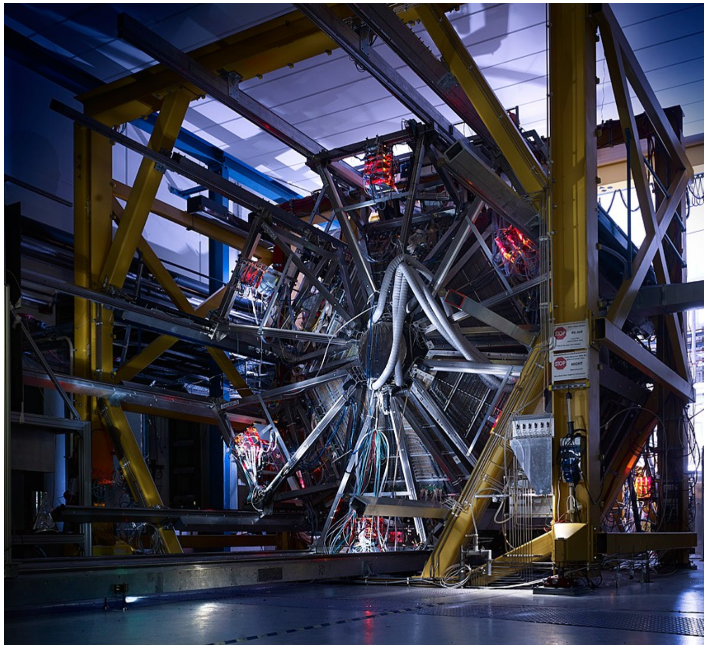
Studies of Time-Like Baryon Transition Form Factors with HADES

HADES



OUTLINE:

1) Motivations of the HADES experiment.
2) HADES detector.
3) Electromagnetic structure of baryons.
4) Results on baryon transition form factors from proton- and pion-induced reactions.
5) Studies of hyperons transition form factors.
6) Summary and outlook.

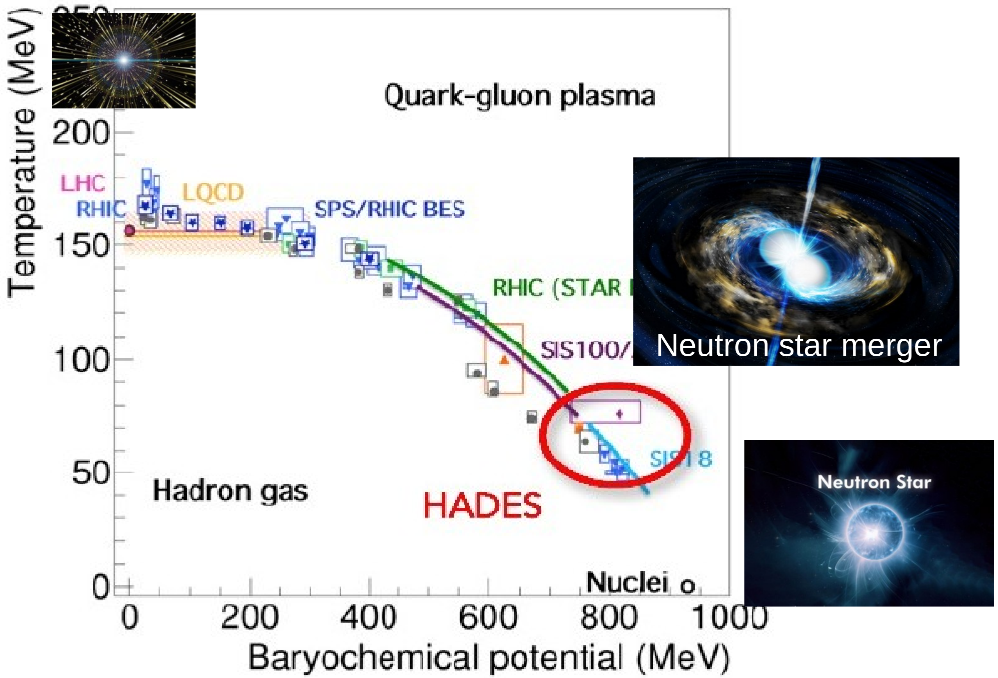
IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

Izabela Ciepał

THE HENRYK NIEWODNICZAŃSKI INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES

GSI FAIR GSI Helmholtzzentrum für Schwerionenforschung

HADES: exploring dense QCD matter



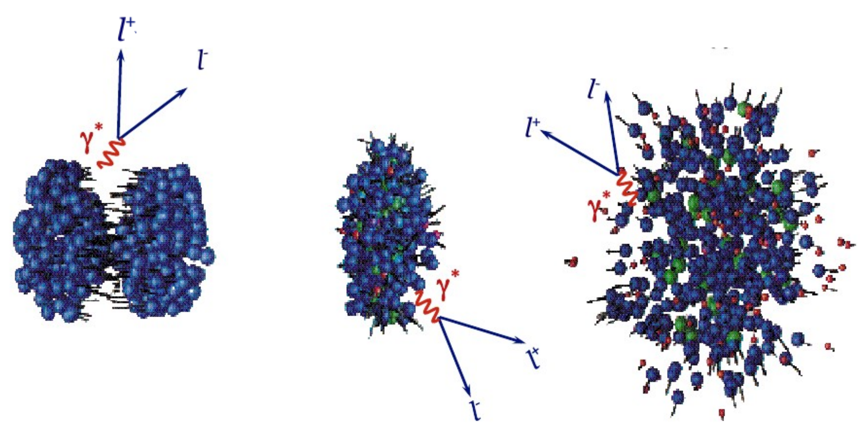
- ➔ Equation-of-State: First order transition ?
- ➔ Search for a critical point
- ➔ Chiral symmetry restoration
- ➔ Hadron properties in hot and dense nuclear matter
- ➔ Role of baryonic resonances, hyperons
- ➔ Complementary to SPS, RHIC,..

A+A: 1-3A GeV

$\sqrt{s}$=2-2.4 GeV

Observables:

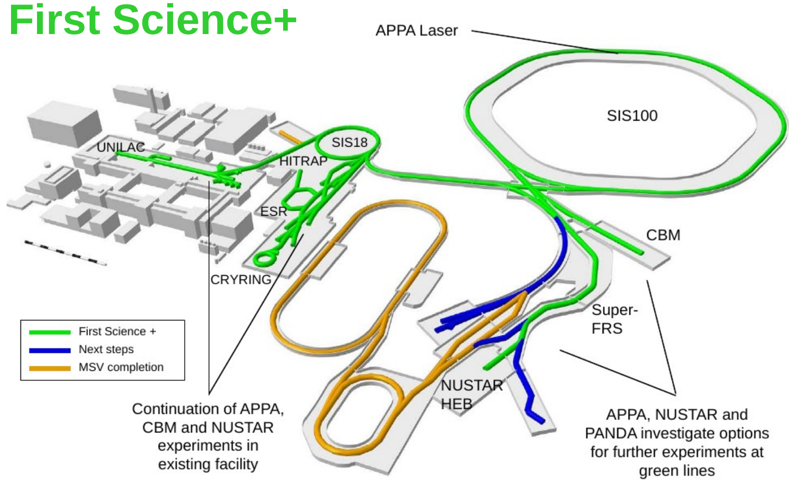
- ✓ Correlations and fluctuations
- ✓ Collective effects
- ✓ Strangeness
- ✓ **Dileptons (l^+l^-)**



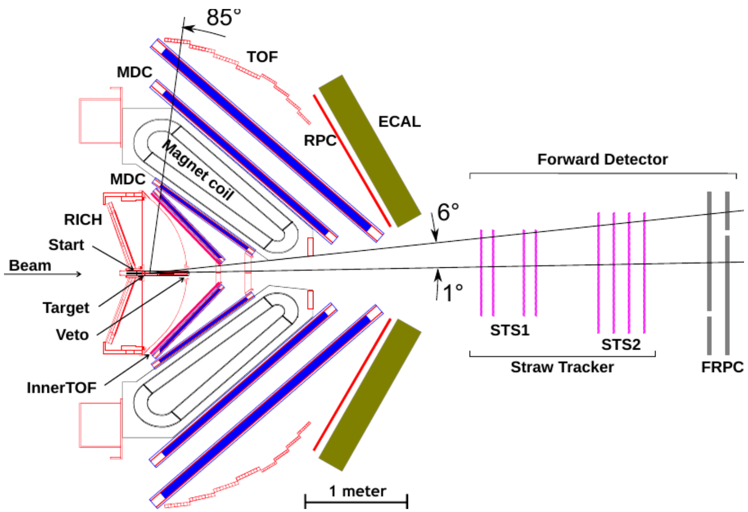
HADES - High Acceptance DiEelectron Spectrometer

