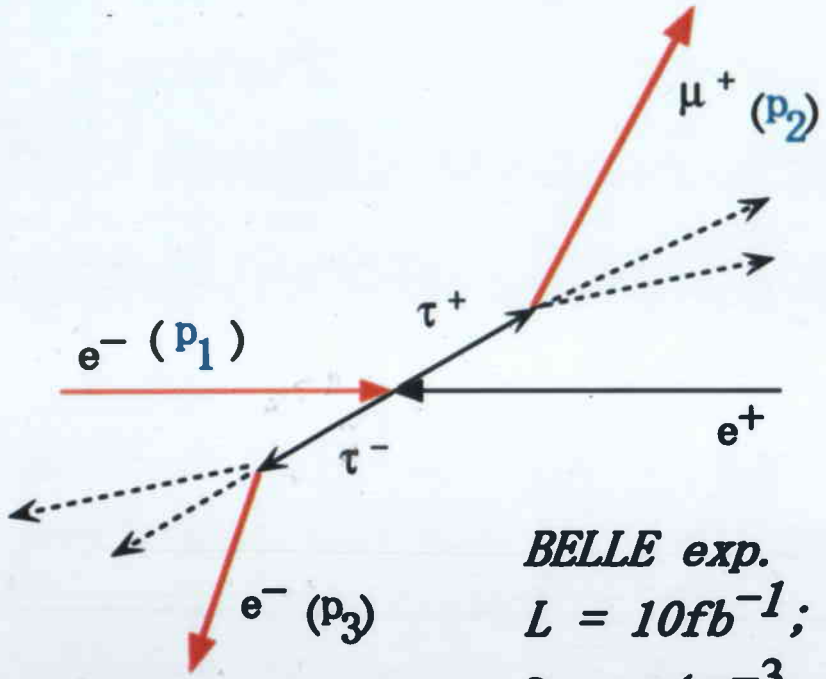
Test of T/CP Invariance in $e^+e^- \rightarrow \tau^+ \tau^-$

Test of T-invariance: EDM (n, e, atom), n β-decay, triple correlation (σ, p) of nucleon
P=even, T=odd

- pure leptonic transition :
  $\mu \rightarrow e\nu\nu$ (no violation, 2.3% : H. Burkard et al. PL 160B('85) 343.)

$$\langle A \rangle = \langle p_1 \cdot (p_2^+ \times p_3^-) \rangle \text{ in } e^+e^- \rightarrow \tau^+\tau^- ; \tau \rightarrow (\mu / e)\nu\nu$$

