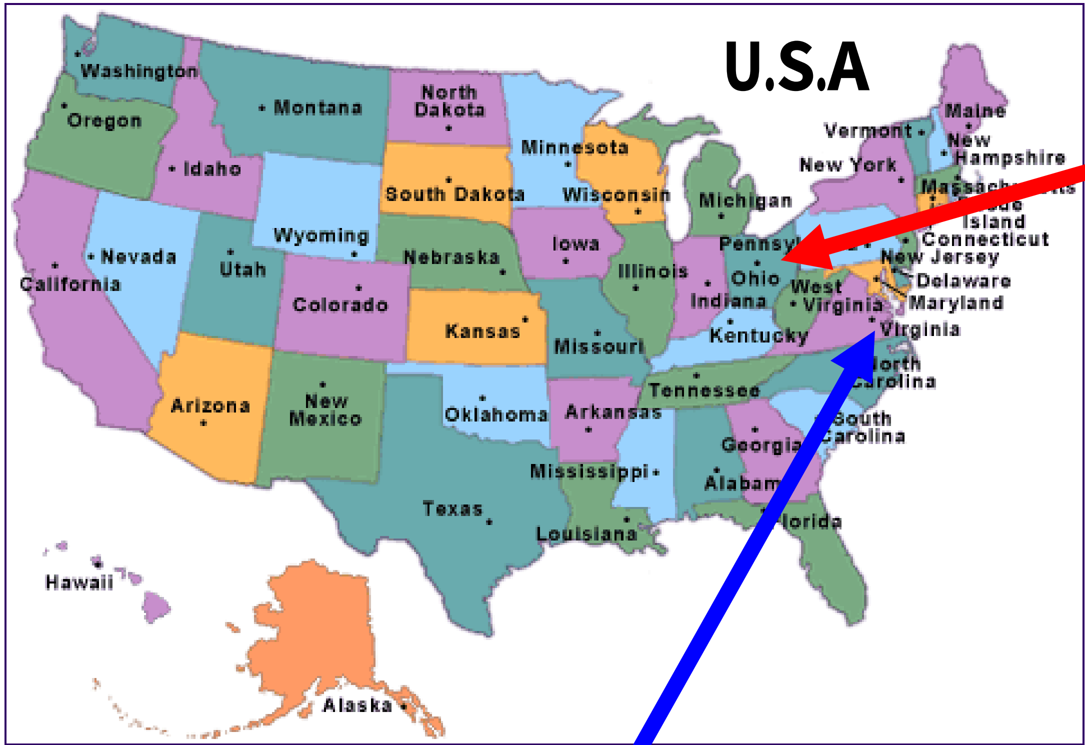
ϕ-meson photoproduction
New results from LEPS/SPring-8

APPEAL Seminar
September 8th, 2004

Tsutomu Mibe

Ohio university
for the LEPS collaboration

Ohio University and Jefferson lab.



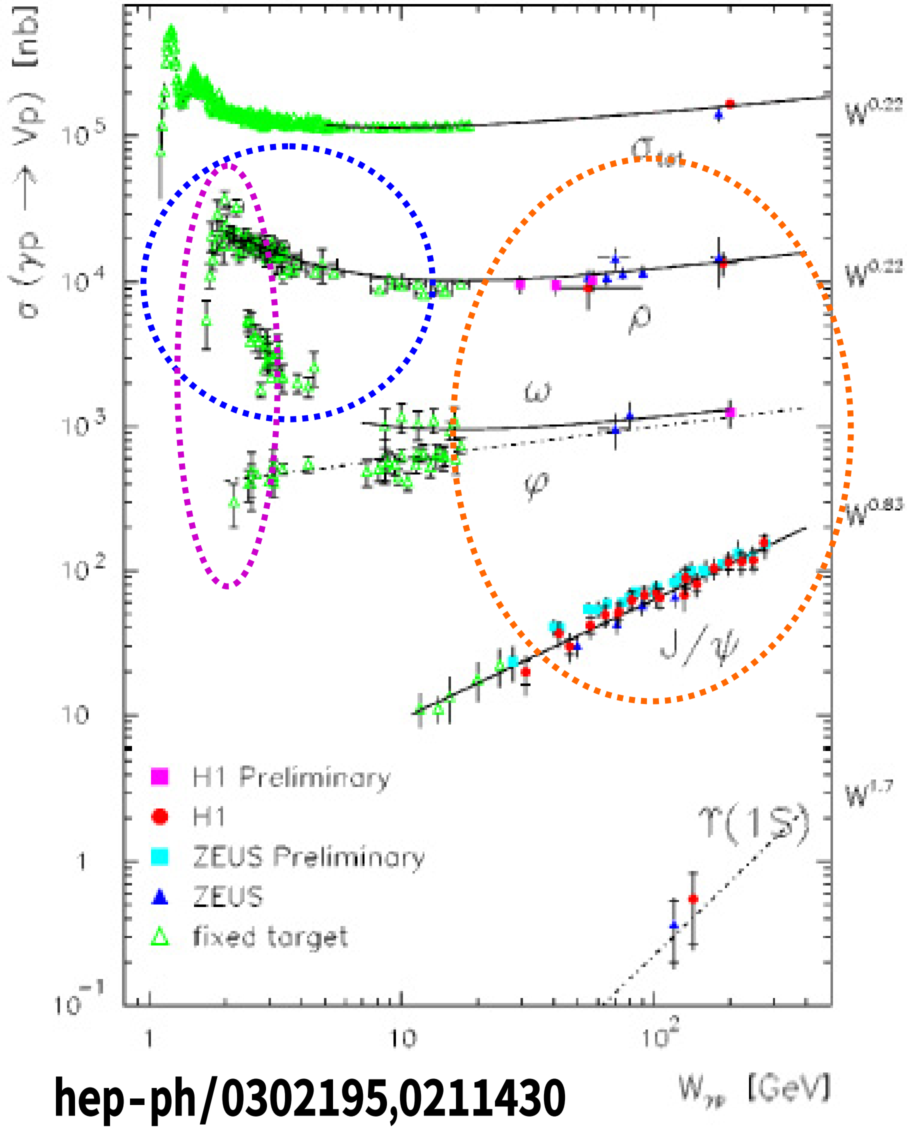
Ohio University
Athens, OH

Jefferson laboratory
Newport News, VA

Outline

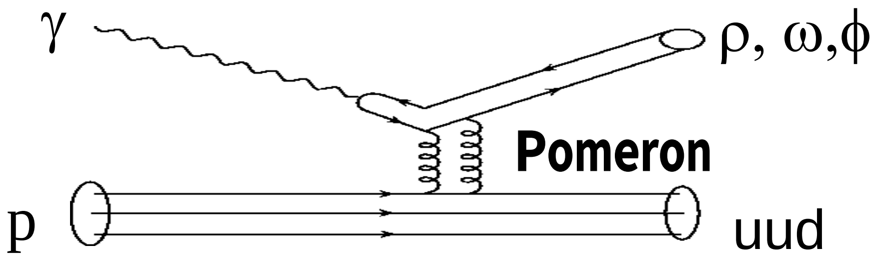
- Physics motivation
- Experiment at LEPS/Spring-8
- Data analysis
- Results and discussions
- Summary

Vector Meson Photoproduction

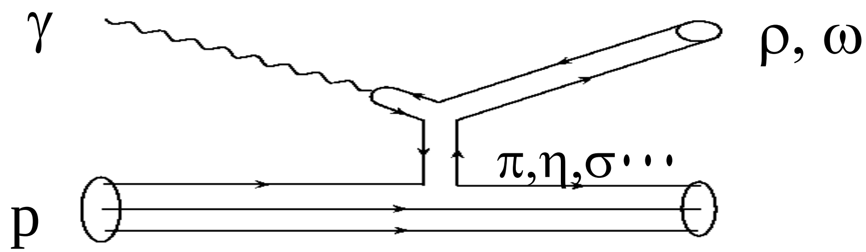


hep-ph/0302195,0211430

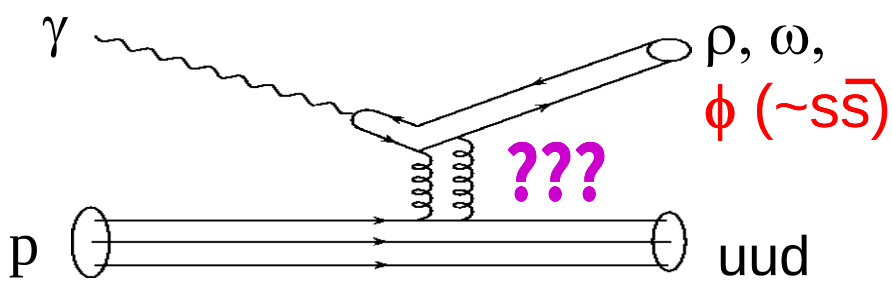
Pomeron exchange



Meson exchange



0+ Glueball exchange ??



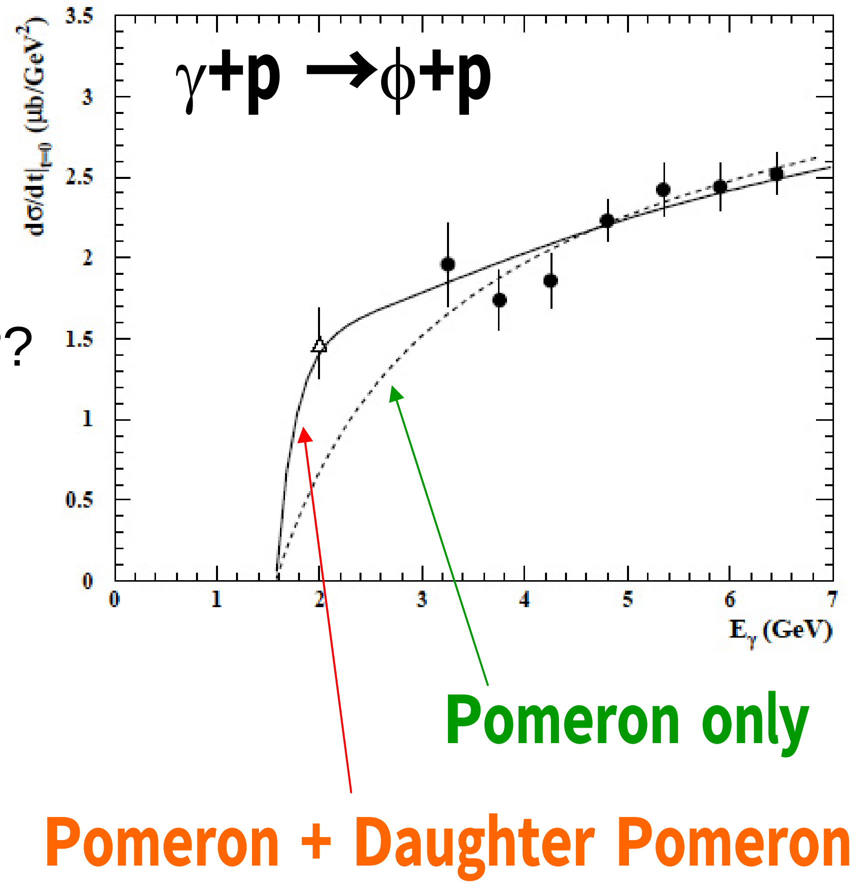
Glueball hunt by ϕ meson photoproduction

Application of Regge phenomenology to Daughter pomeron trajectory.