GSI Helmholtzzentrum für Schwerionenforschung

FAIR First Science+

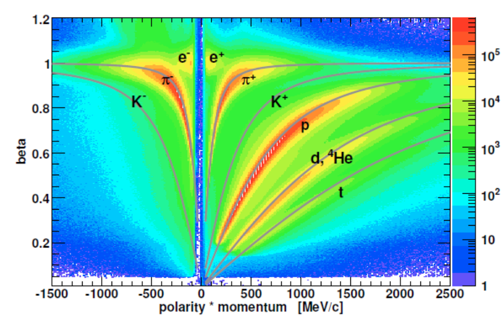


- ✓ SIS18 beams: protons (1-4.5GeV), nuclei (1-2AGeV), pions (0.4-2 GeV) secondary beam
- ✓ Spectrometer with ΔM/M~ 2% at ρ/ω
- ✓ PID (π/p/K): ToF (TOF/RPC, T0 detector), tracking (dE/dx)
- ✓ momenta, angles: MDC+ magnetic field
- ✓ e+,e-: RICH
- ✓ neutral particles: ECAL
- ✓ full azimuthal, polar angles $18^O - 85^O$
- ✓ e+e- pair acceptance ~0.35



Fair-Phase0 upgrade:

- **ECAL** (2017-2021)
- RICH (2018)
- **Forward Detector** (2021)
- **iTOF** (2021)
- START - LGAD



Emissivity of QCD matter

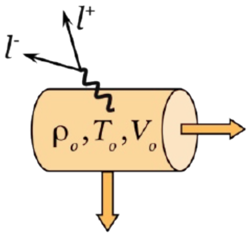
low-mass dilepton rate (***emissivity***) from a thermalized source

L.D. McLerran, T. Toimela, Phys. Rev. D 31, 545 (1985)

$$\frac{dN_{ee}}{d^4xd^4q} = \frac{-\alpha^2}{\pi^3 M^2} f^{BE}(T, q_0)\, \mathrm{Im}\, \Pi_{em}(M, q, T, \mu_B)$$

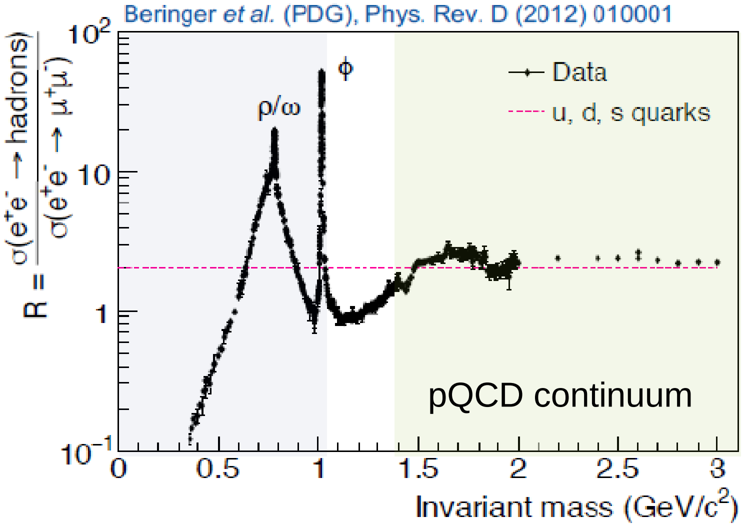
thermal Bose distribution

spectral function



spectral function in **VACUUM**:

$$R = \frac{\sigma(e+e- \to hadrons)}{\sigma(e+e- \to \mu+\mu-)} \propto \frac{1}{M_{ee}^2} \mathrm{Im}\, \Pi_{em}$$



LMR: dileptons with M<1 GeV - spectral function saturated with vector mesons, with **ρ (1⁻⁻)** playing the main role

$$Im\Pi_{em}^{vac} = \sum_{v=\rho,\omega,\phi} \left(\frac{m_v^2}{g_v}\right)^2 ImD_v^{vac}(M)$$

In medium ρ spectral function

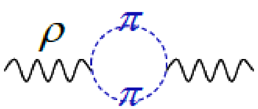
ρ meson propagator
Rapp&Wambach

$$D_\rho(M,q,\mu_B,T)=\left[M^2-m_\rho^2-\Sigma_{\rho\pi\pi}-\Sigma_{\rho B}-\Sigma_{\rho M}\right]^{-1}$$

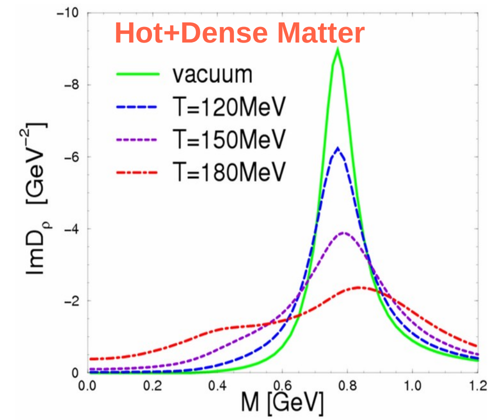
***Nuclear matter*: additional terms (ρ self-energies)**

dominant role of baryonic resonances R (Δ, N(1520), ….)

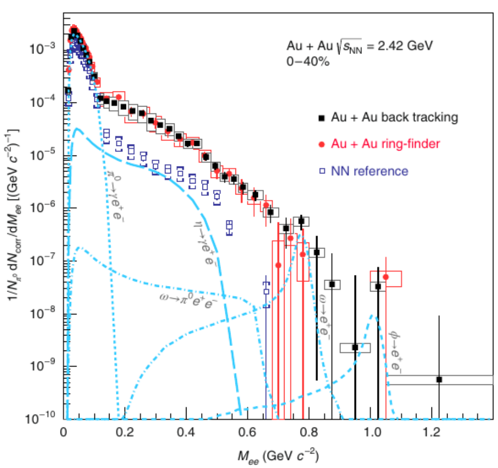
Vacuum:

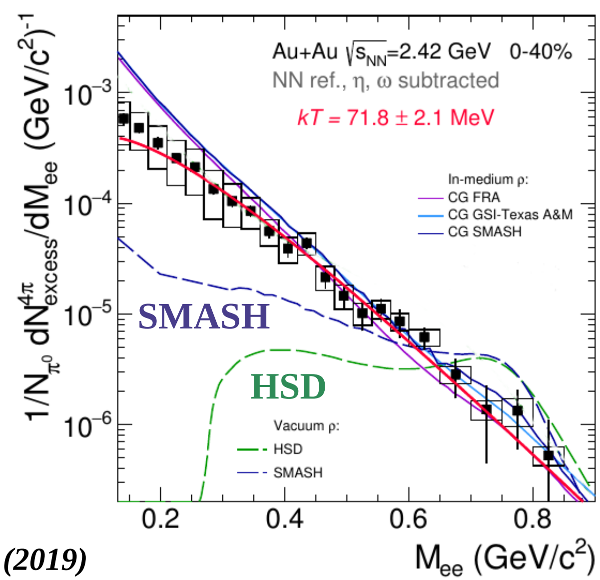


in-medium ρ spectral fun.
ρ broadening



R. Rapp, J. Wambach
Eur. Phys. J. A 6, 415 (1999)





experimental evidences from RHIC, SPS, SIS18,..

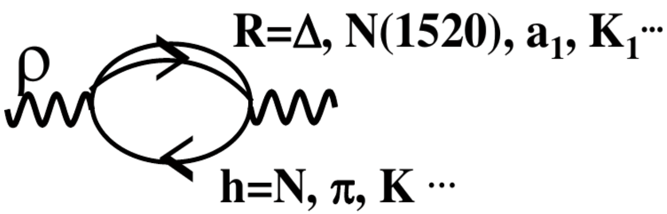
HADES, Nature Phys. 15, 10, 1040 (2019)

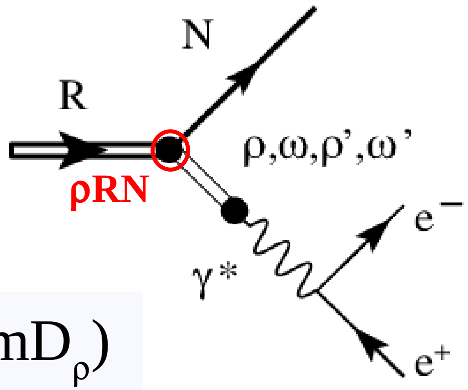
In medium ρ spectral function – connection to baryon Dalitz decay

***<u>Nuclear matter</u>*: additional terms (ρ self-energies)**

dominant role of baryonic resonances R (Δ, N(1520), ….)