p_i = momentum unit-vectors

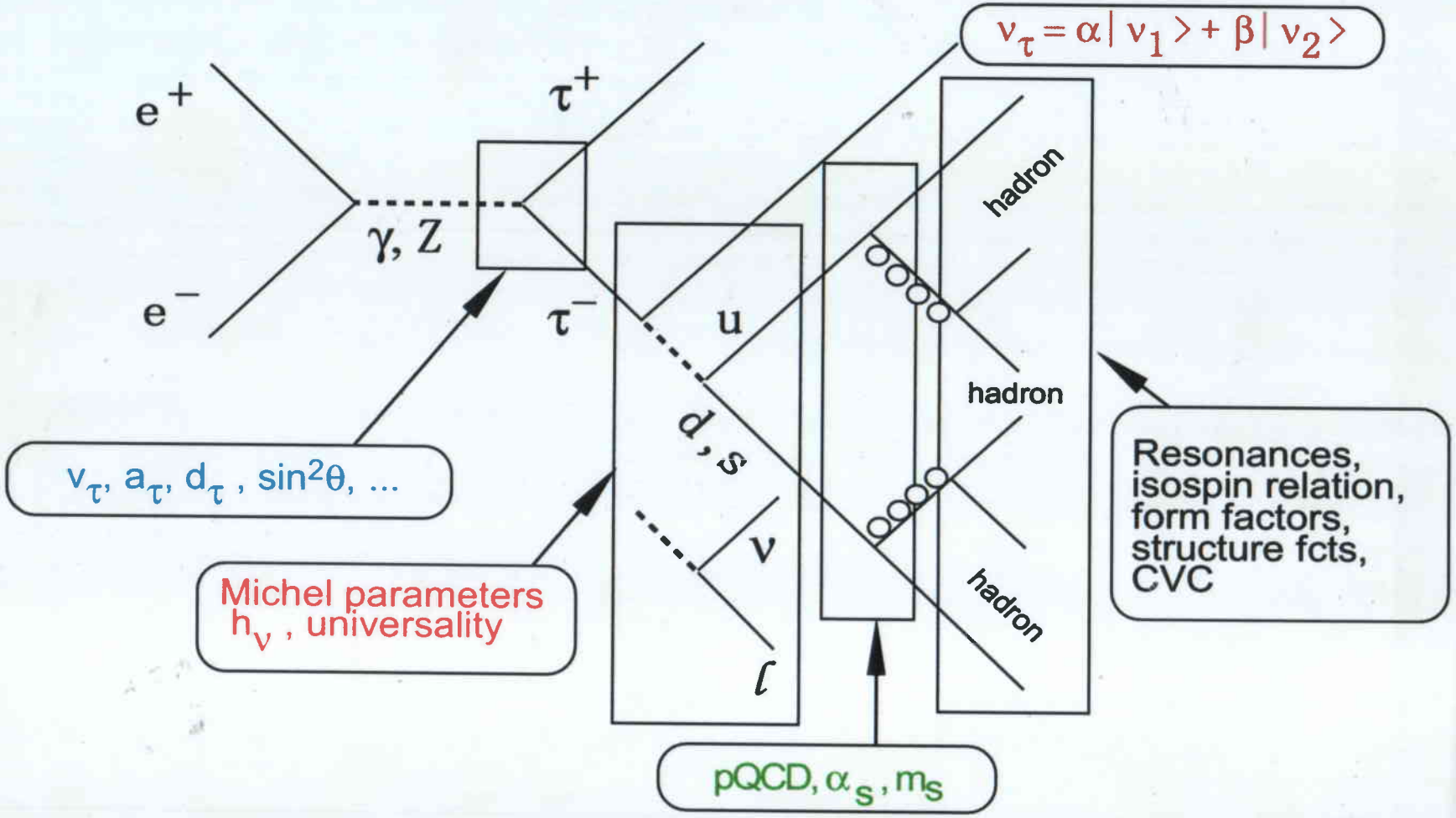


BELLE exp.
$L = 10fb^{-1}$;
$\delta = O(10^{-3})$

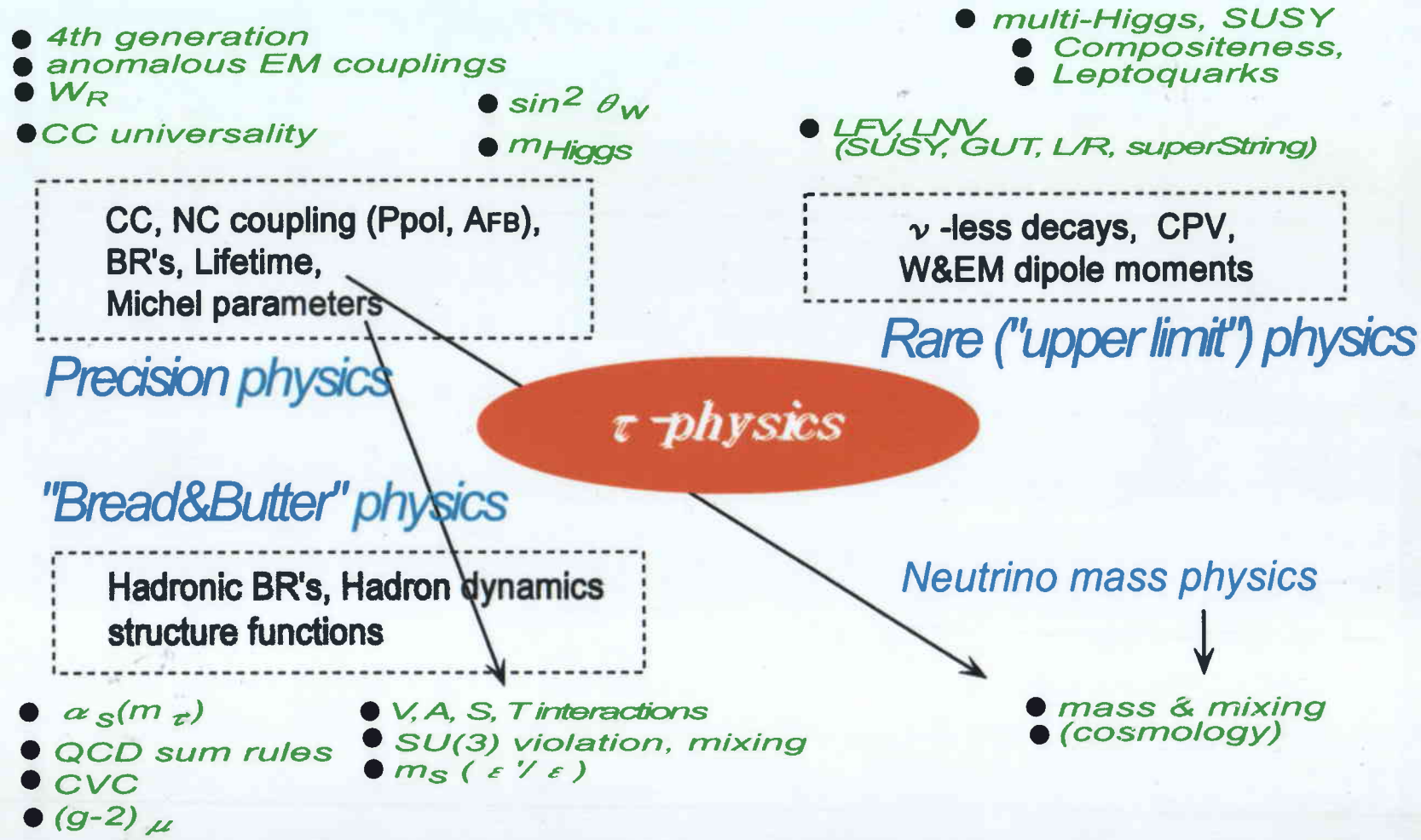
SM = no violation.
needs two interfering amp's with opposite CP phases.