T. Nakano and H. Toki,
(in proceedings of EXPAF'97)

Pomeron ⬌ Glueball ($J^p = 2^+$)

Daughter Pomeron ⬌ Glueball ($J^p = 0^+$) ??



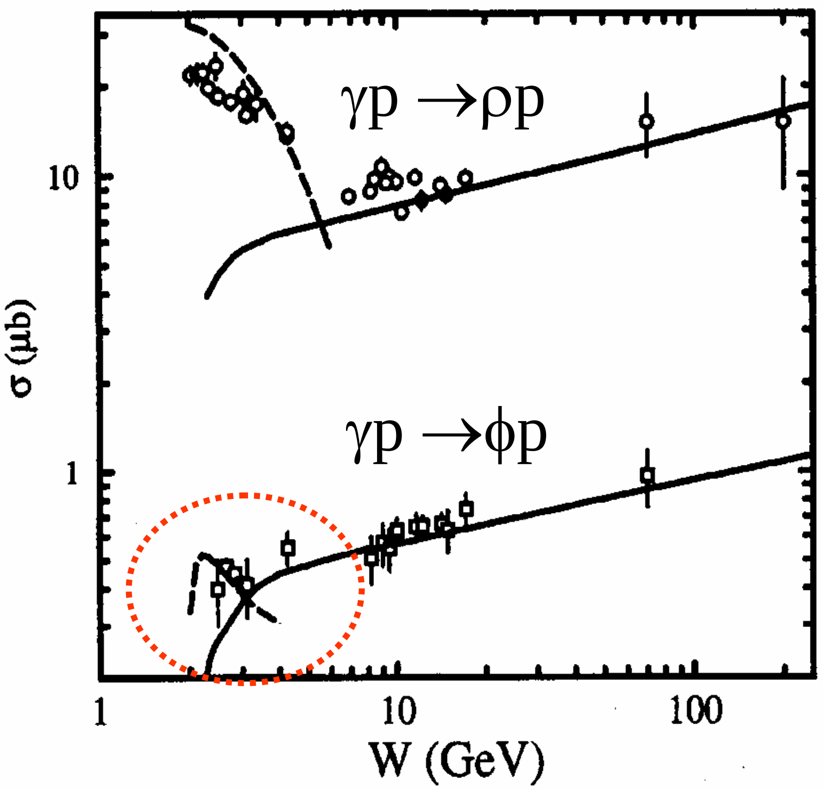
Pomeron + Daughter Pomeron

$$\frac{d\sigma}{dt}(\gamma p \to \phi p)(t=0) = C\left(\frac{p_\phi}{p_\gamma}\right)^2\left(\left(\frac{s-u}{2s_0}\right)^{0.16} + a\left(\frac{s-u}{2s_0}\right)^{\delta}\right)$$

a=0.63, δ=-3.46

Data from DESY(1978),Bonn(1974)

Ordinary meson exchange



Data from: LAMP2('83),
DESY('76), SLAC('73),
CERN('82),
FNAL('79,'82), ZEUS('95,'96)

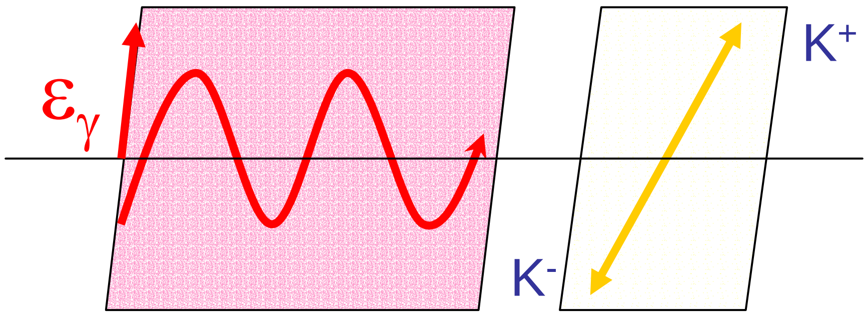
M.A. Pichowsky and T.-S. H. Lee
PRD 56, 1644 (1997)

—— **Prediction from Pomeron exchange**

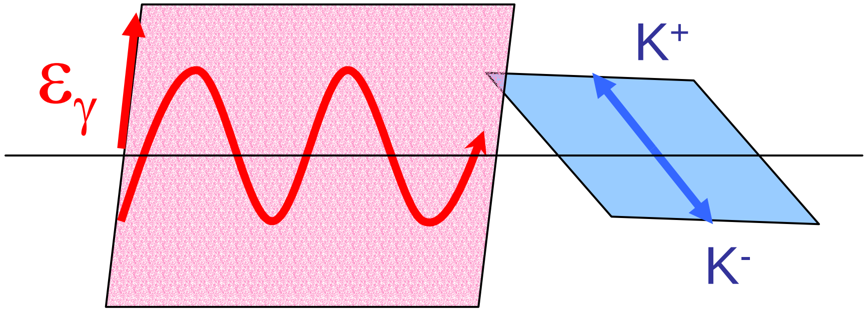
- - - **Prediction from meson exchange**

Polarization observables with linearly polarized photon

$\phi \rightarrow K^+K^-$



Photon Polarization



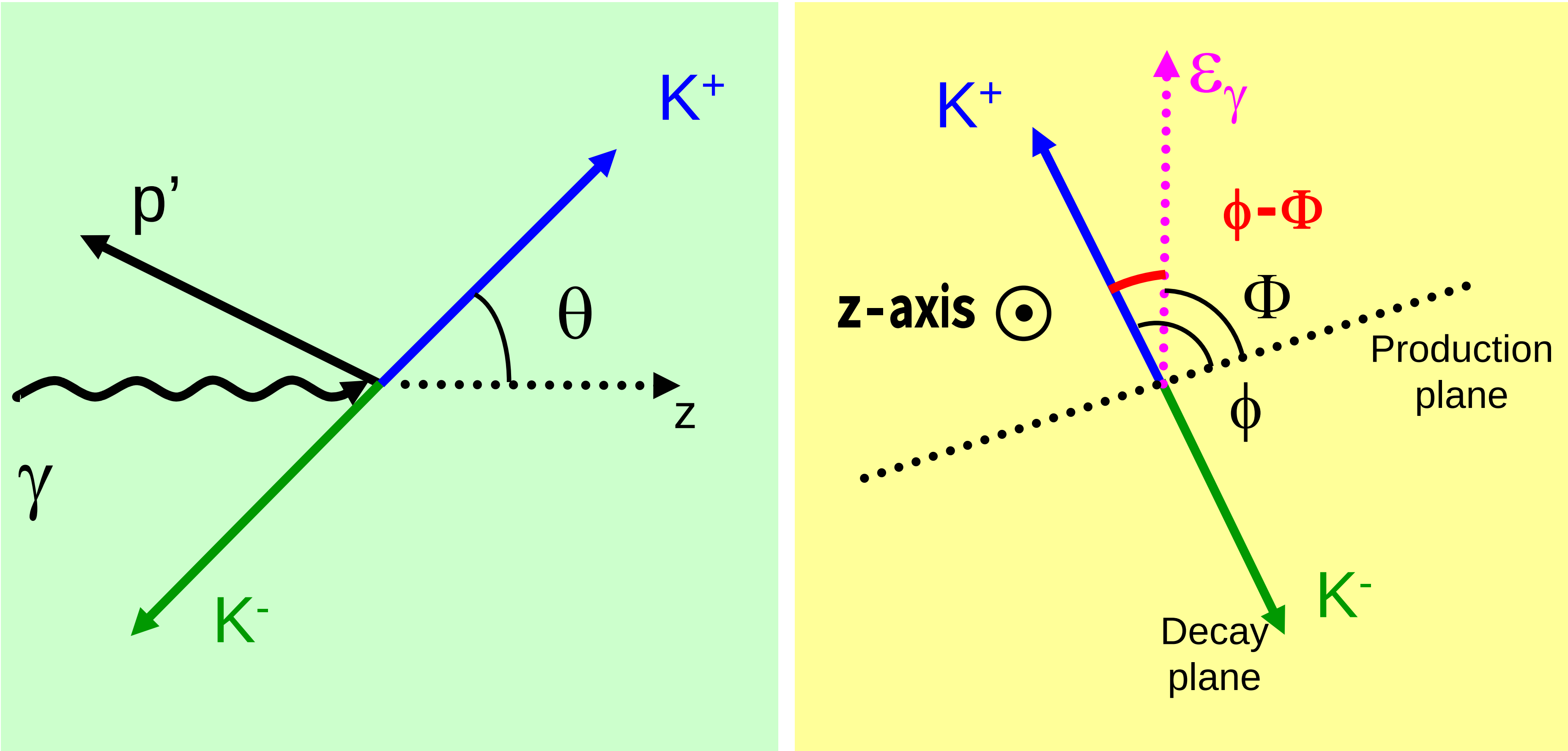
Decay Plane // $\vec{\gamma}$
natural parity exchange $(-1)^J$
(Pomeron, 0+ glueball, Scalar mesons)

Decay Plane $\perp$ $\vec{\gamma}$
unnatural parity exchange $-(-1)^J$
(Pseudoscalar mesons π,η)

Decay angular distribution of ϕ meson $\longrightarrow$ Relative contributions from natural, unnatural parity exchanges

Decay angular distribution of ϕ meson

ϕ meson rest frame (Gottfried-Jackson(GJ) frame)

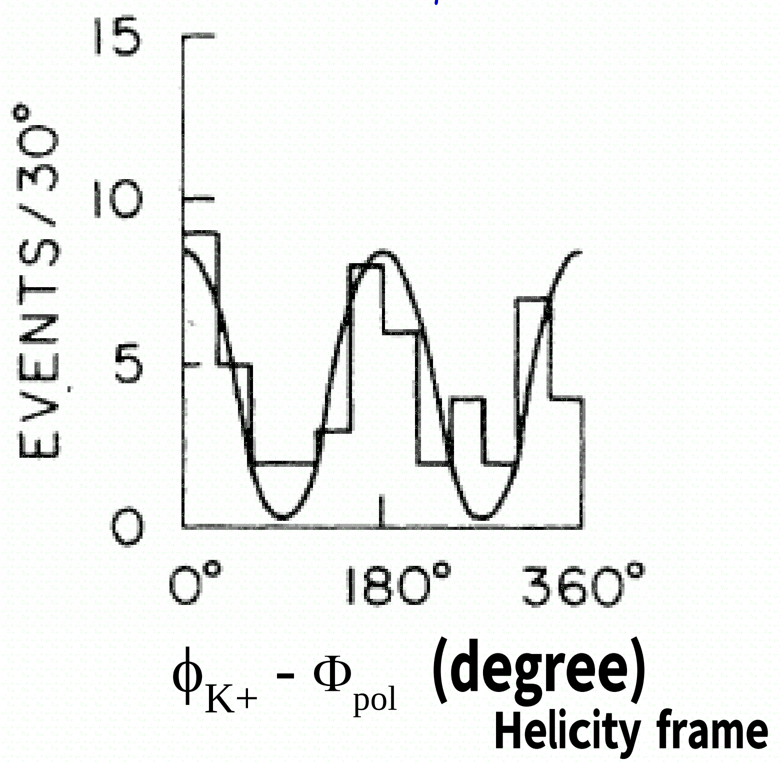


Available data

SLAC

linear pol. , E_γ=2.8,4.8 GeV
(J. Ballam et al. PLD 7 (1972)3150)