$\Sigma_{\rho B,M}$ =

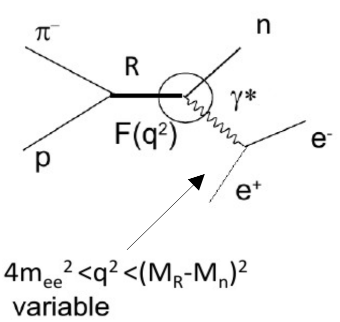




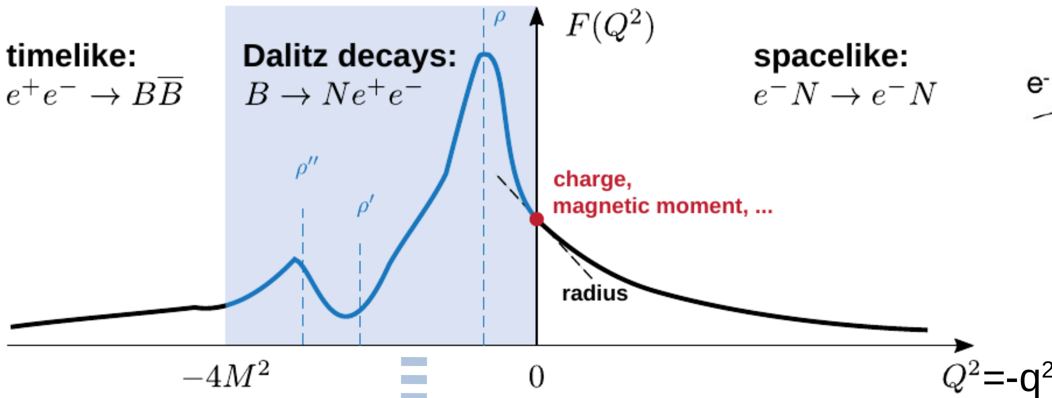
- in-medium spectral function (ImD_ρ) depends on ρRN coupling studied in $N^*(\Delta) \rightarrow N e^+e^-$ Dalitz decays

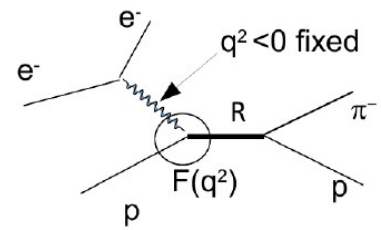
➔ **dedicated HADES hadron physics program to study Dalitz decays in NN and πN collisions**

Electromagnetic structure of baryons



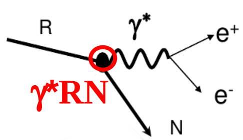
no data available





charge, shape, structure

$$q^2 = M^2_{inv}(e^+e^-) = M^2_{\gamma^*} > 0$$



R → N Transition Form Factor

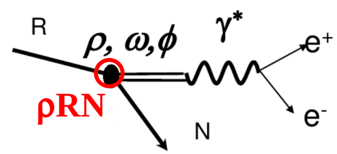
$$\frac{d\Gamma(\Delta \to Ne^+e^-)}{dq^2} = f\left(m_\Delta, q^2\right)\left(\left|G_M^2(q^2)\right| + 3\left|G_E^2(q^2)\right| + \frac{q^2}{2m_\Delta^2}\left|G_C^2(q^2)\right|\right)$$

M. I. Krivoruchenko, et. al
Annals Phys. 296, 299 (2002)

QED
transition
of point-like
particles

$G_{M/E/C}$: Form-Factors ($A_{1/2}$, $A_{3/2}$, $S_{1/2}$)
internal structure of hadrons
(various models)

Vector Meson Dominance model:
important role of vector mesons: $J^{PC} = 1^{--}$ (γ^*)



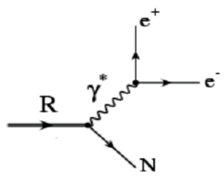
Dalitz decays of baryon resonances

Vector Meson Dominance Models (VMD)

hadrons ⟷ photons

Baryons Dalitz decays – (Hades), calculations of eTFF based on VMD:

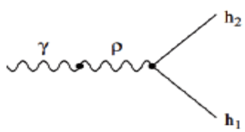
→ QED "point-like"
R-γ^* vertex



M. Zetenyi et al., PRC 67, 044002 (2003)

→ *strict* VMD (VMD2)

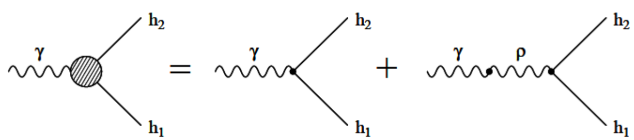
- Nρ coupling
- used in HI transport models



$$\Gamma_\rho^{VDM2} = \left(\frac{M_0}{M}\right)^3 \Gamma_\rho^0$$

***Sakurai**, Phys. Rev 22 (1969) 981*
M. I. Krivoruchenko et al., Ann. Phys. 296, 299 (2002)

→ 2-component VMD (VMD1)



Kroll, Lee & Zuminio Phys. Rev. 157, 1376 (1967)

- Nρ and Nγ couplings
- used in calculations of in-medium spectral functions

$$\Gamma_\rho^{VDM1} = \left(\frac{M}{M_0}\right) \Gamma_\rho^0$$

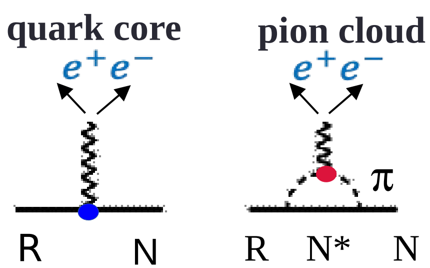
etFF of baryons: models

Covariant quark model +VMD

T. Pena & G. Ramalho

N-Δ(1232): *Phys.Rev. D93, 033004 (2016)*
N-N(1520): *Phys. Rev. D95, 014003 (2017)*
N-N(1535): *Phys.Rev. D101, 114008 (2020)*

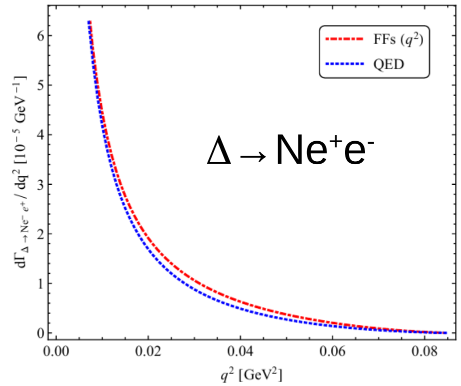
VMD:
quark FF
pion FF



Dispersion theory

S. Leupold et al.

S. Leupold
arXiv:2401.17756 (2024)



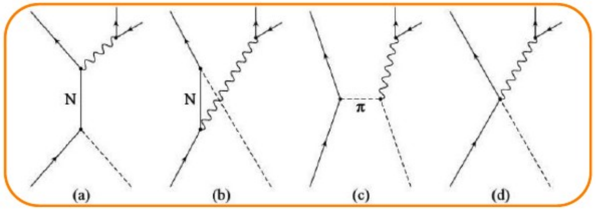
Two-component Lagrangian model

M. Zetenyi & G. Wolf

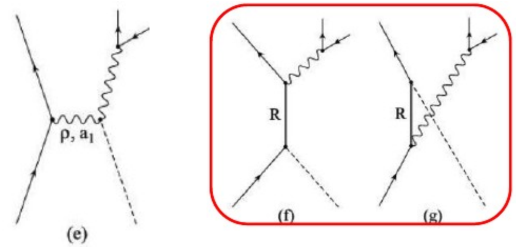
PRC 86, 065209 (2012)
PRC 104, 015201 (2021)

microscopic calculations of πN → Ne+e-

Born terms

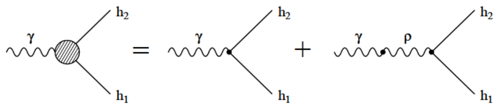


baryon resonances



N(1440)
N(1520)
N(1535)