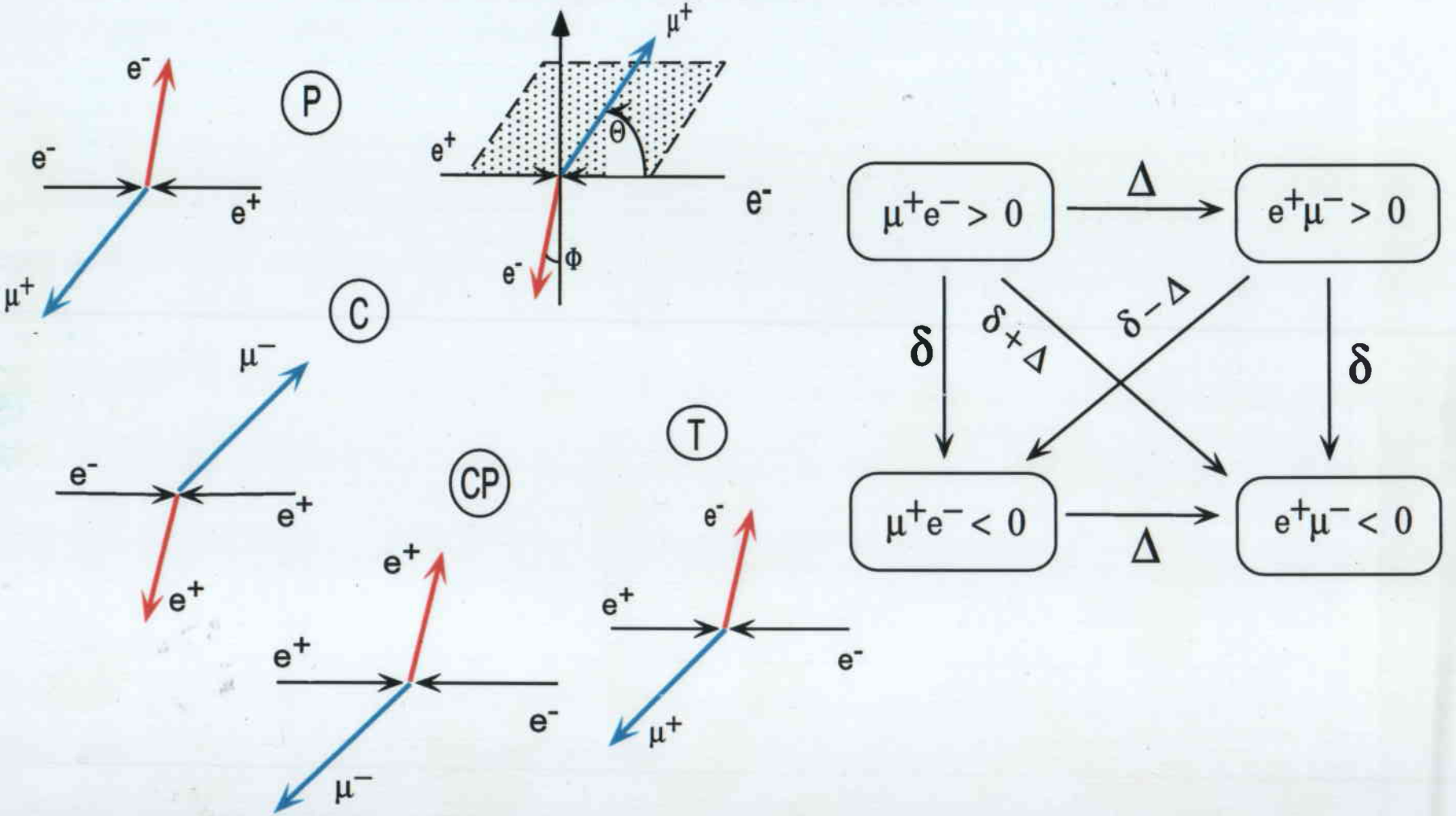
New Physics:
- leptonic CKM ($m_\nu \neq 0$) ;
- τ EDM ;
- multi-Higgs model ;
- scalar leptoquark model ;
- SUSY(R-parity conserving/violating) model ;
- Dirac/Majorama ν-mass

