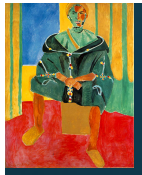
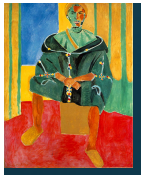


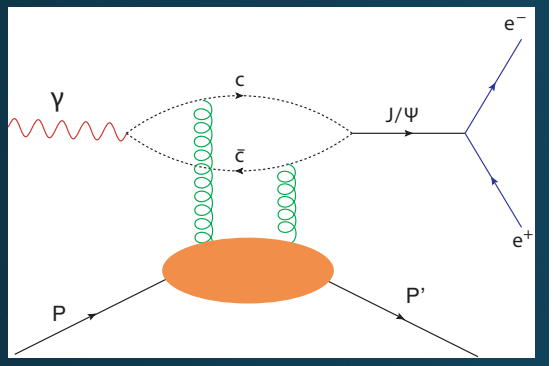
The J/Psi-N Physics with SoLID: Update

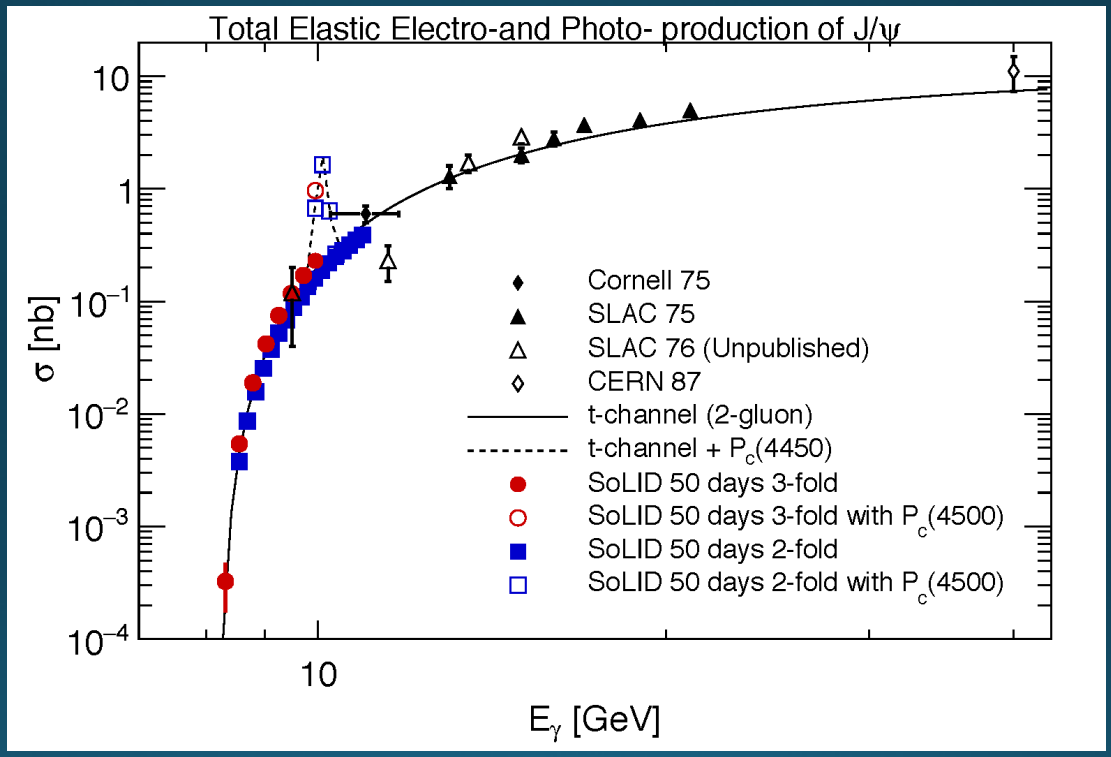
Zein-Eddine Meziani
Temple University

- J/Psi-N Physics Overview with SoLID
  - Measurement of Threshold Electro- and Photo-Production of J/Psi
    - Extraction of the J/Psi-nucleon interaction (scattering length/ binding)
  - Measurement of the Angular Asymmetry of the leptonic decay-pair
    - Extraction of the real part of the production amplitude
  - The proton mass and the trace (conformal) anomaly
- Summary