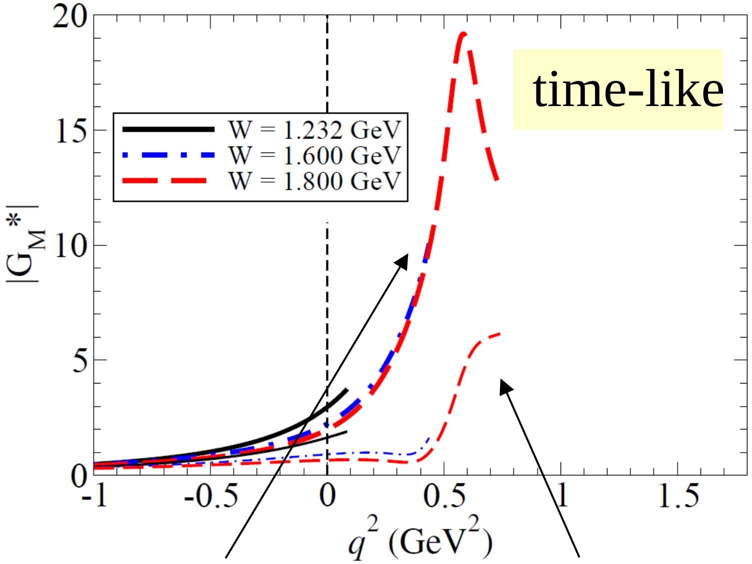
2-component VMD:



Meson cloud effect

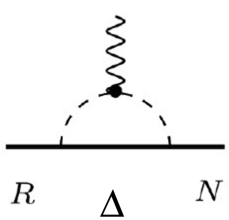
$\Delta_{33}(J=3/2) \rightarrow N(J=1/2)$

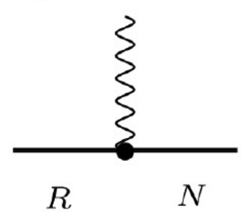
G. Ramalho, T. Peña
Phys. Rev. D 93, 033004 (2016)



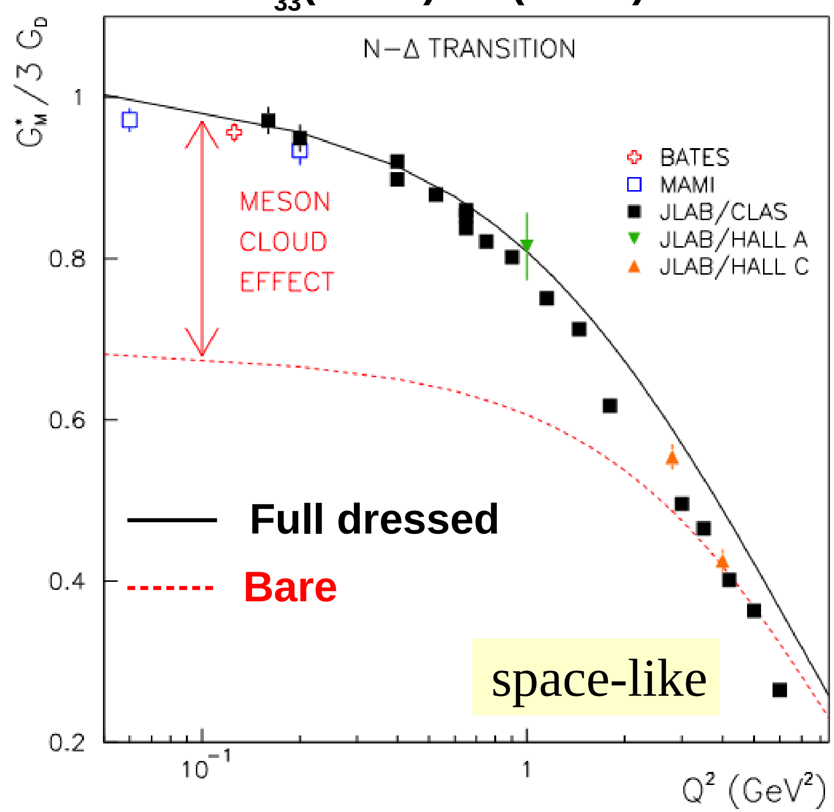
quark core
+ pion cloud

bare quark core

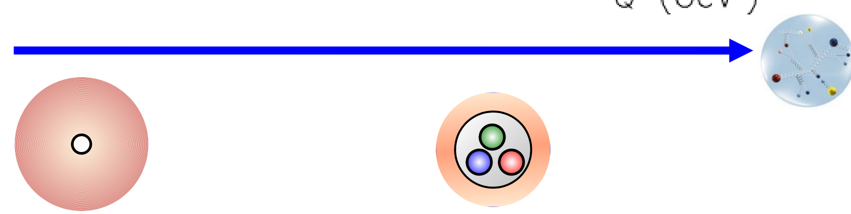




$\Delta_{33}(J=3/2) \rightarrow N(J=1/2)$



I. G. Aznauryan and V. D. Burkert,
Prog. Part. Nucl. Phys. 67, 1 (2012)



dressed quark core
+dense meson clouds

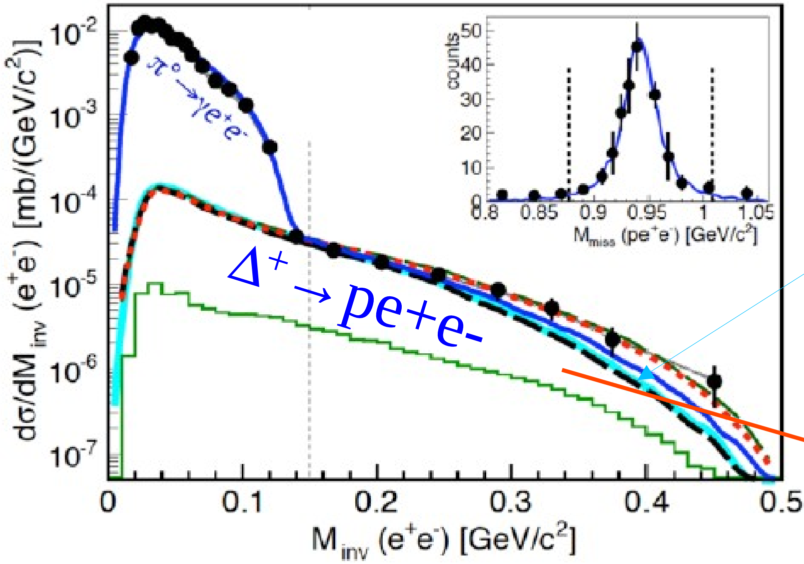
small meson cloud
dressed quark core dominates

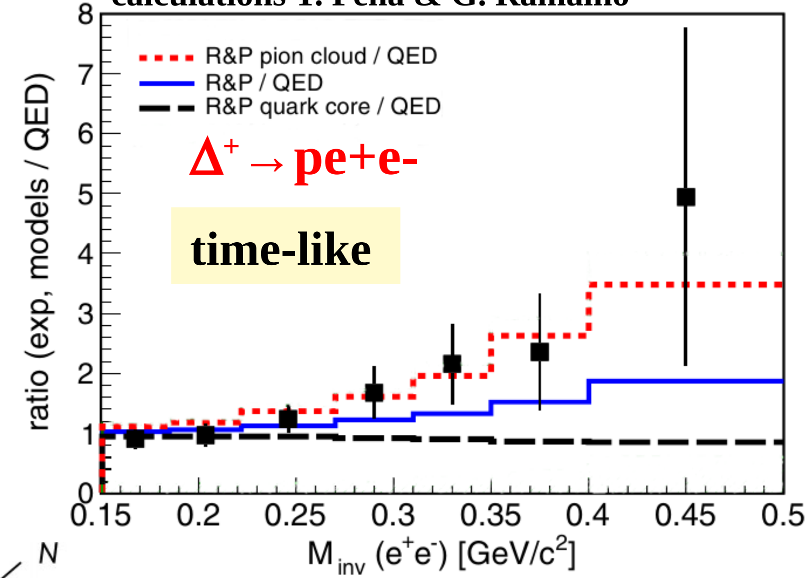
Δ (1232) resonance - exclusive pe+e- analysis

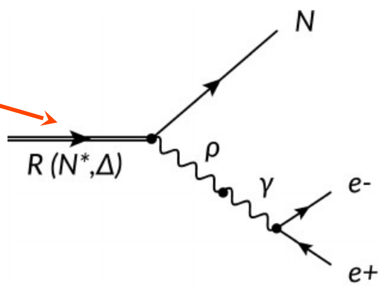
HADES: Phys. Rev. C 95, 065205 (2017)