Tau lepton's Nutshell (by Kuhn)



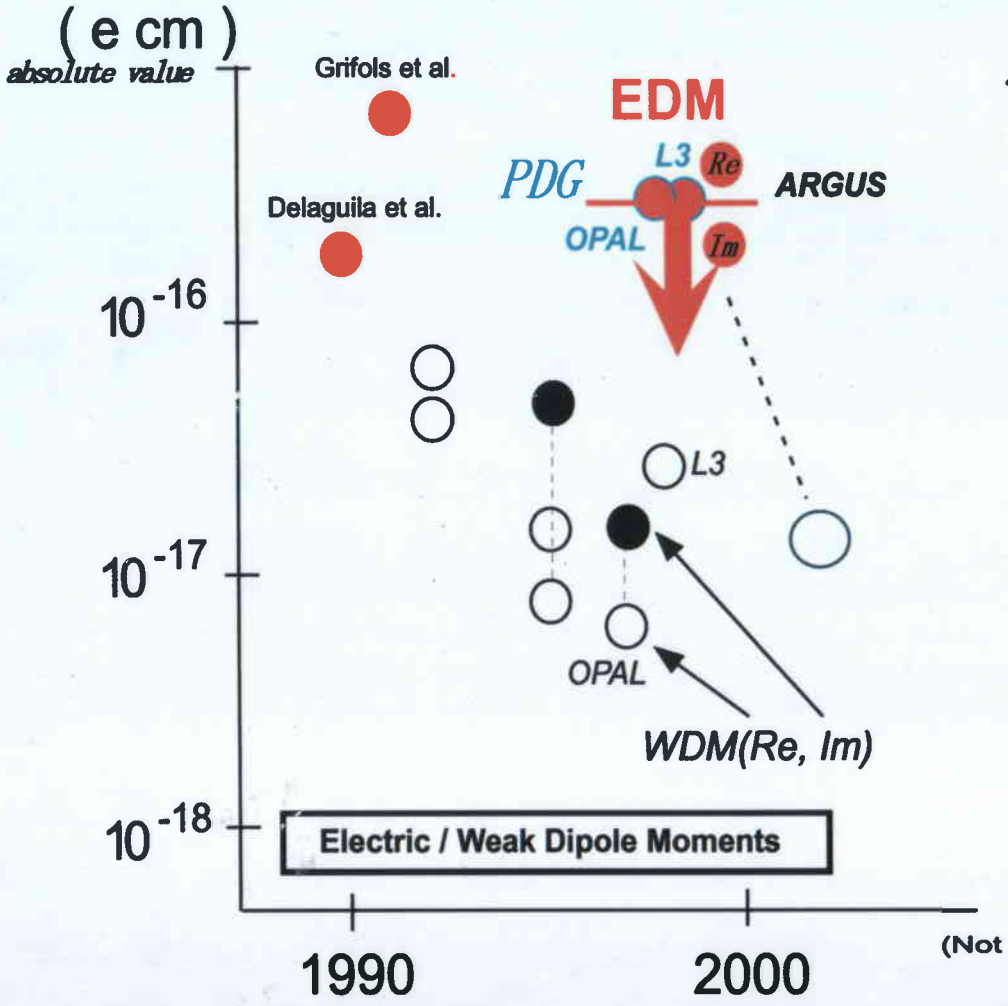
Prospective View of Tau Physics

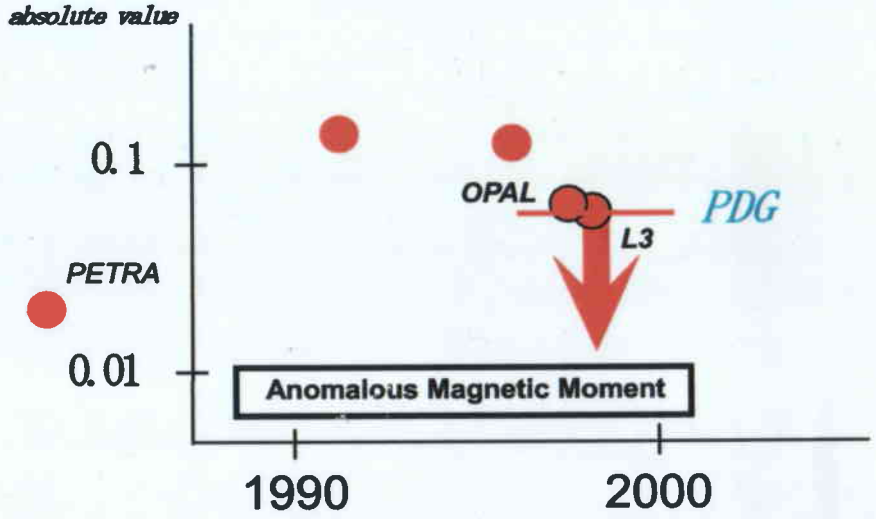



P
e⁻
e⁻
e⁺
μ⁺
μ⁺
e⁺
θ
e⁻
e⁻
Φ
C
μ⁻
e⁻
e⁺
e⁺
CP
e⁺
e⁺
e⁻
μ⁻
T
e⁻
e⁺
e⁻
μ⁺
μ⁺e⁻ > 0
Δ
e⁺μ⁻ > 0
δ
δ+Δ
δ−Δ
δ
μ⁺e⁻ < 0
Δ
e⁺μ⁻ < 0