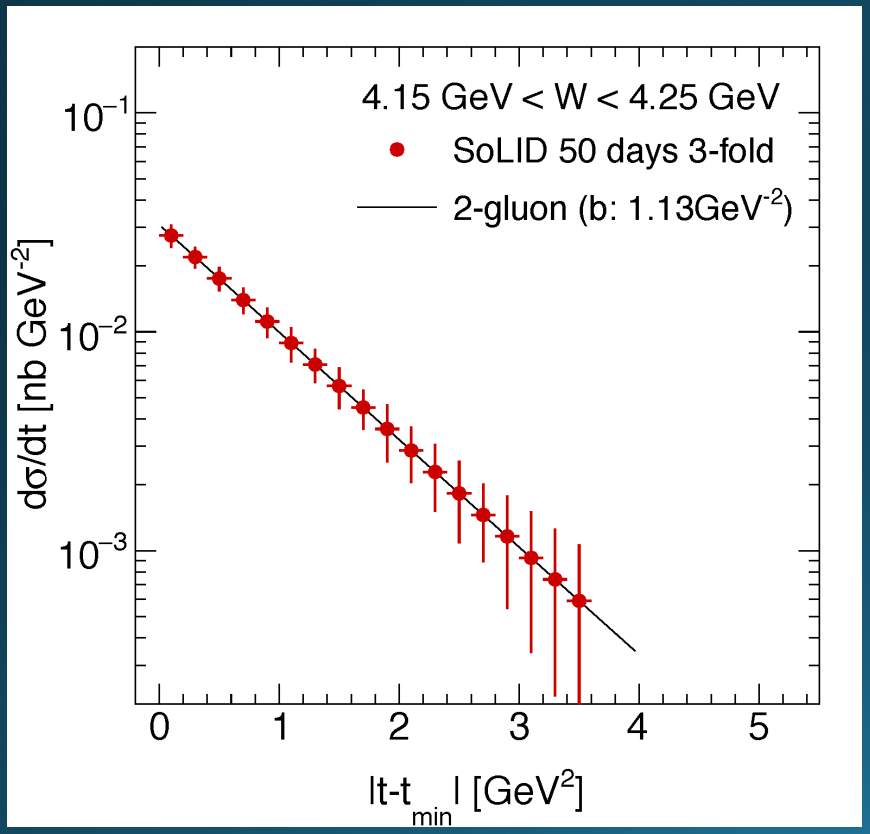
Measurement of Threshold Electro- and Photo-Production of J/psi