53 events in E_γ=2.8,4.8 GeV



Bonn

Unpol, E_γ=2.0 GeV (NP B70(1974)257)

CLAS @J-lab

Unpol, E_γ=3.3-3.6 GeV (PRL85(2000)4862)
(hep-ex/0311024)

Unpol, linear pol. data at E_γ=1.6-2.5 GeV

SAPHIR @ELSA/Bonn

Unpol, E_γ=1.6-2.6 GeV (EPJ A17(2003)269)

New measurements near threshold at LEPS @SPring-8

linear pol. , E_γ=1.6-2.4 GeV

Super Photon ring-8 GeV SPring-8

- Third-generation synchrotron radiation facility
- Circumference: 1436 m
- 8 GeV
- 100 mA
- 62 beamlines

LEPS collaboration

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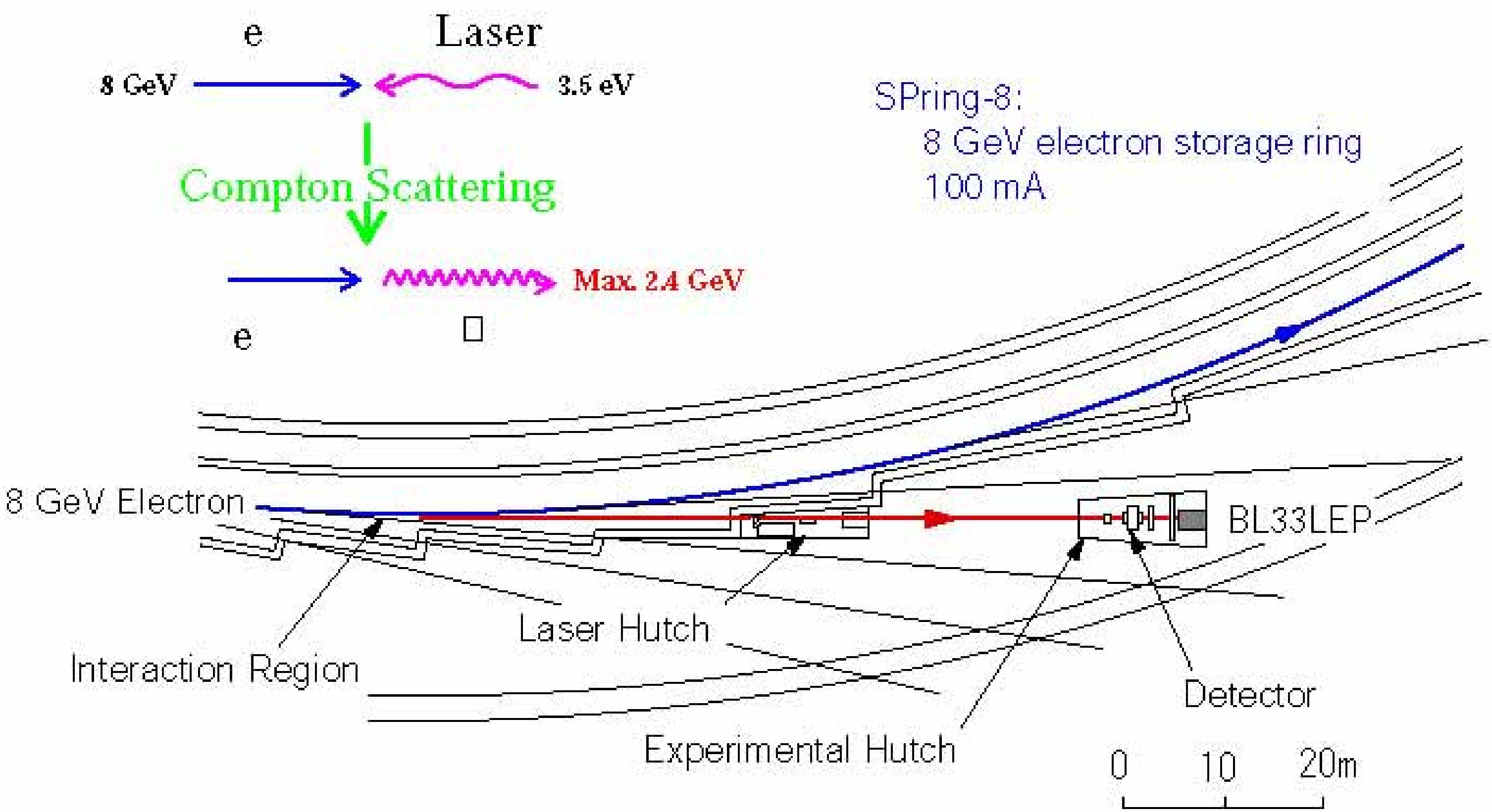
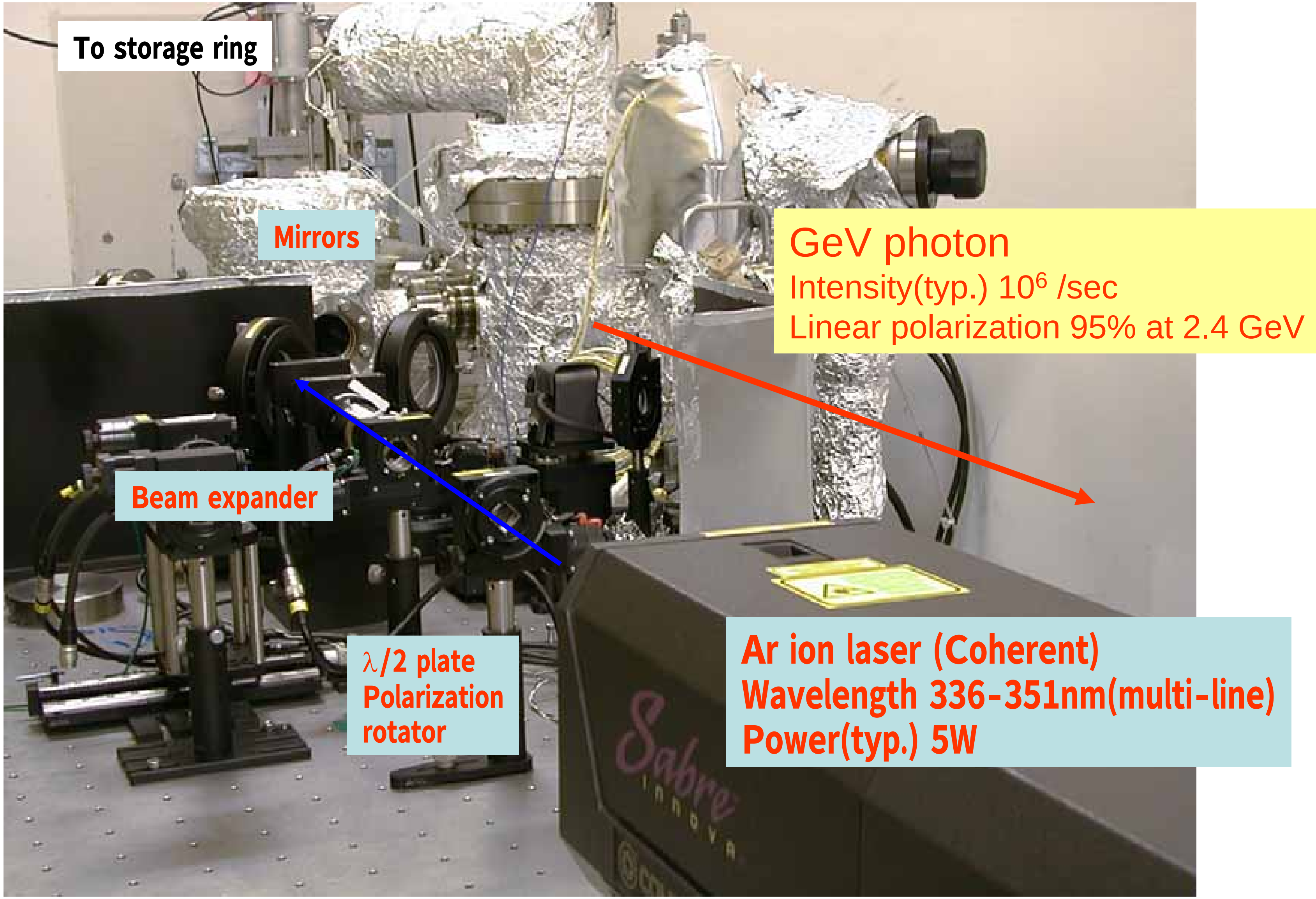
The LEPS facility