Experimental search on Tau's Moments

(from PDG)



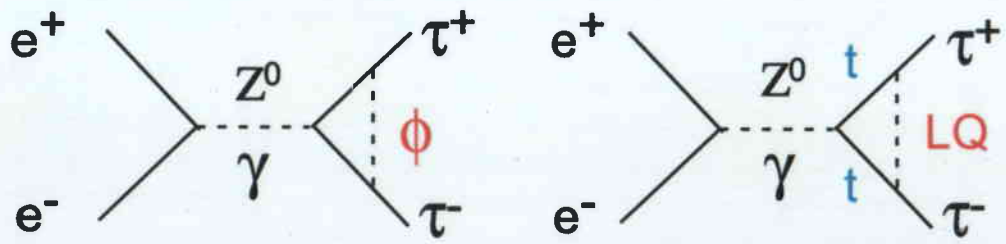


(Not official values)

PDG	$\|d_\tau\| < 3.1 \times 10^{-16}$ ecm at 95% CL	
ARGUS	$\|Re(d_\tau)\| < 4.6 \times 10^{-16}$ ecm	
	$\|Im(d_\tau)\| < 1.8 \times 10^{-16}$ ecm	
Belle	$\|Re(d_\tau)\| < 4.6 \times 10^{-17}$ ecm	
	$\|Im(d_\tau)\| < 1.8 \times 10^{-17}$ ecm	

- Search for new CPV interaction ≫ parametrized by dipole form factor (EDM, WDM) ≫

  Dipole moment interactions arise from quantum loop effects ≫ introduce a mass dependent



exchange scalar field in multi-Higgs model

exchange lepto-quark in lepto-quark model

multi-Higgs	m_τ^3
SUSY	m_τ
lepto-quark	$m_t^2 m_\tau$
Majorana ν	$m_\nu^2 m_\tau$

τ EDM 10^{-19} ecm

- CPV Lagrangian : $L_{CP} = -\frac{i}{2}\tau\,\sigma^{\mu\nu}\,\gamma_5\,\tau\,d_\tau(s)\,F_{\mu\nu}$

$$M = M_{SM} + Re(d_\tau)\,M_{Re} + Im(d_\tau)M_{Im} + |d_\tau|^2 M_d$$

$M_{Re} \propto (S_+ \times S_-)k_{\tau+}$項 $+ (S_+ \times S_-)p_{e+}$項 ; $M_{Im} \propto (S_+ - S_-)k_{\tau+}$項 $+ (S_+ + S_-)p_{e+}$項

- Belle analysis

$e^+e^- \to \tau^+\tau^- \to X^+Y^-$

(X; Y = eνν, μνν, πν, ρν, ...)

8 combinations = ρρ, ππ, πρ, μρ, ρe, μπ, eπ, eμ

1.2M events in total

$$O_{Re} = \frac{|M_{Re}|^2}{|M_{SM}|^2} \qquad O_{Im} = \frac{|M_{Im}|^2}{|M_{SM}|^2}$$