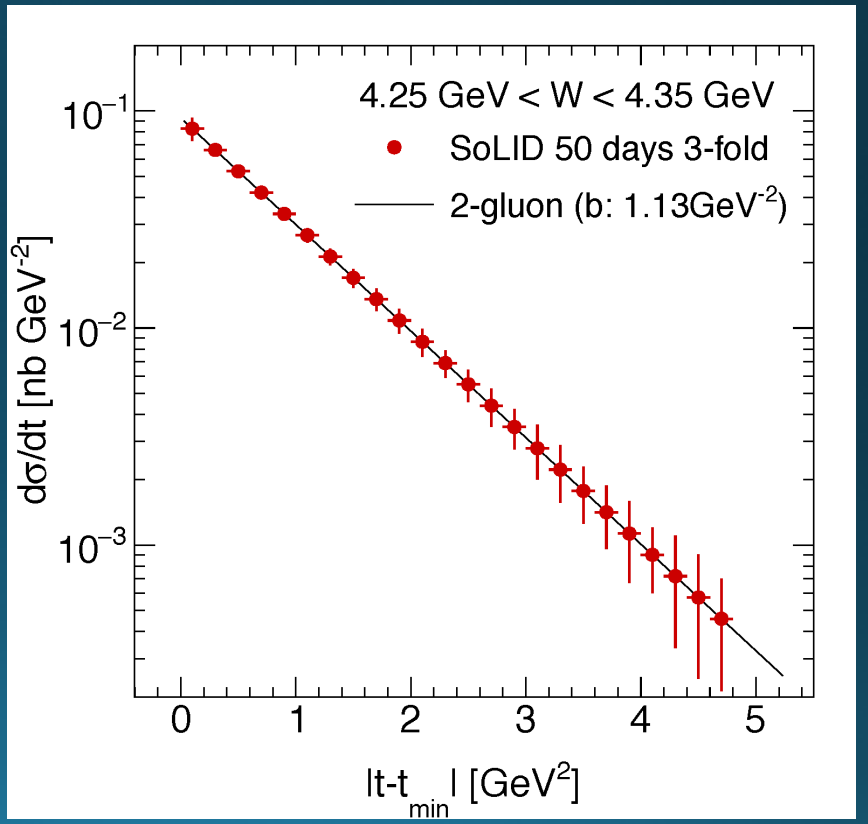


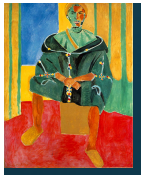


Sylvester Jooster
New Simulation
Including updated detector
geometrical setup

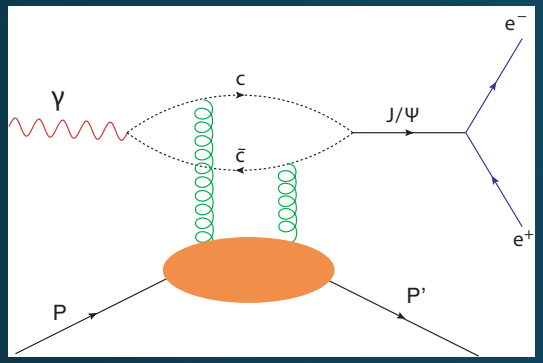
$|t-t_{min}|$ distributions at 2 different bins





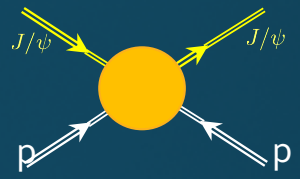


Extracting the scattering length and binding energy of the J/Psi-Nucleon interaction



Oleksii Gryniuk, M. Vanderhaeghen, PRD 94, 074001 (2016)

- Spin averaged $J/\psi - p$ scattering amplitude related to scattering length $a_{\psi p}$



$$\nu \equiv pq = \frac{s-u}{4}$$

$$T_{\psi p}(\nu = \nu_{el}) = 8\pi(M + M_\psi)a_{\psi p}$$

- Binding is related to the scattering length for a nucleus by

$$B_{\psi p} \simeq \frac{8\pi(M + M_\psi)a_{\psi p}}{4MM_\psi}\rho_{nm}$$

- Unitarity lead to:

$$\mathrm{Im}T_{\psi p}(\nu) = 2\sqrt{s}q_{\psi p}\sigma^{tot}_{\psi p}(\nu)$$

- Causality and crossing lead to the dispersion relation:

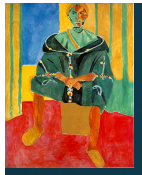
$$\mathrm{Re}T_{\psi p}(\nu) = T_{\psi p}(0) + \frac{2}{\pi}\nu^2 \int_{\nu_{el}}^{\infty} d\nu' \frac{1}{\nu'} \frac{\mathrm{Im}T_{\psi p(\nu')}}{\nu'^2 - \nu^2}$$

Cross section is parametrized

$$\sigma^{tot}_{\psi p} = \sigma^{el}_{\psi p} + \sigma^{inel}_{\psi p}$$

$$\sigma^{el}_{\psi p} \propto C_{el}\left(1 - \frac{\nu_{el}}{\nu}\right)^{b_{el}}\left(\frac{\nu_{el}}{\nu}\right)^{a_{el}}$$

$$\sigma^{inel}_{\psi p} \propto C_{in}\left(1 - \frac{\nu_{in}}{\nu}\right)^{b_{in}}\left(\frac{\nu_{in}}{\nu}\right)^{a_{in}}$$