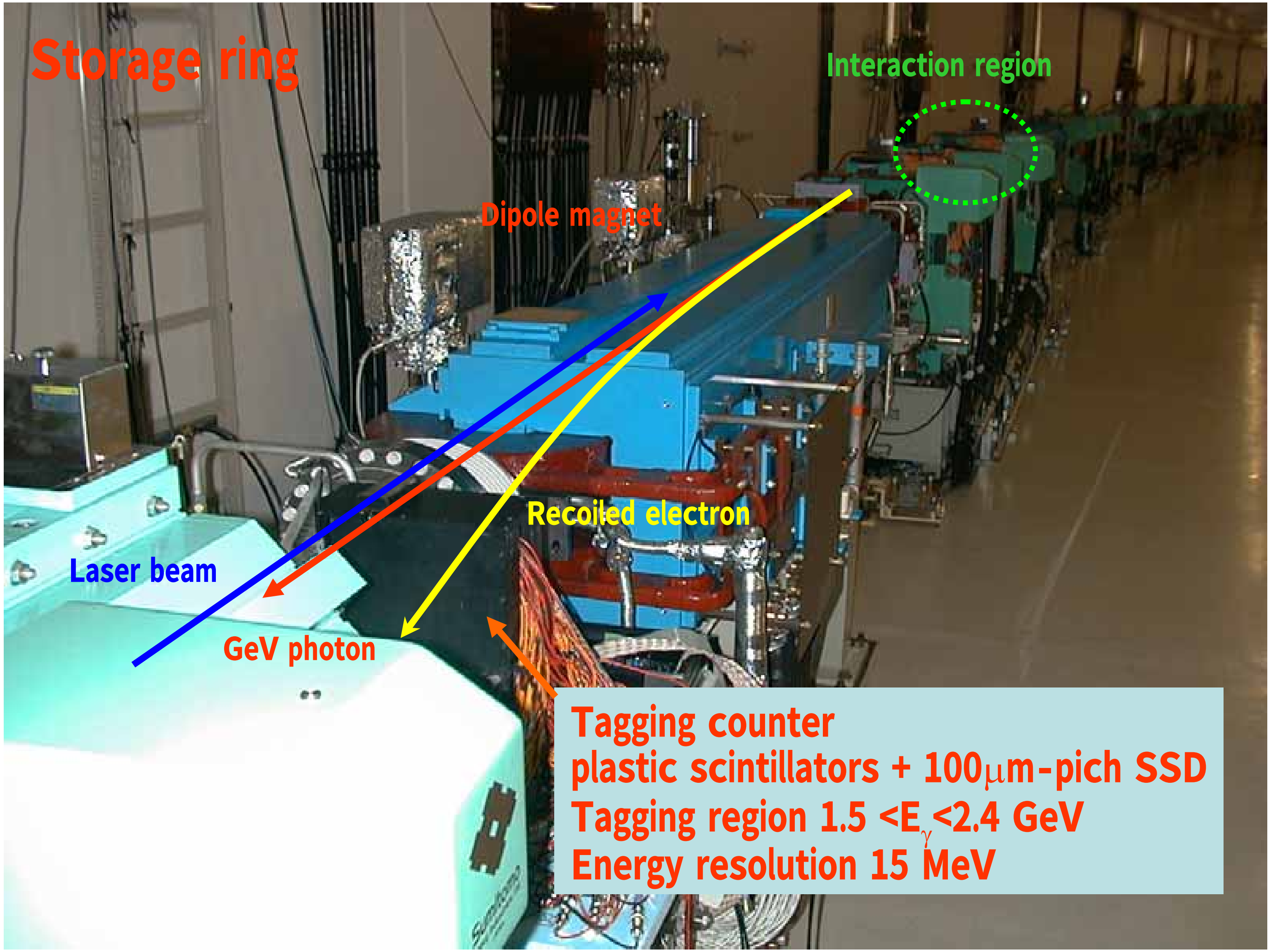
Laser Electron Photon at SPring-8



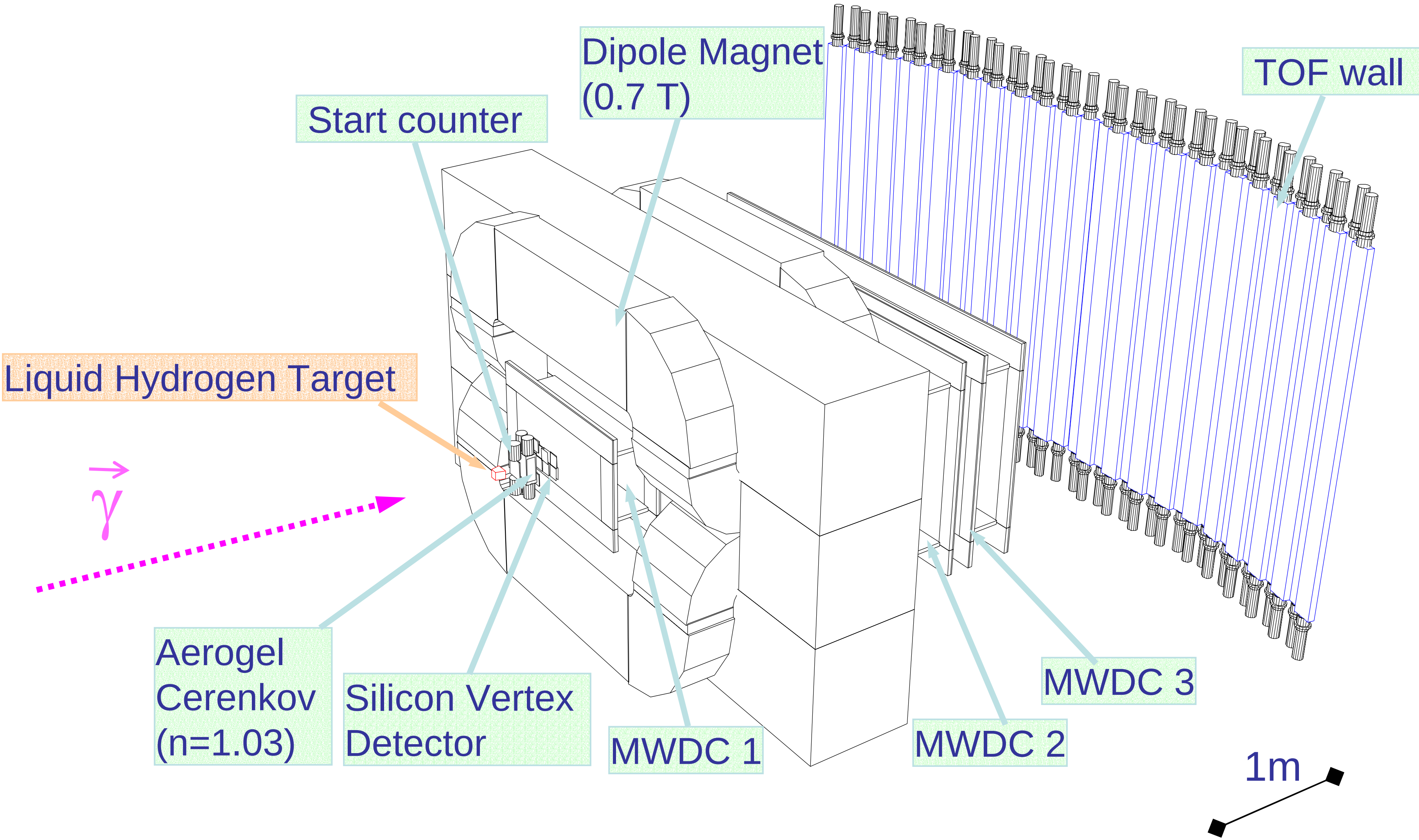
Linearly polarized photon



The tagging counter



Charged particle spectrometer



Summary of data taking

- Trigger condition : TAG*STA*$\overline{\text{AC}}$*TOF
- Run period

  2000, Dec. – 2001, June (50mm-long LH2 target)

  2002, May – 2003, Apr (150mm-long LH2 target)

  2002, Oct. – 2003, June (150mm-long LD2 target)

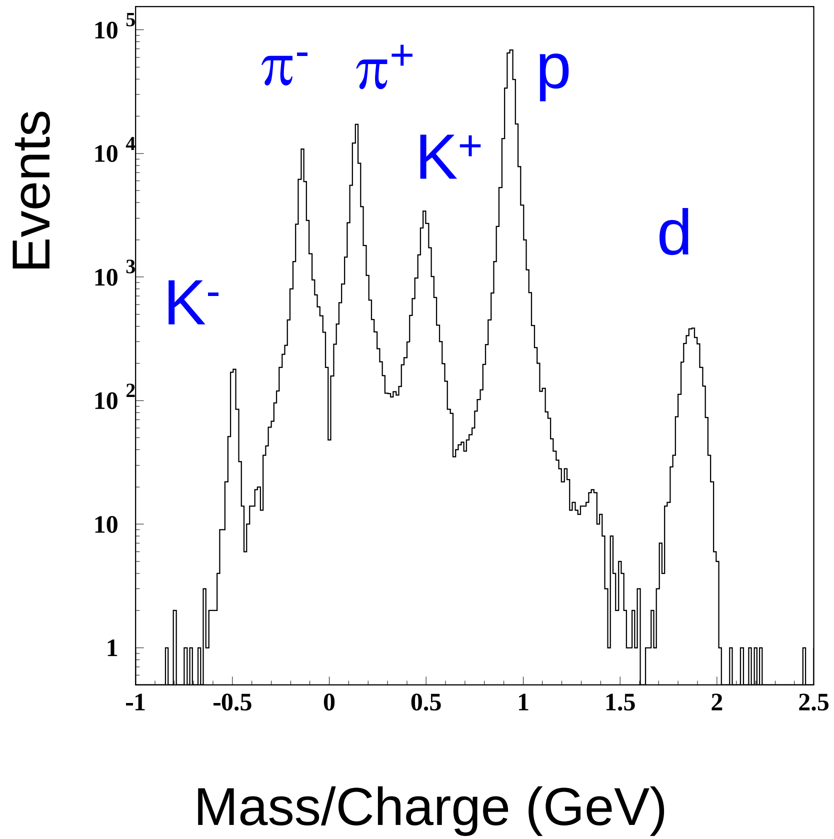
- The first data set with 50mm-long LH2 target
  - Total number of trigger

    $1.83*10^8$ trigger (48% Horizontal, 52% Vertical pol.)
  - Number of events with charged tracks

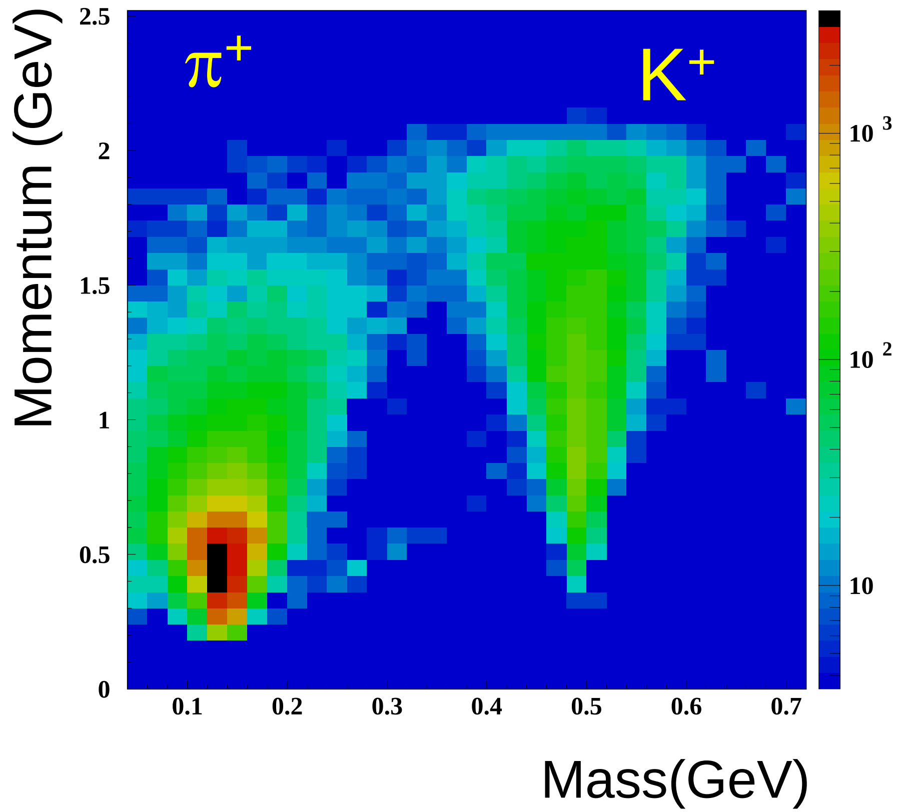
    $4.37*10^7$ events

Charged particle identification

Reconstructed mass



K/π separation (positive charge)