Optimal observable method

Tau-pair event selection

Data

29.5fb^{-1} at KEKB/Belle experiment $\rightarrow 26.8 \times 10^6$ τ-pairs

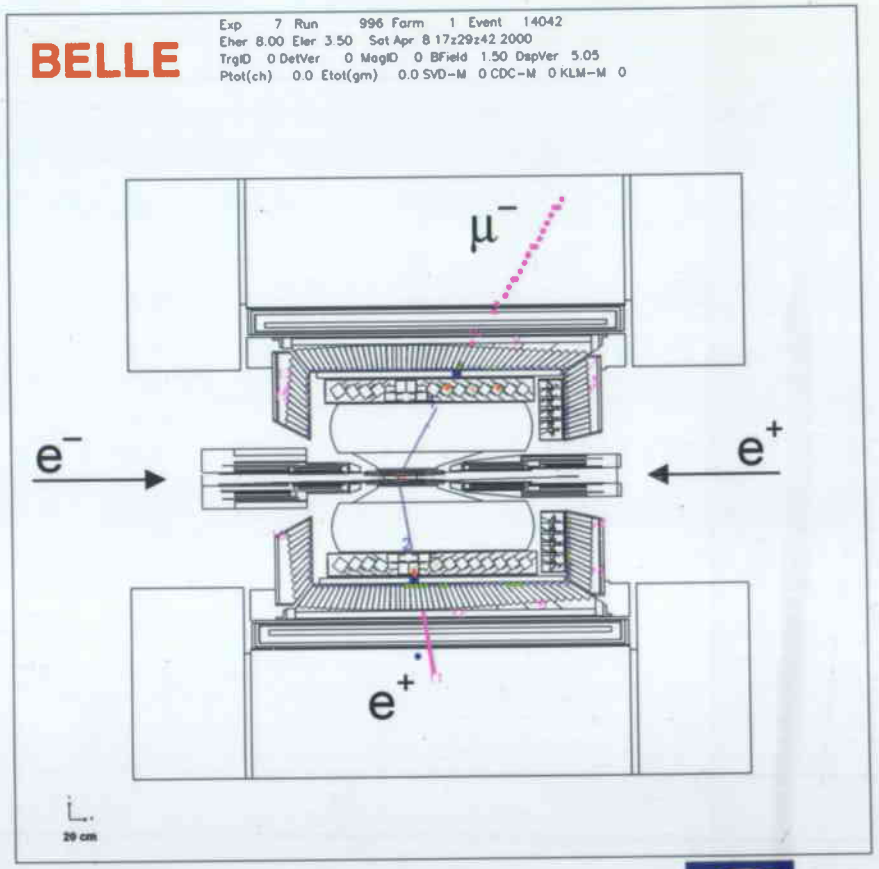
Event selection

select 8 final state modes exclusively

$\tau\tau \rightarrow e\mu 4\nu$, $e\pi 3\nu$, $\mu\pi 3\nu$, $e\rho 3\nu$,
$\mu\rho 3\nu$, $\pi\rho 2\nu$, $\rho\rho 2\nu$, $\pi\pi 2\nu$

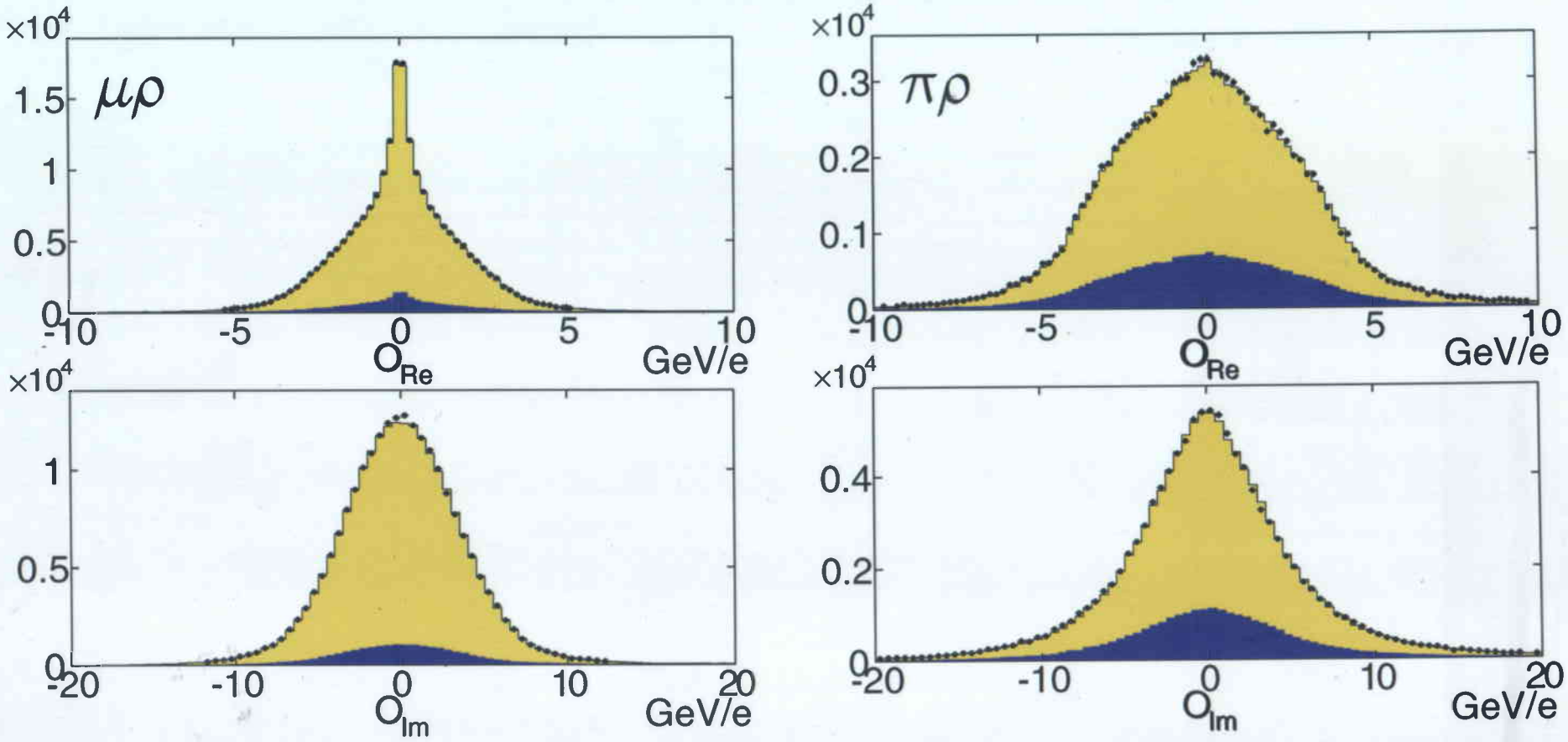
- 2 charged tracks, no γ except for π^0
- Barrel region, high momentum track
  - e, μ, π : probability
    - e: purity 99%, eff. 92%
    - μ: purity 98%, eff. 91%
    - π: purity 89%, eff. 81%
  - $\rho^{\pm} : \rightarrow \pi^{\pm}\pi^0$
    - $\pi^{\pm}$: not (e,μ)
    - π^0: $0.11 < M(\gamma\gamma) < 0.15$ GeV/c^2