Forward J/ψ-p scattering in relation to γ -p scattering

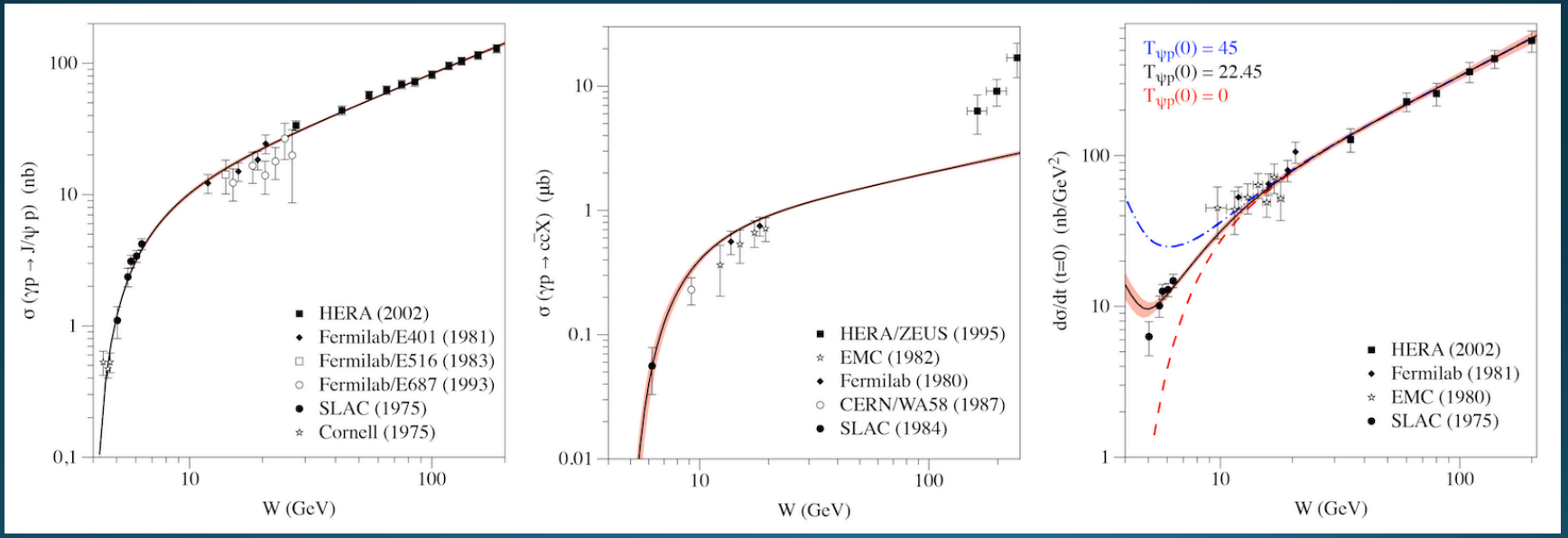
Vector Dominance Model (VDM) Assumption

$$\sigma^{el}_{\psi p} = \left(\frac{M_\psi}{f_\psi}\right)^2 \left(\frac{q_{\gamma p}}{q_{\psi p}}\right)^2 \sigma(\gamma p \to \psi p)$$

$$\sigma^{inel}_{\psi p} = \left(\frac{M_\psi}{e f_\psi}\right)^2 \left(\frac{q_{\gamma p}}{q_{\psi p}}\right)^2 \sigma(\gamma p \to c\bar{c}X)$$

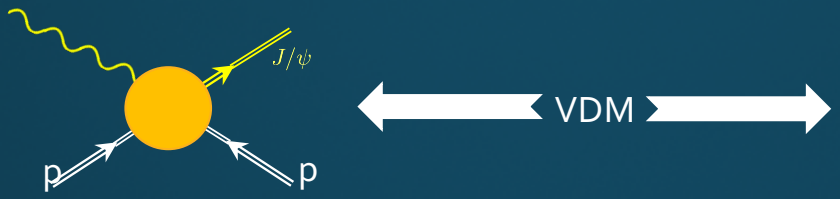
$$\frac{d\sigma}{dt}|_{t=0}(\gamma p \to \psi p) = \left(\frac{e f_\psi}{M_\psi}\right)^2 \left(\frac{q\psi p}{q_{\gamma p}}\right)^2 \frac{d\sigma}{dt}|_{t=0}(\psi p \to \psi p)$$

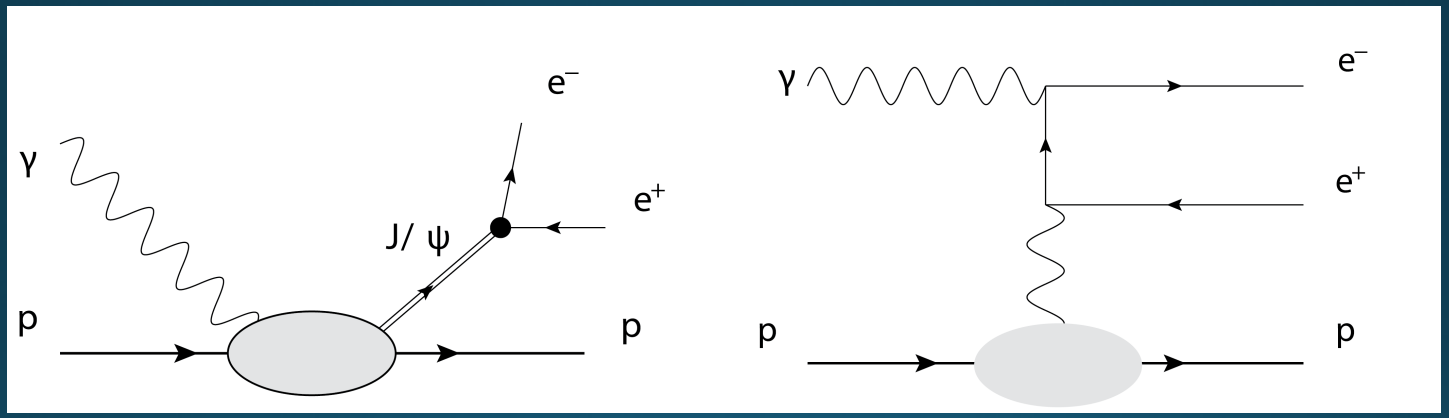
Oleksii Gryniuk, M. Vanderhaeghen, PRD 94, 074001 (2016)