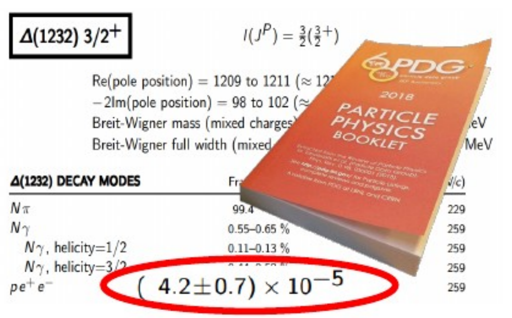
pp → ppe+e- @1.25 GeV

- energy below η production threshold
- cross sections for Δ^+ ($p\pi^+$, $p\pi^0$) from PWA









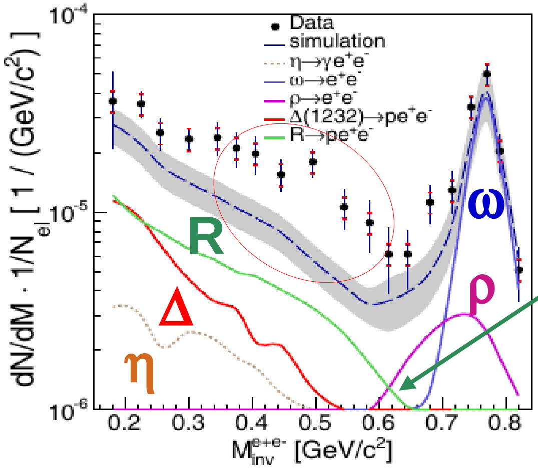
$$\frac{d\Gamma(\Delta \to Ne^+e^-)}{dq^2} = f\left(m_\Delta, q^2\right)\left(\left|G_M^2(q^2)\right| + 3\left|G_E^2(q^2)\right| + \frac{q^2}{2m_\Delta^2}\left|G_C^2(q^2)\right|\right)$$

effective eTFF

Dalitz decay studies of heavier baryons

HADES: EPJ A50, 82 (2014)

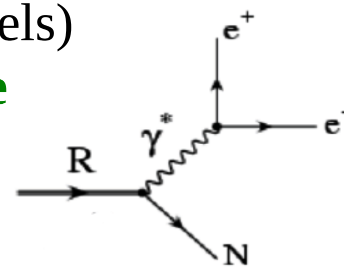
pp → ppe⁺e⁻ @3.5 GeV

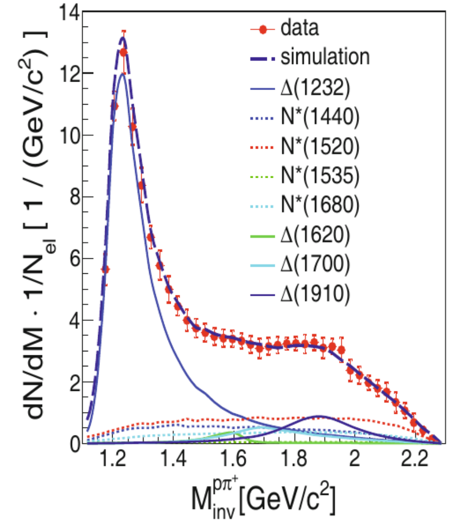


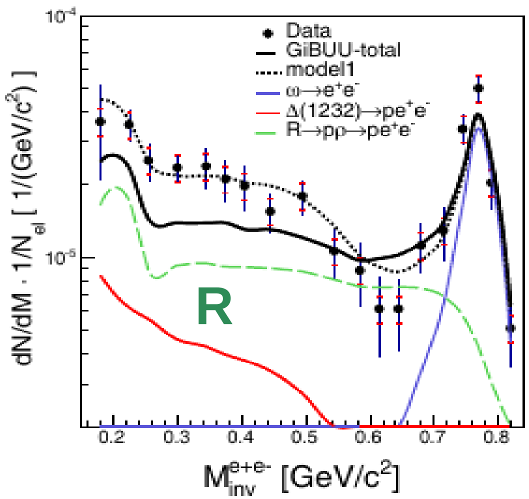
Dalitz decays of **point-like** baryonic resonances (constrained by ppπ⁰ and pnπ⁺ channels)

QED reference

R → pe+e-

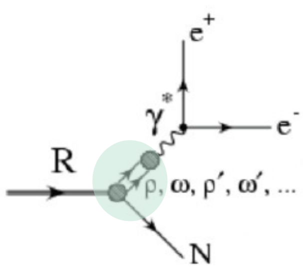






- comparison to GiBUU transport model
- with a 2-step process:

R → pρ → pe+e-



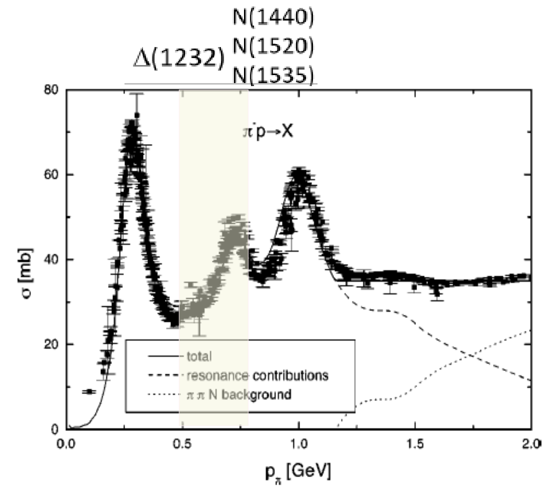
model 1 = GiBUU, but with modified cross sections (HADES simul.)

Pion beam facility @ GSI

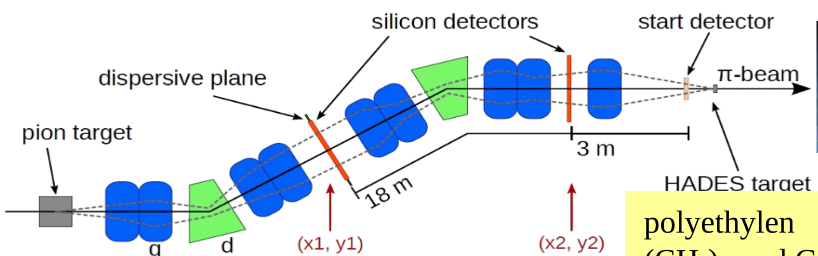
Eur. Phys. J. A 53, 188 (2017)

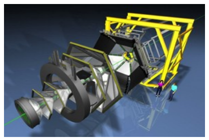
- **selectivity:** producion of resonance with given mass in s-channel
- 2-pion channels: $\pi^- p \rightarrow n\pi^+\pi^-$, $\pi^- p \rightarrow p\pi^-\pi^0$ $(\sqrt{s} = 1.46 - 1.55\,GeV)$
  - complete the very scarce pion beam data base for hadronic couplings
- dilepton channel R → Ne+e-, **never** measured in pion induced reactions - time-like electromagnetic structure of baryons

2^{nd} resonance region



- ➢ reaction **N+Be**, 8-10*10^{10} N_2 ions/spill (4s)
- ➢ secondary **π^-** with **I ~ 2-3 10^5/s**
- ➢ p = 650, **685**, 733, 786 (+/- 1) MeV/c
- ➢ **PE $(CH_2)_n$** and **C** targets



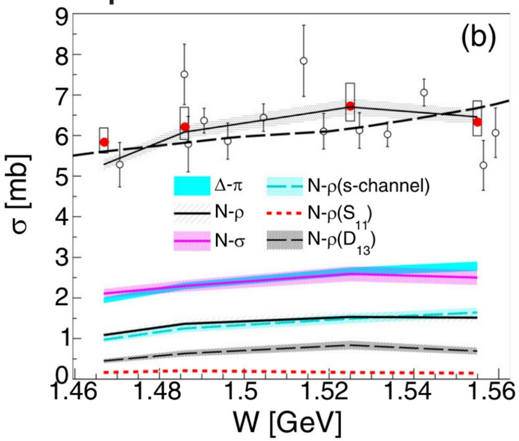


polyethylen $(CH_2)_n$ and C

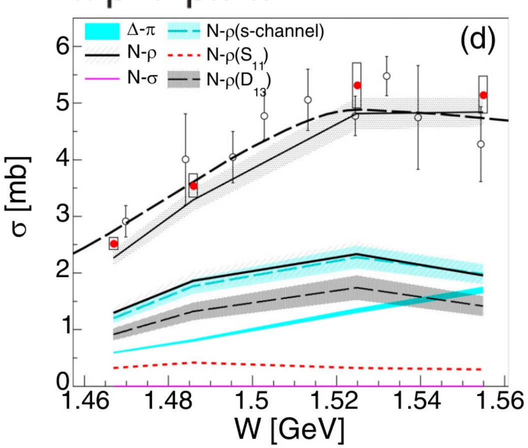
2-pion production in $\pi^- p$

HADES: Phys. Rev. C 102, 024001, (2020)