$e^+e^- \rightarrow \tau^+\tau^- \rightarrow e^{\pm}\mu^{\mp} + (4\nu)$ candidate



Observable distributions

● Exp. data ☐ MC(d_τ=0) ■ MC background



- Good agreement btw. data and MC (d_τ=0)

EDM vs. observable

Mean of observable is proportional to EDM.

$$\langle \mathcal{O}_{Re} \rangle \propto \int \mathcal{O}_{Re} d\sigma = \int \mathcal{M}^2_{Re} d\phi + Re(d_\tau) \int \frac{(\mathcal{M}^2_{Re})^2}{\mathcal{M}^2_{\rm SM}} d\phi$$

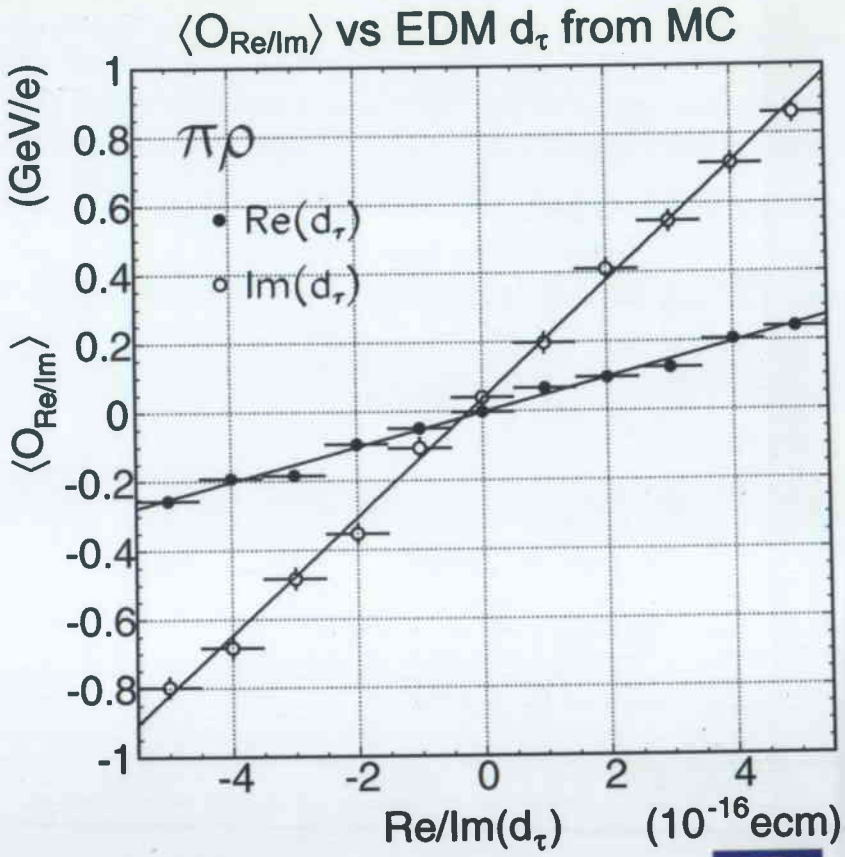
In the experiment,

- detector resolution
- asymmetric acceptance
- initial radiation etc.