Simultaneous fitting $T(0) = 22.5 \pm 2.5 \Rightarrow a_{\psi p} \sim 0.05\text{fm} \Rightarrow B_\psi \sim 3\text{MeV}$

Lepton pair photoproduction

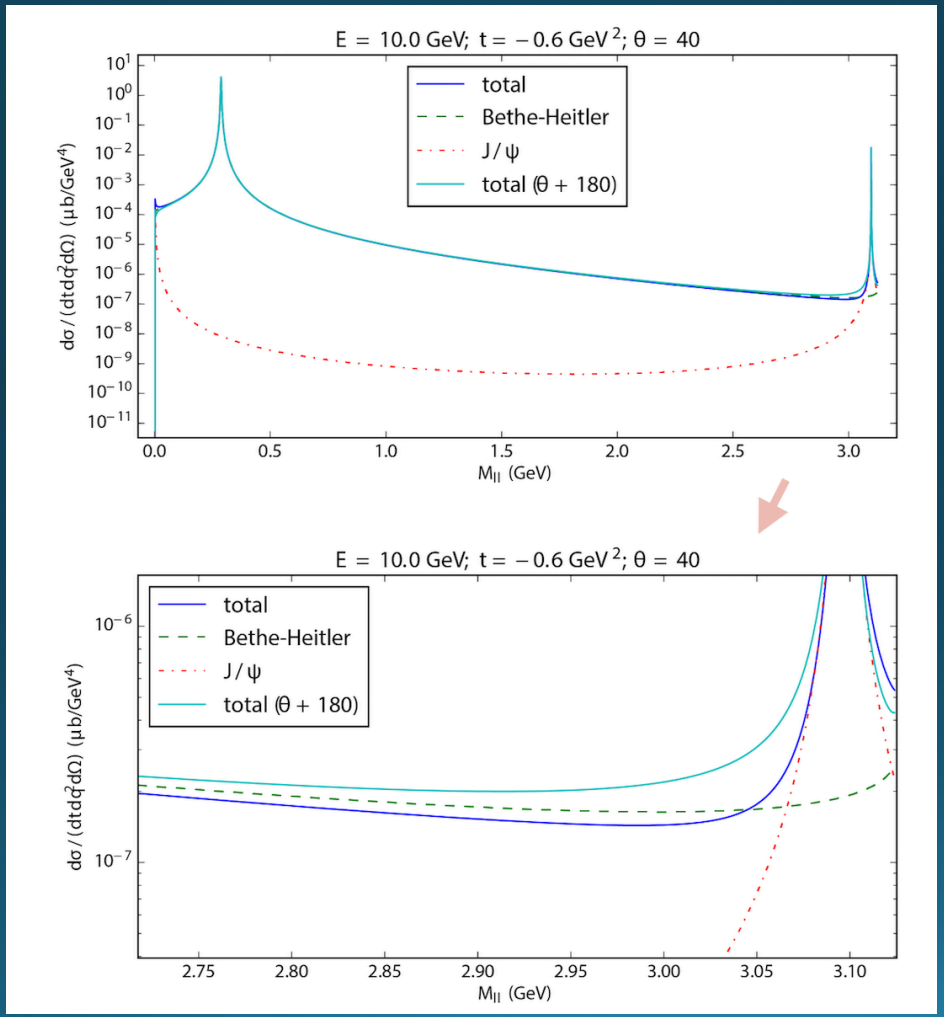




$$e^+ \leftrightarrow e^-$$

$$|T_\psi + T_{BH}|^2 = |T_{\psi^2}|^2 + 2\mathrm{Re}T_\psi T_{BH} + |T_{BH}|^2$$