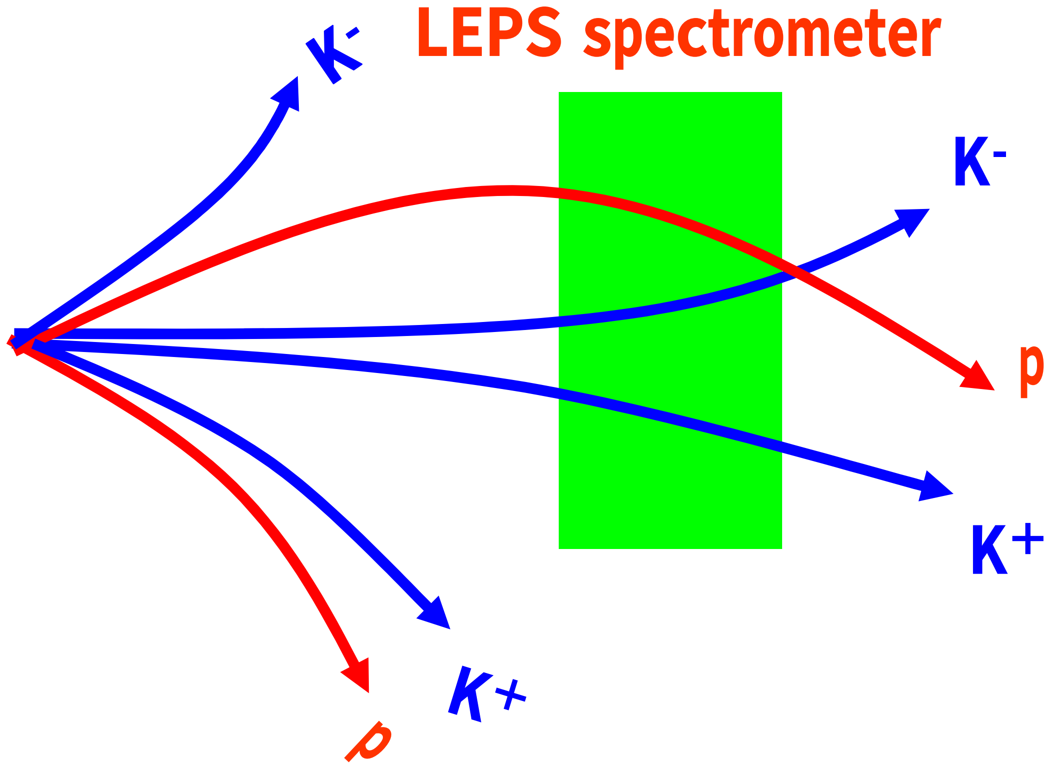


σ(mass) = 30 MeV(typ.) for 1 GeV/c Kaon

Charged particle identification

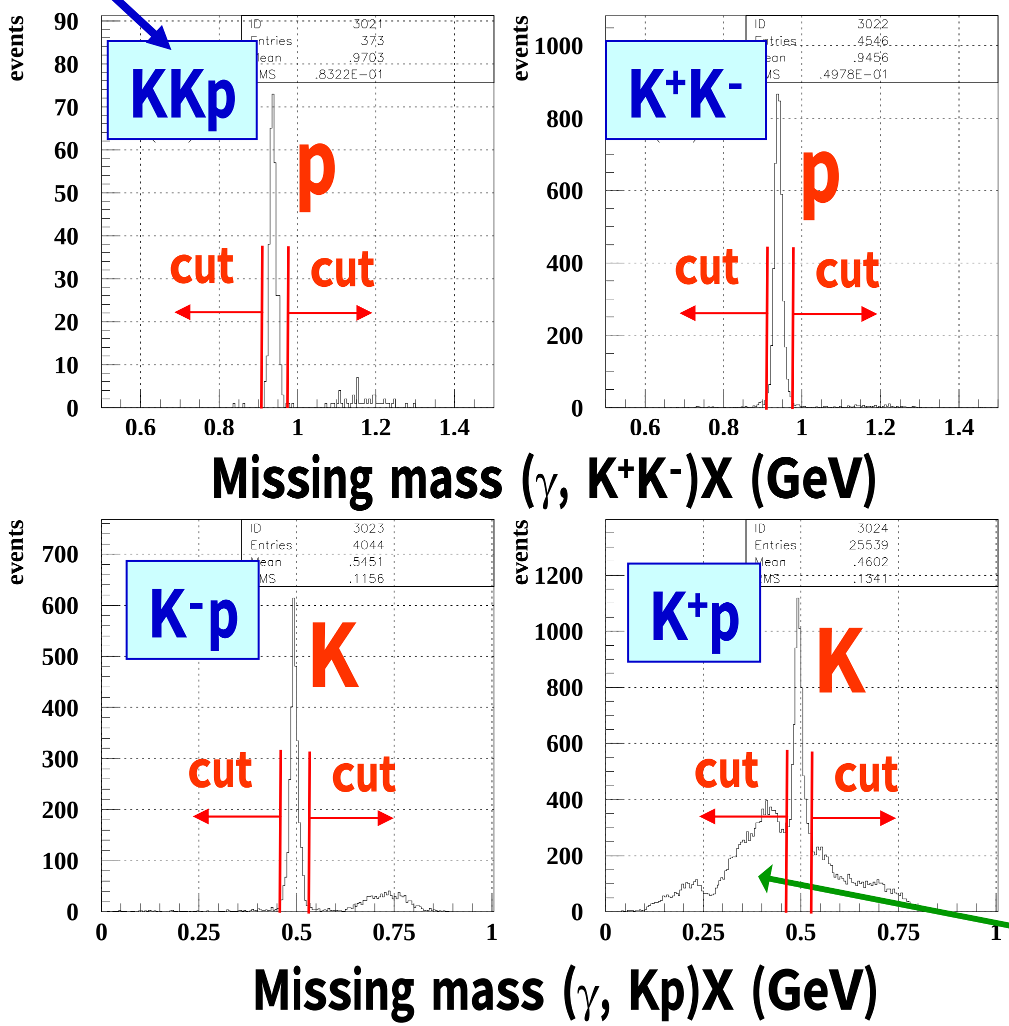
$$\gamma p \rightarrow \phi p \rightarrow K^+K^-p$$

- KKp mode
  - K^+ track
  - K^- track
  - proton track
- K^+K^- mode
  - K^+ track
  - K^- track
- K^+p mode
  - K^+ track
  - proton track
- K^-p mode
  - K^- track
  - proton track