$\pi^- p \rightarrow n\pi^+\pi^-$



$\pi^- p \rightarrow p\pi^0\pi^-$



Bn-Ga PWA: *pwa.hisp.uni-bonn.de*

2π data included in the fit

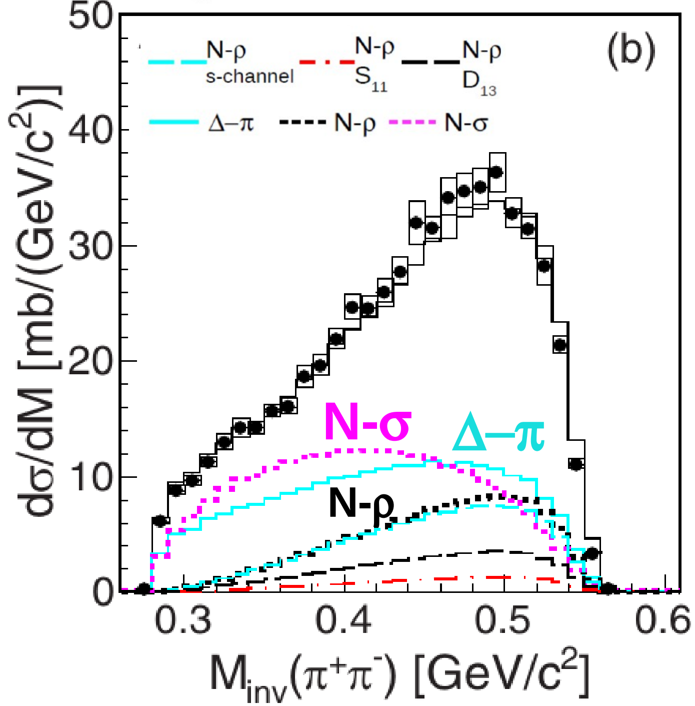
Reaction	Observable	W (GeV)	
$\gamma p \rightarrow \pi^0\pi^0 p$	DCS, Tot	1.2-1.9	MAMI
$\gamma p \rightarrow \pi^0\pi^0 p$	E	1.2-1.9	MAMI
$\gamma p \rightarrow \pi^0\pi^0 p$	DCS,Tot	1.4-2.38	CB-ELSA
$\gamma p \rightarrow \pi^0\pi^0 p$	P, H	1.45-1.65	CB-ELSA
$\gamma p \rightarrow \pi^0\pi^0 p$	T, P_x, P_y	1.45-2.28	CB-ELSA
$\gamma p \rightarrow \pi^0\pi^0 p$	P_x, P_x^c, P_x^s (4D)	1.45-1.8	CB-ELSA
$\gamma p \rightarrow \pi^0\pi^0 p$	P_y, P_y^c, P_y^s (4D)	1.45-1.8	CB-ELSA
$\gamma p \rightarrow \pi^+\pi^- p$	DCS	1.7-2.3	CLAS
$\gamma p \rightarrow \pi^+\pi^- p$	I^c, I^s	1.74-2.08	CLAS
$\pi^- p \rightarrow \pi^0\pi^0 n$	DCS	1.29-1.55	Crystal Ball
$\pi^- p \rightarrow \pi^+\pi^- n$	DCS	1.45-1.55	HADES
$\pi^- p \rightarrow \pi^0\pi^- p$	DCS	1.45-1.55	HADES

unique data set

ρ meson production:

- **s-channel D_{13} (N(1520) $3/2^-$) dominant contribution**
- N(1520) → Nρ BR=12.2 +/- 2 %
- N(1535) → Nρ BR=3.2 +/- 0.6 %

$\pi^- p \rightarrow n\pi^+\pi^-$

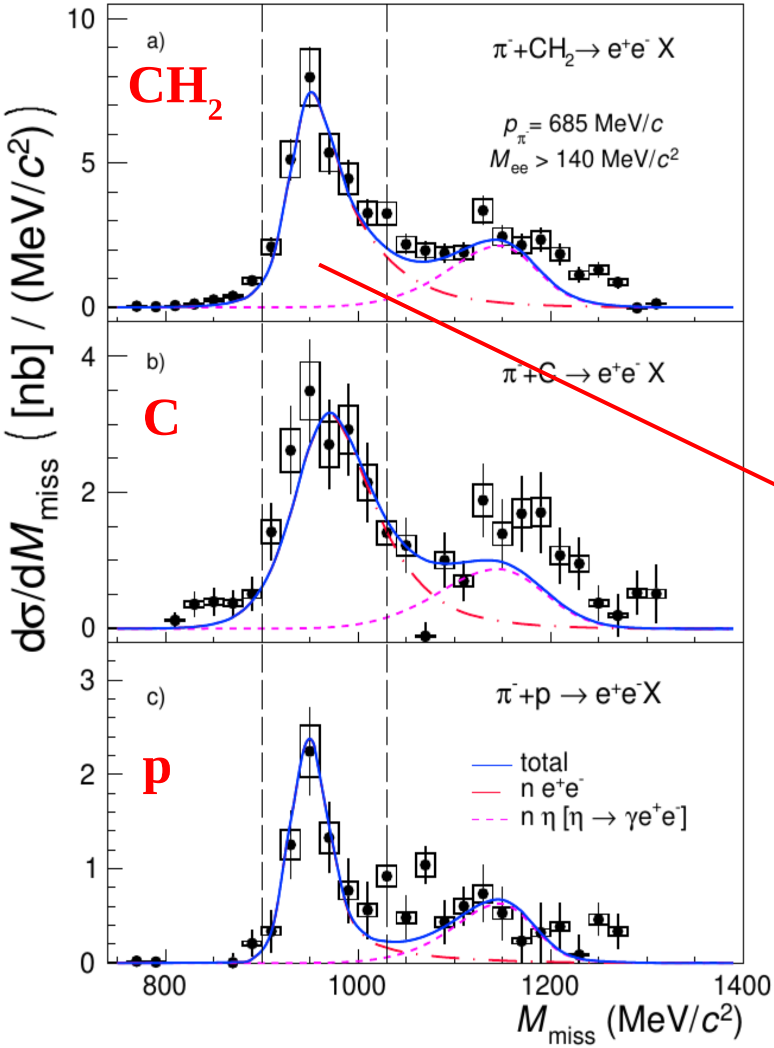


reference ρ mass spectrum for e+e- analysis

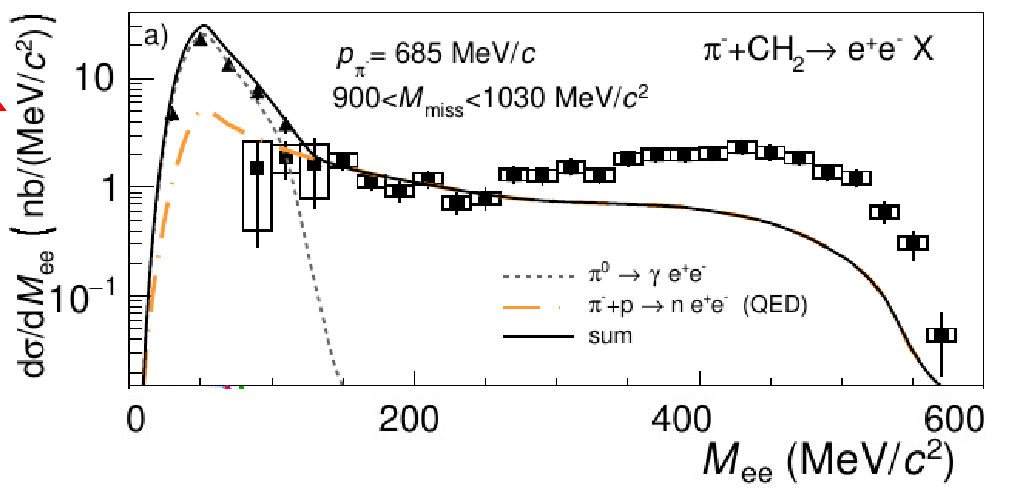
8 new entries: branching ratios of N(1440), N(1535), N(1520) to 2π channels (Δπ, Nρ, Nσ)

Selection of quasi-free $\pi^- p \rightarrow ne^+e^-$

HADES Coll. arXiv:2205.15914 [nucl-ex]
HADES Coll. arXiv:2309.13357 [nucl-ex]