J/ψ vs Bethe-Heitler cross section

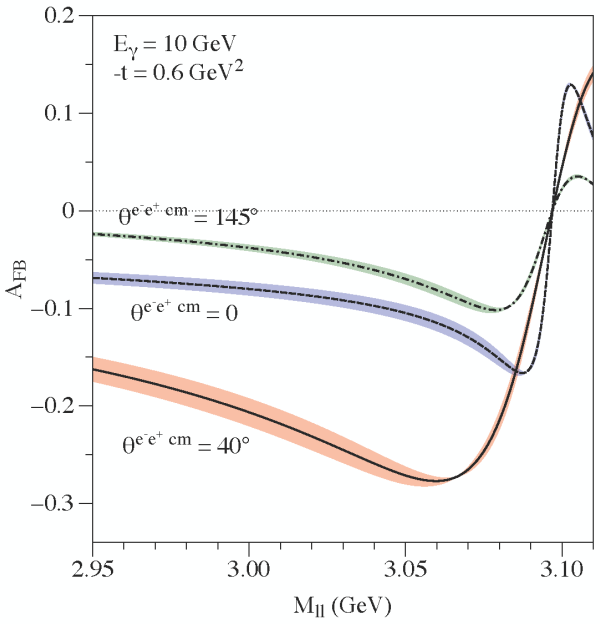


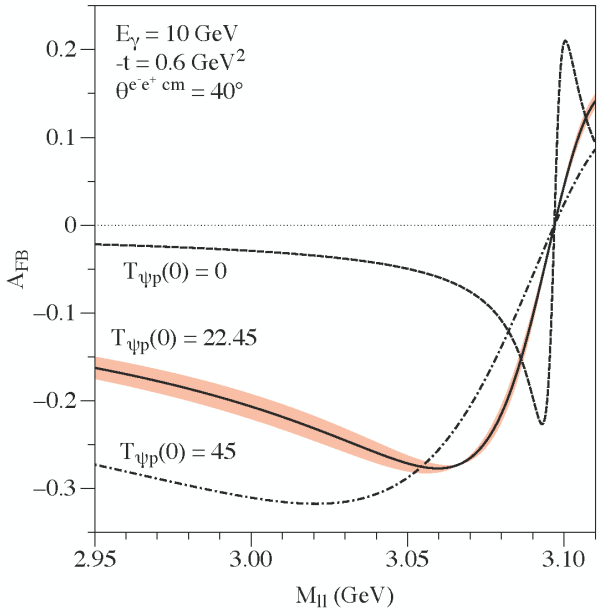
Asymmetry near the J/ψ peak

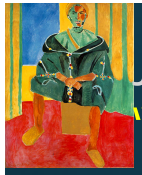
interference term

$$A_{\rm FB} \equiv \frac{\frac{d\sigma}{d\Omega}(\theta_{cm}) - \frac{d\sigma}{d\Omega}(\theta_{cm}-\pi)}{\frac{d\sigma}{d\Omega}(\theta_{cm}) + \frac{d\sigma}{d\Omega}(\theta_{cm}-\pi)} = \frac{\sum_s 2\,{\rm Re}T_\psi\, T_{BH}}{\sum_s |T_\psi|^2 + \sum_s |T_{BH}|^2}$$