Missing mass distribution

Reconstruction mode



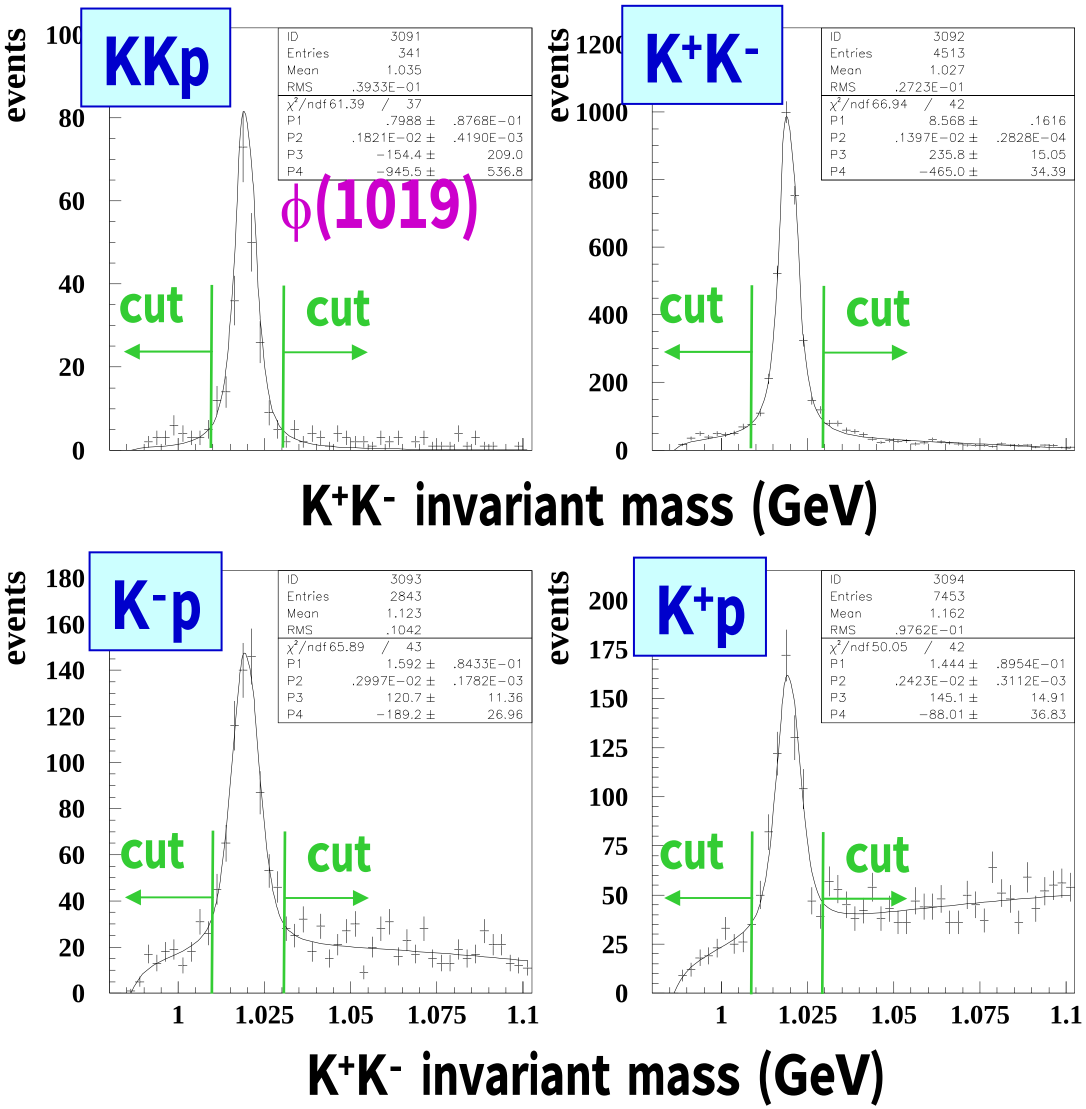
Missing mass resolution
σ=10 MeV

Cut condition for KK modes
$|M(\gamma,KK)-M_p|< 30$ MeV

Cut condistion for Kp modes
$|M(\gamma,Kp)-M_K|< 30$ MeV

Backgrounds from hyperon resonances

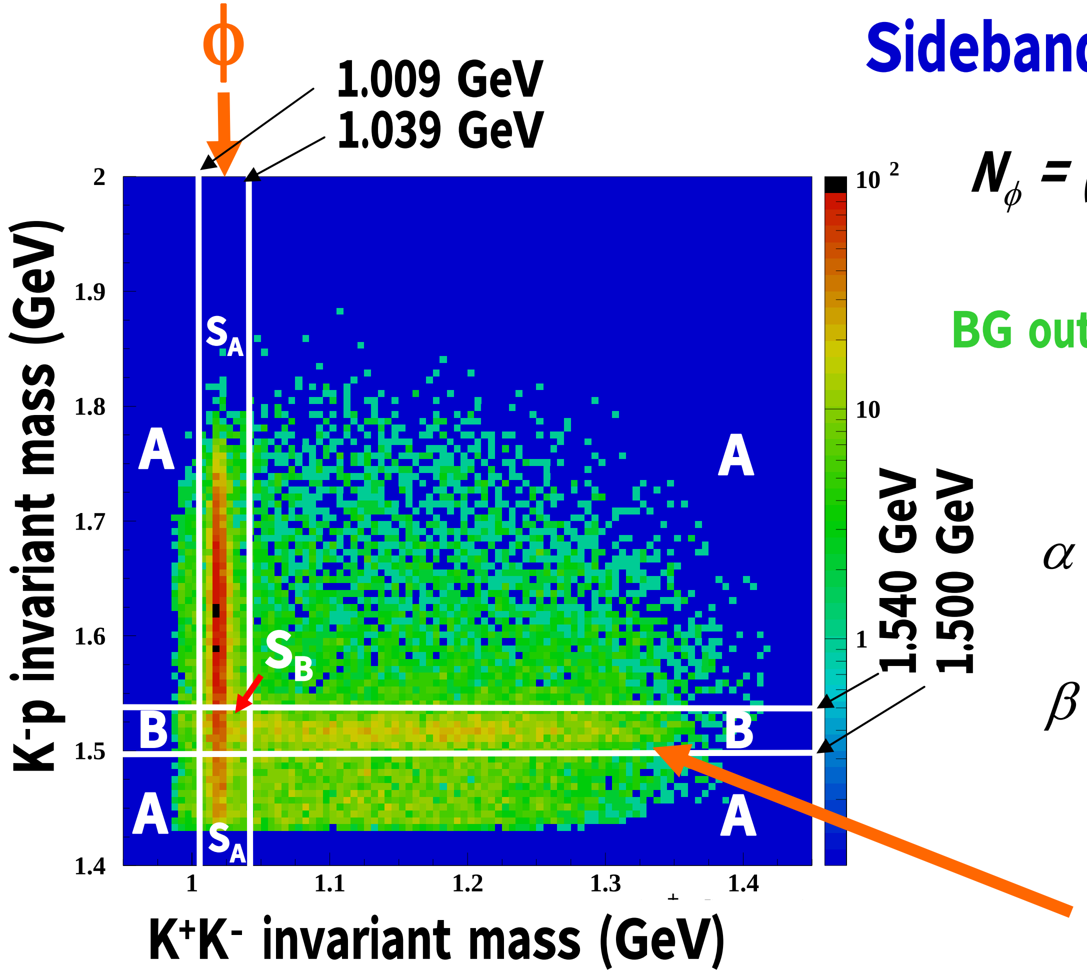
KK invariant mass cut



Cut condistion for ϕ selection

$|M_{KK}-1.019| < 10$ MeV

Background subtraction



Sideband subtraction

$$N_\phi = (S_A + S_B) \;\; -\alpha\, A \;\;\; -\beta\, B$$

BG outside of $\Lambda(1520)$ cut

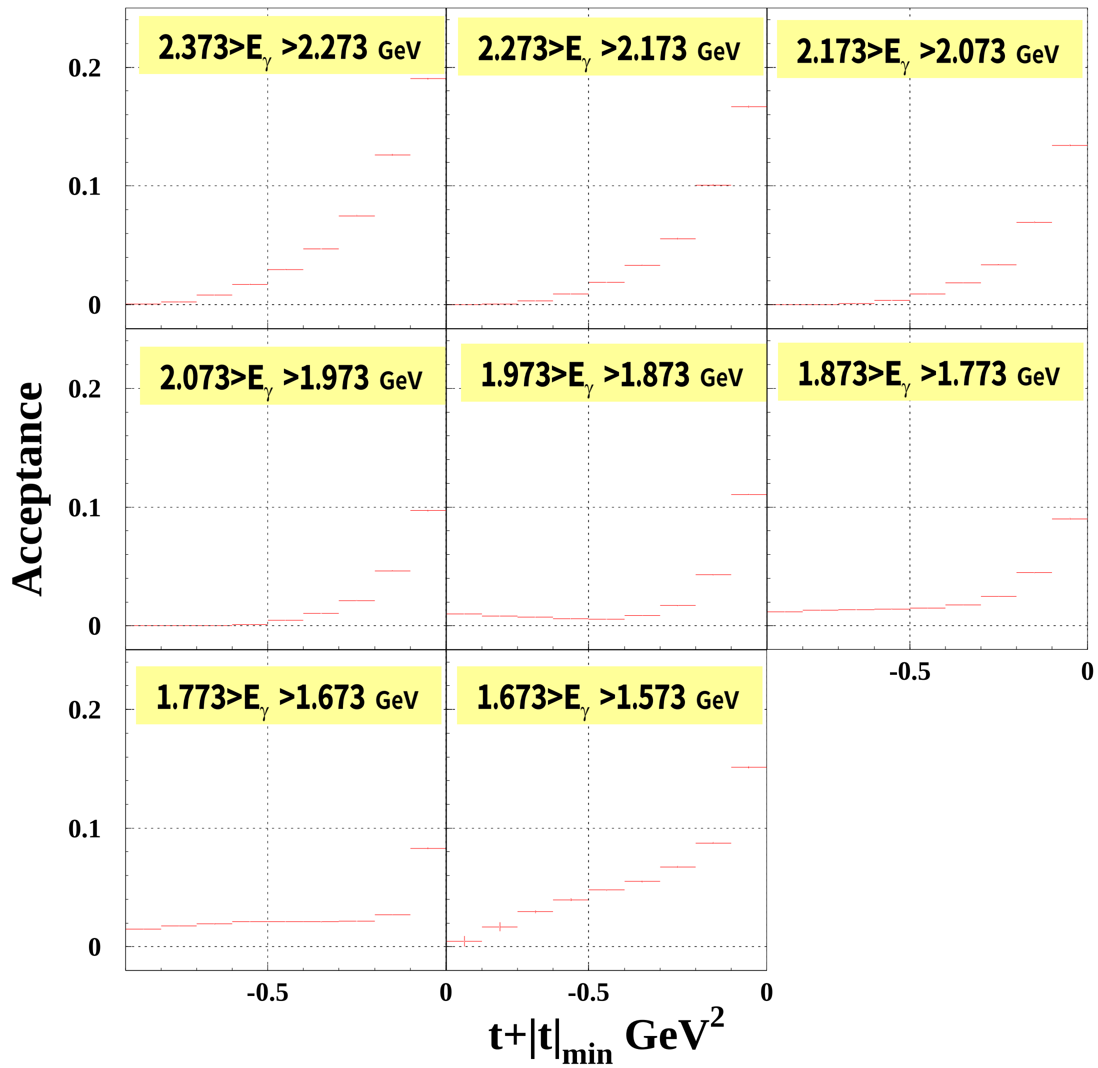
BG inside of $\Lambda(1520)$ cut

$$\alpha = \frac{S_A^{MC}}{A^{MC}} \qquad \beta = \frac{S_B^{MC}}{B^{MC}}$$

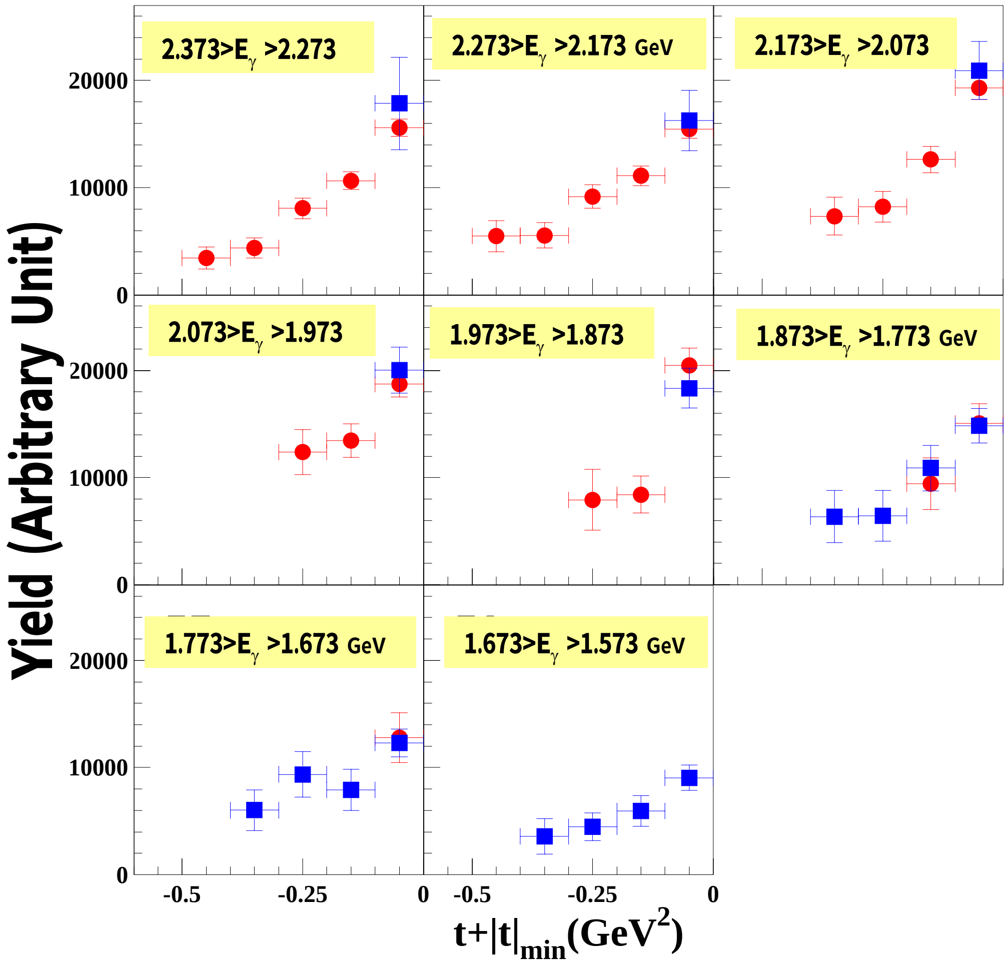
Calculated from KK invariant mass distribution In Monte Carlo simulation

Acceptance

- Monte Carlo simulation based on GEANT3
- All materials and geometry information.
- Detector efficiency and resolution
- Realistic $d\sigma/dt$ and decay angular distribution feedbacked from real data



Consistency between KK and Kp modes



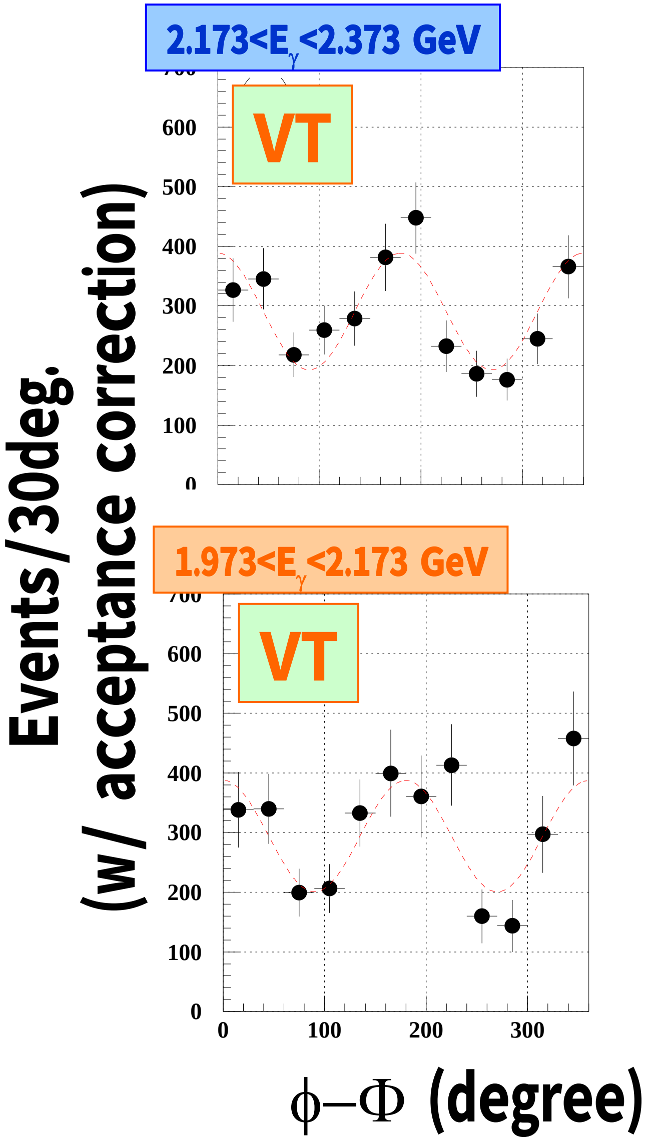
● KK mode
■ Kp mode

Good consistency between KK and Kp modes

⇩

(1) Acceptance calculation,
(2) Background subtraction are working well.