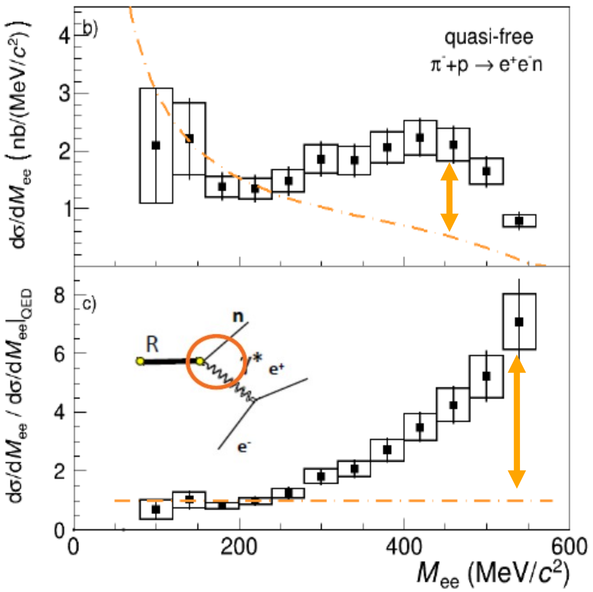
- cut on $invMe^+e^- > 140$ MeV (π^0 removed)
- selection of $\pi^- p \rightarrow ne^+e^-$ exclusive channel using **missing mass cut** (η removed)
- quasi-free treatment of π^-C interaction



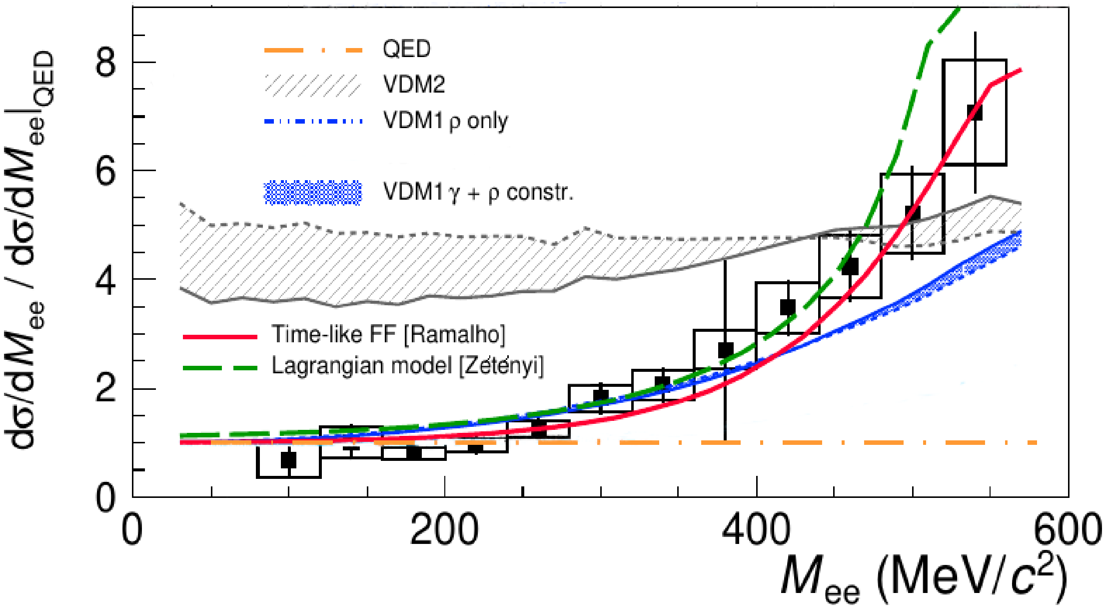
Effective time-like transition form factor

HADES Coll. arXiv:2205.15914 [nucl-ex]
HADES Coll. arXiv:2309.13357 [nucl-ex]

excess over point-like QED



- M_{ee} < 200 MeV/c² data consistent with **QED**
- strong excess at large M_{ee} (up to factor 5)



- **VMD2** (*strict* VMD) overestimates data below 400 MeV (used in HI transport models)
- 2-component VMD (VMD1) gives reasonable description
- Lagrangian model – very promising
- Time-like FF - dominant pion cloud contribution (pion emFF)

$$\Gamma_\rho^{VDM2} = \left(\frac{M_0}{M}\right)^3 \Gamma_\rho^0$$

$$\Gamma_\rho^{VDM1} = \left(\frac{M}{M_0}\right) \Gamma_\rho^0$$

Virtual photon polarization

E. Speranza et al. Phys. Lett. B764, 282 (2017)

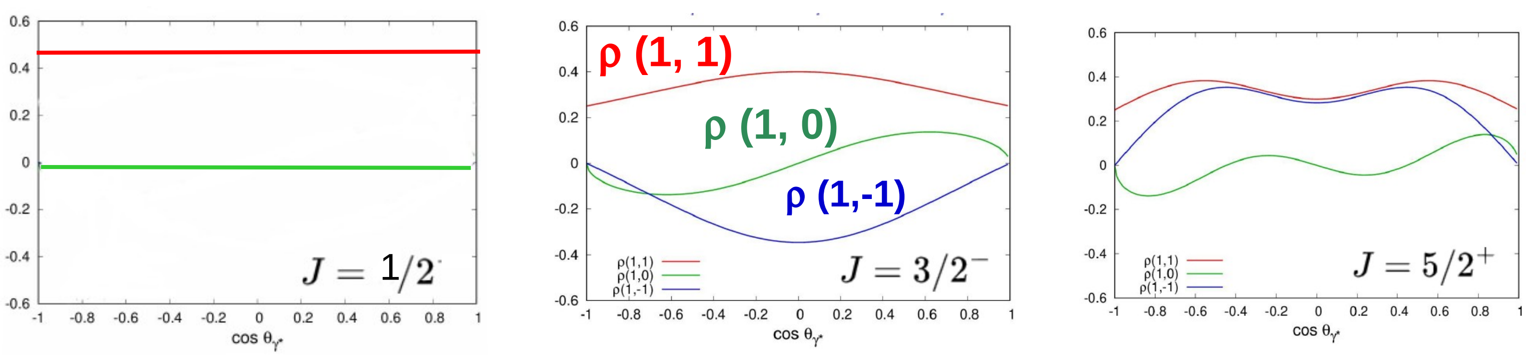
angular distribution of e+e- → polarization of γ* → spin density matrix elements

πN → Nγ* → Ne+e- $\frac{d^3\sigma}{dM_{ee}d\Omega_{\gamma_*}d\Omega_e} \sim |A|^2 = \frac{e^2}{Q^4}\sum_{\Lambda\Lambda'}\rho^{(H)}_{\Lambda\Lambda'}\rho^{(dec)}_{\Lambda\Lambda'}$ **QED: γ* → e+e-**

R → N + γ*

Angular distribution of the lepton pair:

$$|A|^2 \propto 8k^2\left[1-\rho_{11}+(3\rho_{11}-1)\cos^2\Theta+\sqrt{2}Re\rho_{10}\sin 2\Theta\cos\phi+Re\rho_{1-1}\sin^2\Theta\cos 2\phi\right]$$



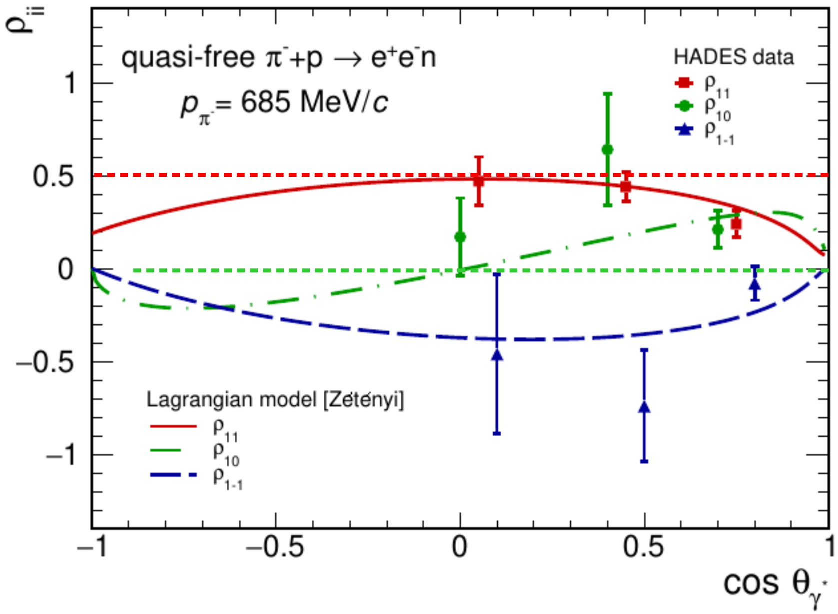
- ➔ $\rho_{\Lambda\Lambda}$ depends on γ* polarization
- ➔ $\rho_{\Lambda\Lambda}$ are combination of G_E, G_{M}, G_C
- ➔ **the angular distribution is sensitive to J^P of the resonance**
- ➔ can be obtain from fit to the experimental angular distribution