$\theta_{\rm cm}$ — scattering angle in a lepton pair CM frame

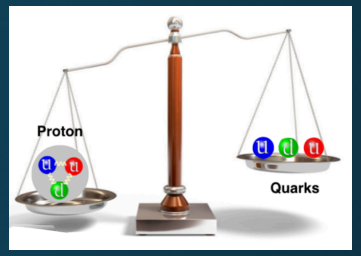




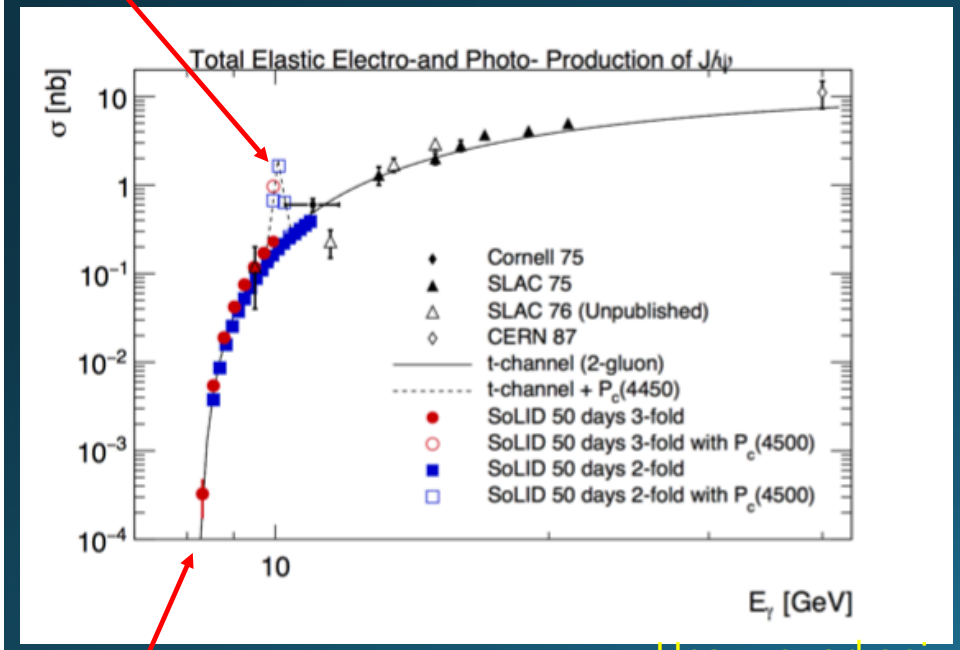


J/Psi@ SoLID; The threshold region, the mass of the proton and the LHCb charm "pentaquark"

- Measure the contribution of the gluons to the mass of the proton directly.
- Poduce and determine the quantum numbers of the LHCb pentaquark if it exist.



LHCb Pentaquark production



Threshold

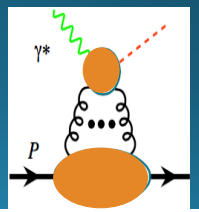
How does QCD generate the mass of the proton?

✧ Trace of the QCD energy-momentum tensor:

$$T^{\alpha}_{\alpha} = \underbrace{\frac{\beta(g)}{2g} F^{\mu\nu,a} F^{a}_{\mu\nu}}_{\text{QCD trace anomaly}} + \sum_{q=u,d,s} m_q (1+\gamma_m) \bar{\psi}_q \psi_q$$

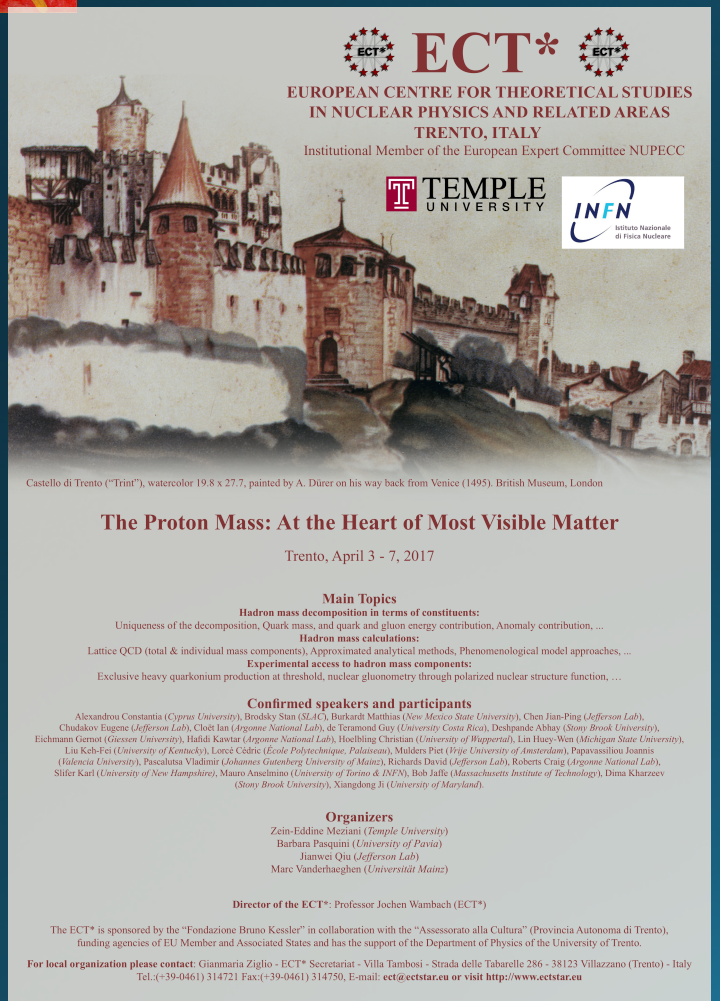
$$\beta(g) = -(11 - 2n_f/3) g^3/(4\pi)^2 + \ldots$$