HZ and VT consistency



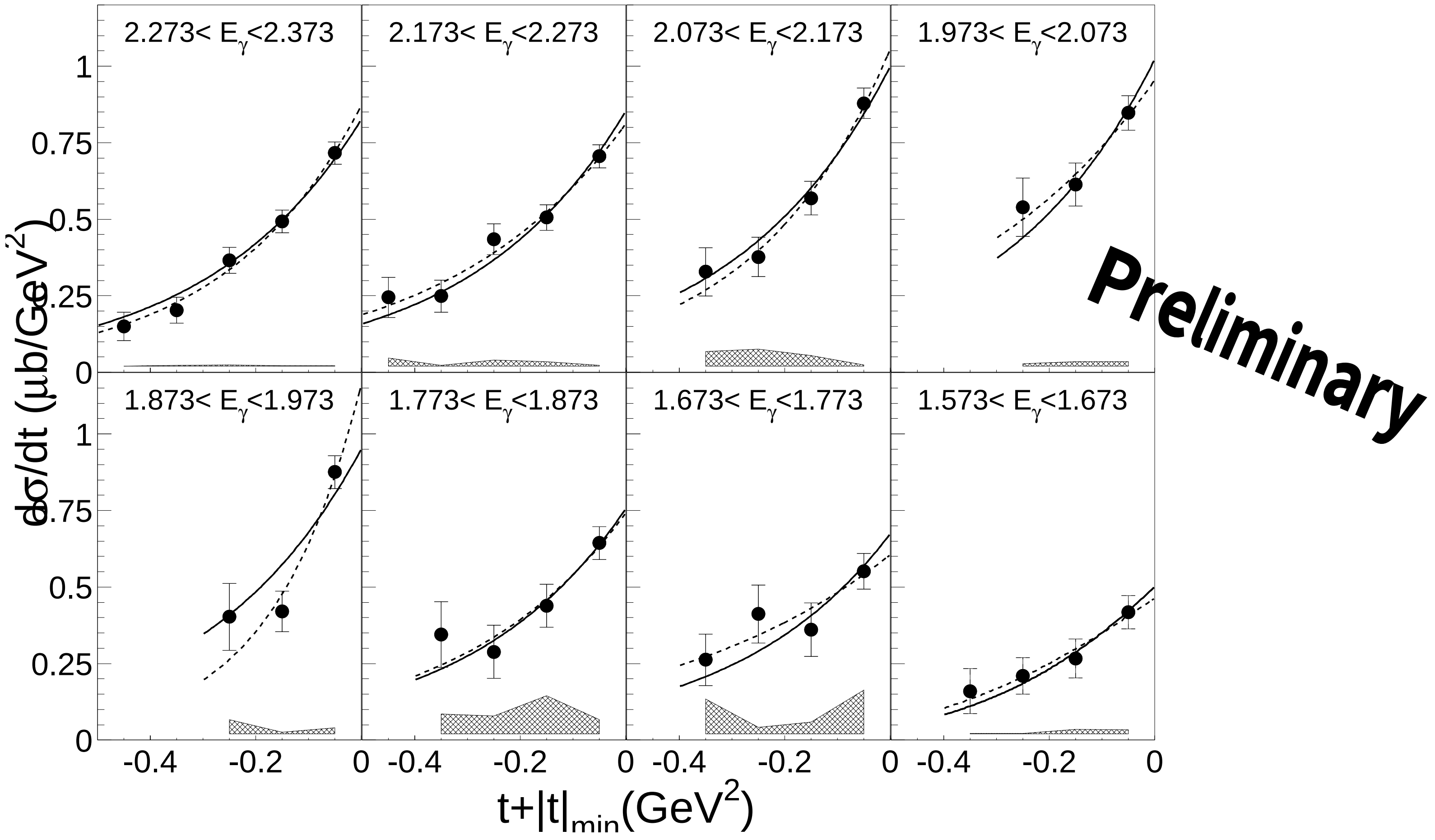
$-0.2 < t+|t|_{min} < 0.$ GeV^2

Simultaneous fit to distributions from VT and HZ data.

Good consistency between HZ and VT data

Results

differential cross sections



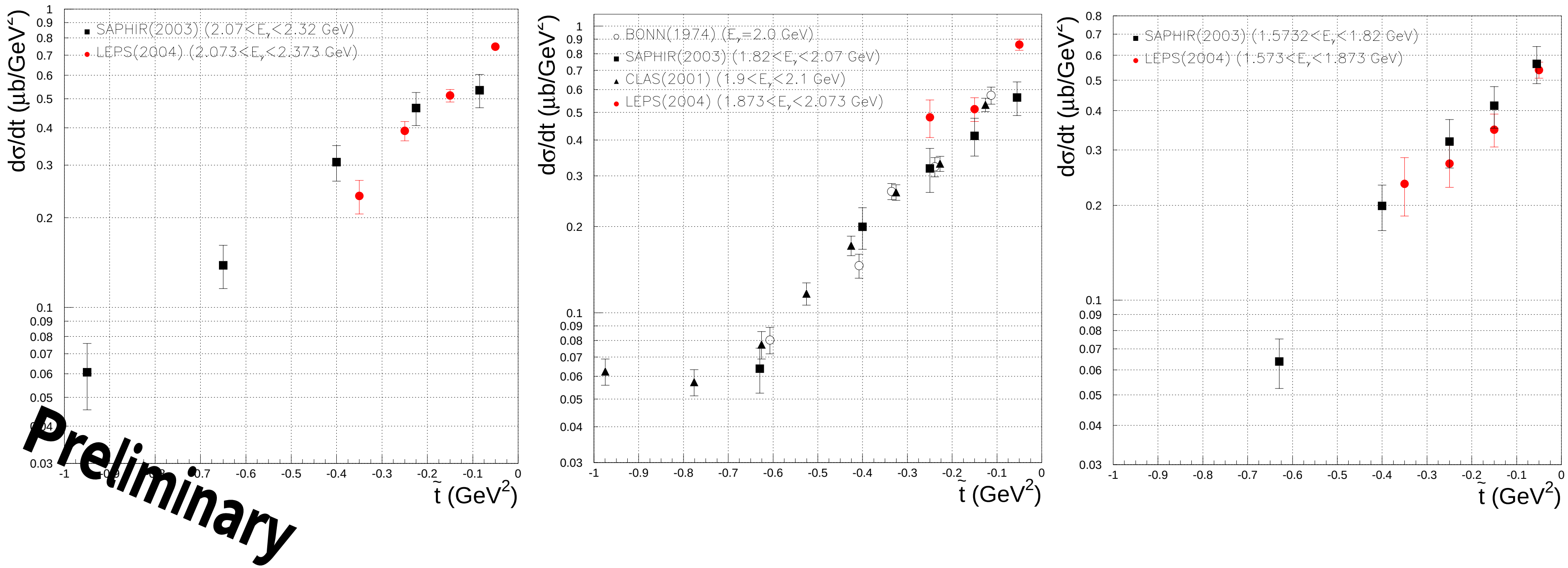
Fitting function

$(d\sigma/dt)_{t+|t|_{min}=0}\, e^{b\,(t+|t|_{min})}$

Solid curve: E_γ independent slope

Dashed curve: E_γ dependent slope

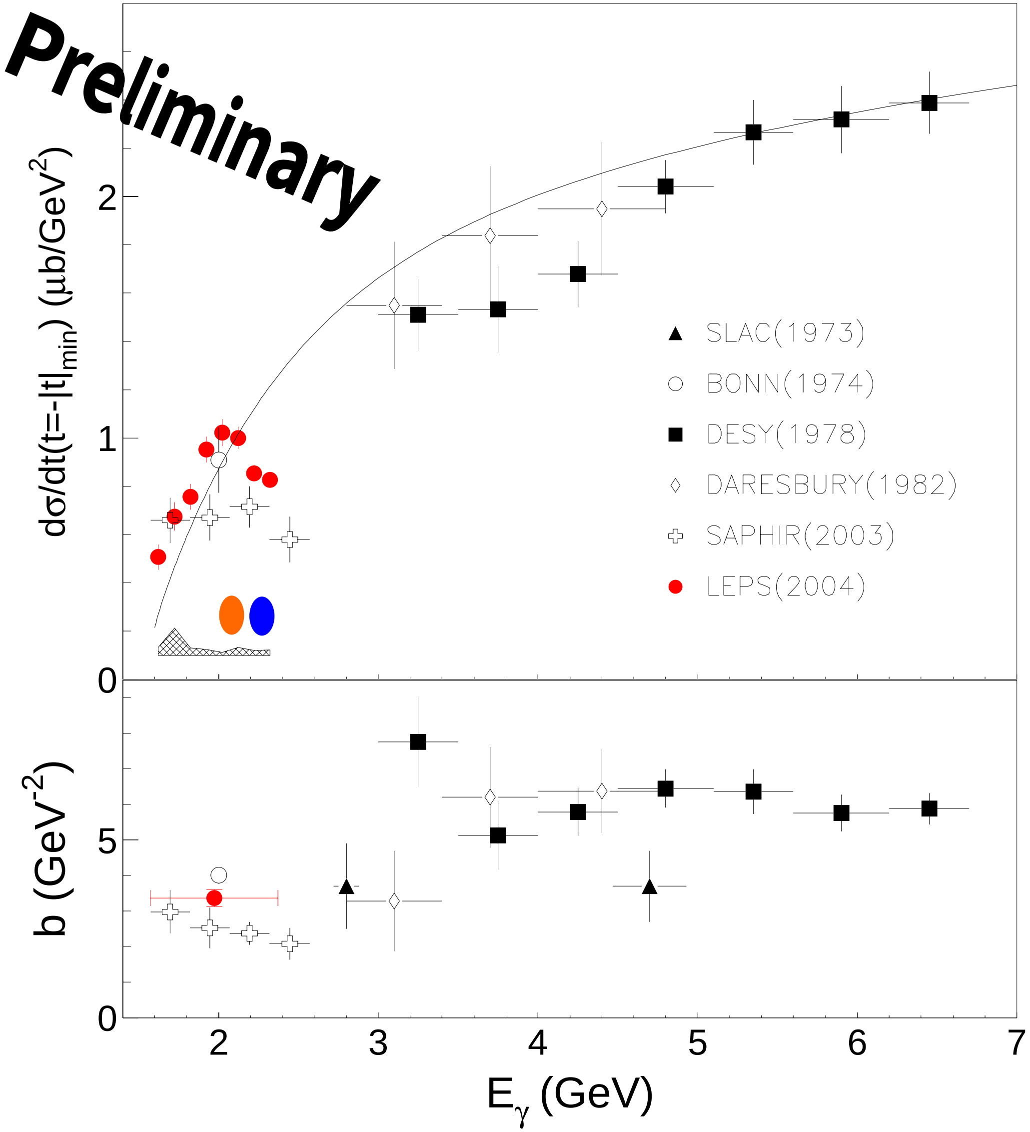
Differential cross sections



SAPHIR
J. Barth et al.
EPJ A17(2003)269

CLAS
D. J. Tedeschi in Proceedings of the International Symposium "EMI2001", Osaka, 2001