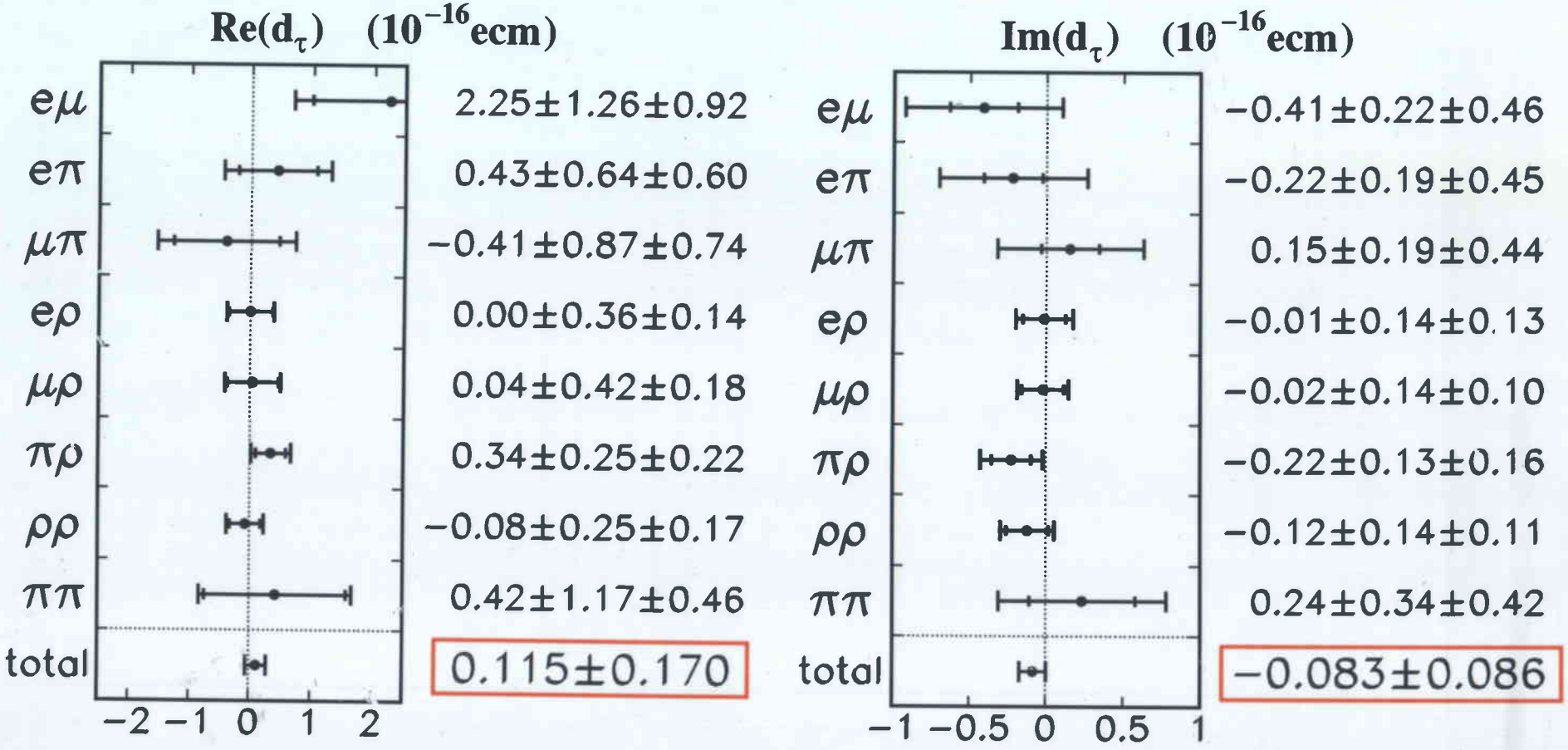
→ Offset and sensitivity shift

use full MC simulation

$$\langle \mathcal{O}_{Re} \rangle = a_{Re} \cdot Re(d_\tau) + b_{Re}$$
$$\langle \mathcal{O}_{Im} \rangle = a_{Im} \cdot Im(d_\tau) + b_{Im}$$



Result



- consistent with zero

Summary

Electric dipole moment of the tau lepton

- exclusively selected tau samples from 29.5fb^{-1} data
- Optimal observable
- Parameters (sensitivity, offset) are obtained from full MC simulation.

Result (preliminary)

$$Re(d_\tau) = (1.15 \pm 1.70) \times 10^{-17}\ e\text{cm}$$
$$Im(d_\tau) = (-0.83 \pm 0.86) \times 10^{-17}\ e\text{cm}$$

- Improvement by one order of magnitude

95% C.L. limit :

Belle : $-2.2 < Re(d_\tau) < 4.5\ (\times 10^{-17}\ e\text{cm}),\quad -2.5 < Im(d_\tau) < 0.9\ (\times 10^{-17}\ e\text{cm})$

LEP : $|d_\tau| < 3.1 \times 10^{-16}\ e\text{cm}$

ARGUS : $|Re(d_\tau)| < 4.6 \times 10^{-16}\ e\text{cm},\quad |Im(d_\tau)| < 1.8 \times 10^{-16}\ e\text{cm}$