J/Ψ, ϒ, …



➡ Heavy quarkonium production near the threshold, from JLab12

Proton Mass Workshop at ECT*



ECT*

EUROPEAN CENTRE FOR THEORETICAL STUDIES
IN NUCLEAR PHYSICS AND RELATED AREAS
TRENTO, ITALY
Institutional Member of the European Expert Committee NUPECC

TEMPLE UNIVERSITY

INFN Istituto Nazionale di Fisica Nucleare

Castello di Trento ("Trint"), watercolor 19.8 x 27.7, painted by A. Dürer on his way back from Venice (1495). British Museum, London

The Proton Mass: At the Heart of Most Visible Matter

Trento, April 3 - 7, 2017

Main Topics

Hadron mass decomposition in terms of constituents:
Uniqueness of the decomposition, Quark mass, and quark and gluon energy contribution, Anomaly contribution, ...

Hadron mass calculations:
Lattice QCD (total & individual mass components), Approximated analytical methods, Phenomenological model approaches, ...

Experimental access to hadron mass components:
Exclusive heavy quarkonium production at threshold, nuclear gluonometry through polarized nuclear structure function, ...

Confirmed speakers and participants

Alexandrou Constantia (*Cyprus University*), Brodsky Stan (*SLAC*), Burkardt Matthias (*New Mexico State University*), Chen Jian-Ping (*Jefferson Lab*), Chudakov Eugene (*Jefferson Lab*), Cloët Ian (*Argonne National Lab*), de Teramond Guy (*University Costa Rica*), Deshpande Abhay (*Stony Brook University*), Eichmann Gernot (*Giessen University*), Hafidi Kawtar (*Argonne National Lab*), Hoelbling Christian (*University of Wuppertal*), Lin Huey-Wen (*Michigan State University*), Liu Keh-Fei (*University of Kentucky*), Lorcé Cédric (*École Polytechnique, Palaiseau*), Mulders Piet (*Vrije University of Amsterdam*), Papavassiliou Joannis (*Valencia University*), Pascalutsa Vladimir (*Johannes Gutenberg University of Mainz*), Richards David (*Jefferson Lab*), Roberts Craig (*Argonne National Lab*), Slifer Karl (*University of New Hampshire*), Mauro Anselmino (*University of Torino & INFN*), Bob Jaffe (*Massachusetts Institute of Technology*), Dima Kharzeev (*Stony Brook University*), Xiangdong Ji (*University of Maryland*).

Organizers

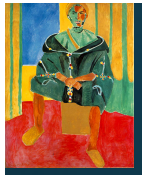
Zein-Eddine Meziani (*Temple University*)
Barbara Pasquini (*University of Pavia*)
Jianwei Qiu (*Jefferson Lab*)
Marc Vanderhaeghen (*Universität Mainz*)

Director of the ECT*: Professor Jochen Wambach (ECT*)

The ECT* is sponsored by the "Fondazione Bruno Kessler" in collaboration with the "Assessorato alla Cultura" (Provincia Autonoma di Trento), funding agencies of EU Member and Associated States and has the support of the Department of Physics of the University of Trento.

For local organization please contact: Gianmaria Ziglio - ECT* Secretariat - Villa Tambosi - Strada delle Tabarelle 286 - 38123 Villazzano (Trento) - Italy
Tel.:(+39-0461) 314721 Fax:(+39-0461) 314750, E-mail: **ect@ectstar.eu or visit http://www.ectstar.eu**

- A workshop was organized at ECT* in trento on the subject of Proton Mass.
- A white paper is under production.
- Already one paper on the arXiv on a new decomposition of the mass
  - C.~Lorcé, ``On the hadron mass decomposition,'' arXiv:1706.05853 [hep-ph].
- Need more work on the connection between experimental observables and the trace anomaly matrix element.



Summary

Progress on implementing the projections of the J/psi experiment with the latest configuration.
Included the SoLID projections of the LHCb "pentaquark" with similar assumptions for coupling as the Hall C LHCb "pentaquark experiment"

A path to extract the scattering length of J/psi-p scattering and binding energy for J/psi-nucleus

A new observable (angular asymmetry in the pair-decay) is proposed to access the real part of the scattering amplitude near threshold. It is known that the real part dominates.

Theoretical work is ongoing to connect the trace anomaly with experimental observables