Differential cross section at $t=-|t|_{min}$



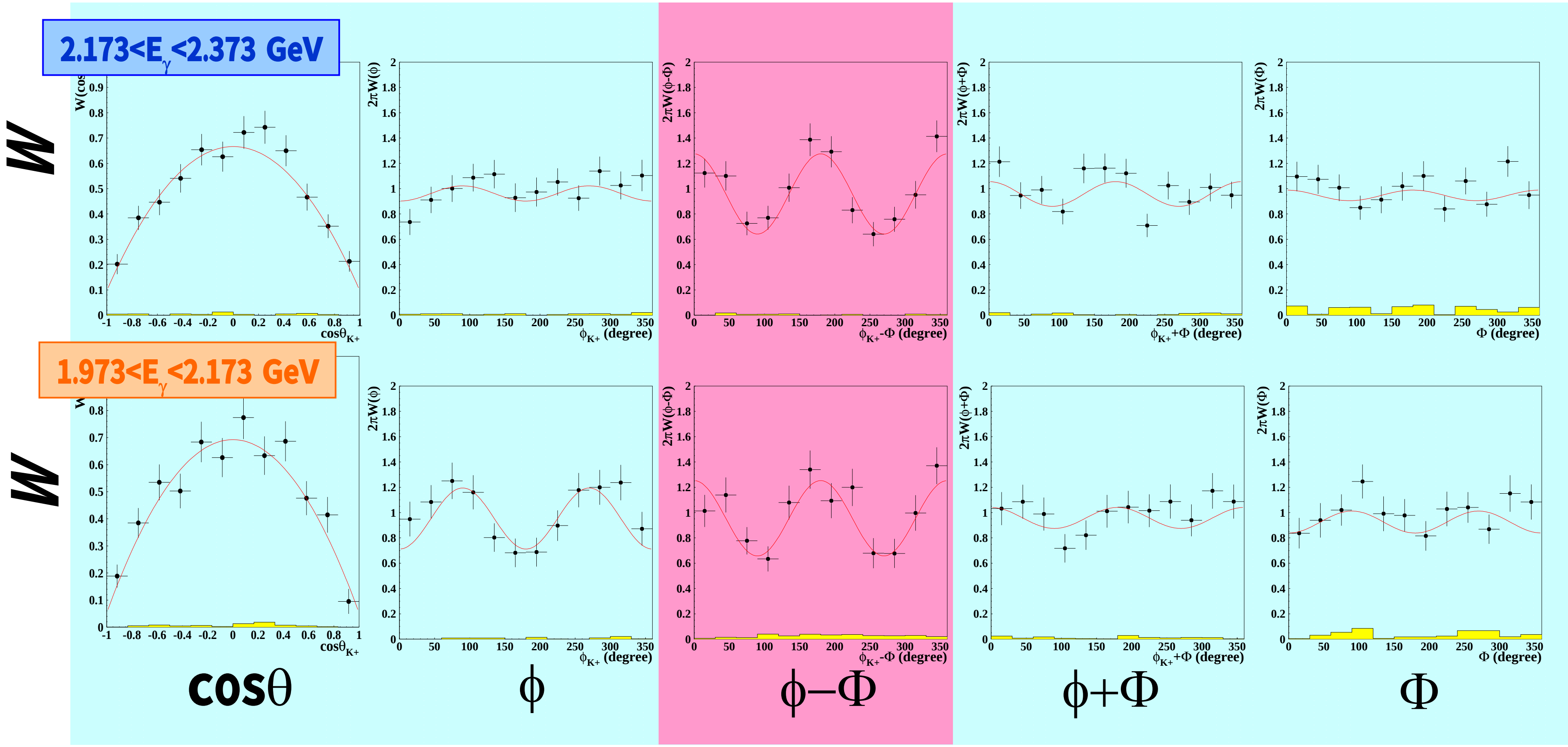
- Peaking structure in $d\sigma/dt$ at $t+|t|_{min}=0$.
- Smaller t slope near threshold

Decay angular distributions at
(1) $2.173<E_\gamma<2.373$ GeV
(2) $1.973<E_\gamma<2.173$ GeV

Solid curve : Model (Pomeron + Pseudo scalar exchange) by A. Titov

Decay angular distribution

$-0.2 < t+|t|_{min} < 0.\ \mathrm{GeV}^2$



- No energy dependence, except for ϕ distribution.
- Natural parity exchange is dominant.

Curves are fit to the data.

Summary of LEPS measurement

- Differential cross section at t=-|t|min
  - Peaking structure around E_γ=2.0 GeV
  - Prediction from Regge theory:
    - contribution from Pomeron increases with energy.
  - Meson and/or glueball exchange could be candidates to make the bump.
- Decay angular distribution
  - Dominant contribution from helicity conserving amplitude.
  - Natural parity exchange (N) > Unnatural parity exchange (UN).
  - No energy dependence in polarization observables. Ratio (N/UN) is energy independent.
- The bump can not be explained by pseudo scalar exchange only.
- Possible presence of additional natural parity exchange.

Open questions

- What is origin of the peaking structure ?
  - Natural parity exchange
  - Signiture of 0^+ glueball ?
  - A fit by simple model failed.

$$\frac{d\sigma}{dt}(\gamma p \rightarrow \phi p)(t=0) = C\left(\frac{p_\phi}{p_\gamma}\right)^2 \left(\left(\frac{s-u}{2s_0}\right)^{0.16} + a\left(\frac{s-u}{2s_0}\right)^{\delta}\right)$$

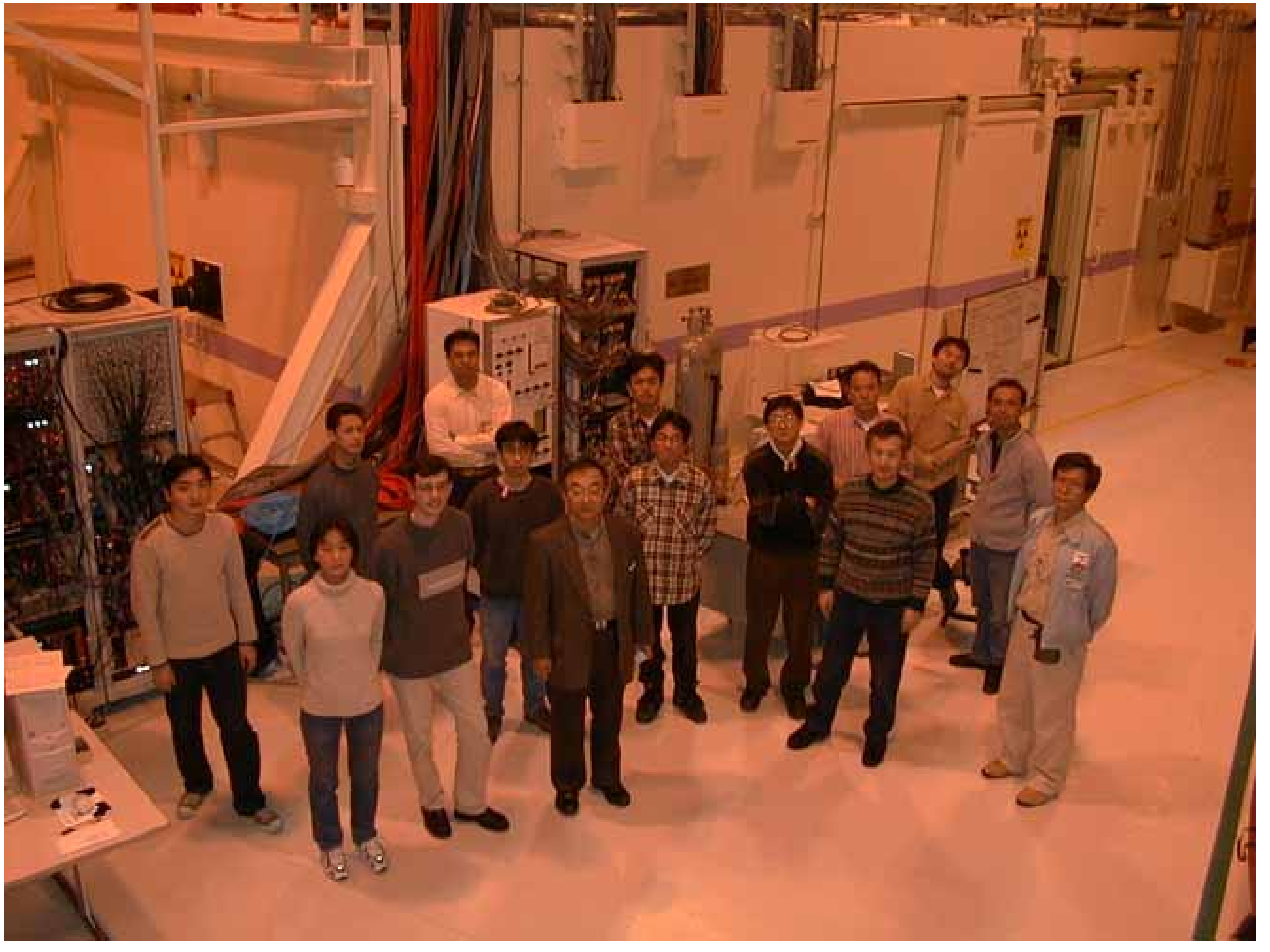
  - Need for further theoretical studies.
- Isospin symmetry ?
  - Glueball should be “flavor blind”
  - LEPS Deuteron target data (2002-2003)
  - CLAS Deuteron data (g2, g10)
- Measurements at E_γ=2.4-3 GeV
  - near future plan at LEPS
  - Ongoing analysis for large |t| at CLAS (g1)

Summary

- New LEPS results for differential cross section of $\gamma p \rightarrow \phi p$ reaction and decay angular distribution near threshold.
- Non-monotonic rise of differential cross section at $t=-|t|_{min}$ with energy
- Dominant contribution from natural parity exchange, no energy dependence near the bump.
- A possible presence of additional natural parity exchange.

Acknowledgements

This work was greatly supported by



and many other persons.

Thank you very much