Virtual photon polarization

HADES Coll. arXiv:2205.15914 [nucl-ex]

$$|A|^2 \propto 8k^2\left[1-\rho_{11}+(3\rho_{11}-1)\cos^2\Theta+\sqrt{2}Re\rho_{10}\sin 2\Theta\cos\phi+Re\rho_{1-1}\sin^2\Theta\cos 2\phi\right]$$

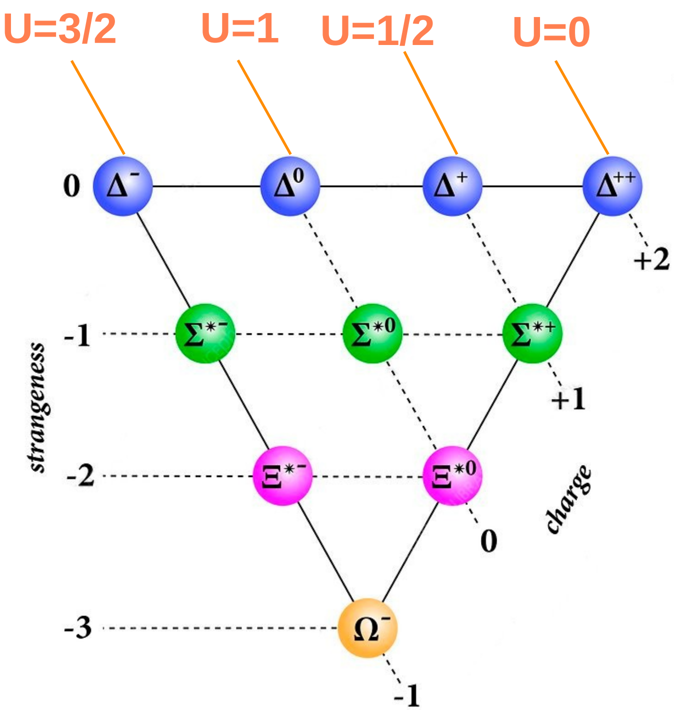
- **SDME ρ_{11}, ρ_{10}, ρ_{1-1} extracted from experiment taking into account acceptance and efficiency (A. Sarantsev) in 3 bins in cosθγ***



- ρ_{11}= 0.5, ρ_{10}= 0 for transverse polarization
- (real photon) => contribution from virtual photon
- angular dependence
- → contributions of spins larger than ½: N(1520) resonance
- **more precise data needed !**

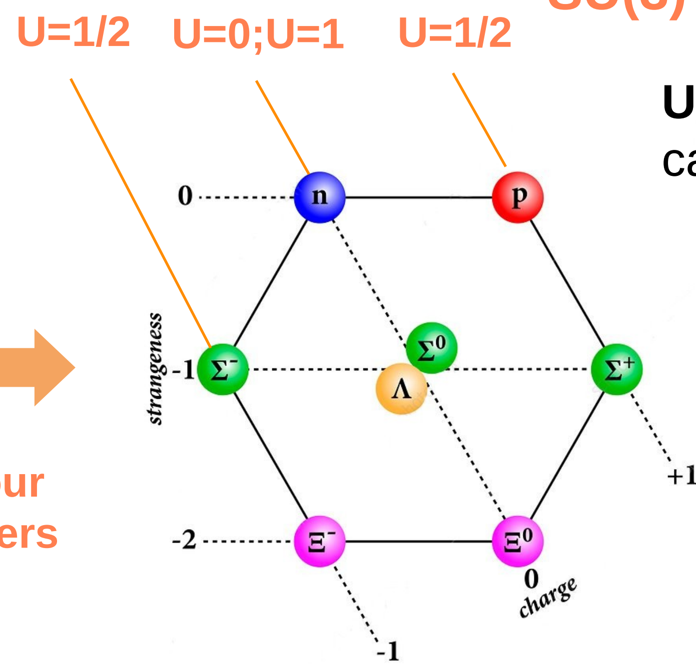
etFF of hyperons

$J^P=3/2^+$ decuplet



flavour partners

$J^P=1/2^+$ octet



SU(3) flavour sym.

U-spin states carry same charge

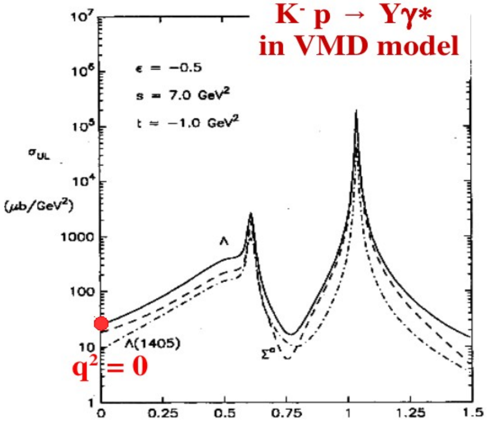
- Transitions **decuplet** ⟶ **octet** with conserved U-spin are allowed in SU(3)
- $\Sigma^*(1385) \rightarrow \Lambda\gamma^*$ ⟷ $\Delta(1232) \rightarrow N\gamma^*$
- $\Lambda(1520) \rightarrow \Lambda\gamma^*$ ⟷ $N^*(1520) \rightarrow N\gamma^*$

} strange *vs* non-strange baryons

G. Ramalho, K. Tsushima
Phys. Rev. D 87, 093011 (2013)

etFF of hyperons
model predictions for the Dalitz decay

R. Williams et. al. PRC48, 1381 (1993)

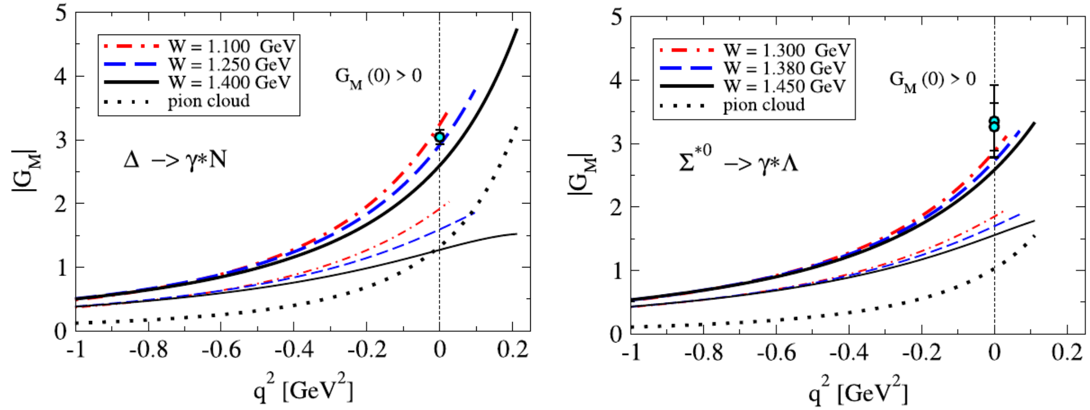


$q^2 = M^2(e+e-)$

VMD:
large effect of vector meson predicted

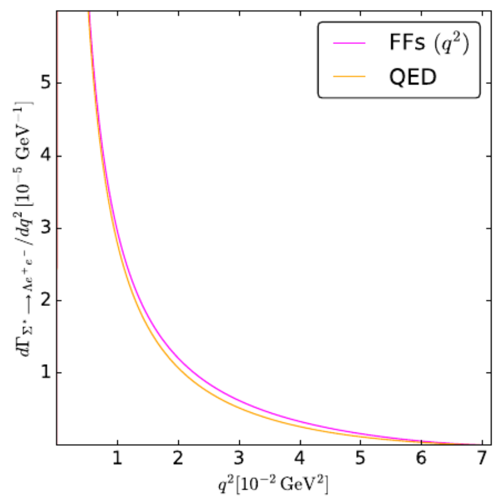
covariant spectator quark model (Σ*, Ξ*)

G. Ramalho, ***Phys. Rev. D 102, 054016 (2020)***



Dispersion theory

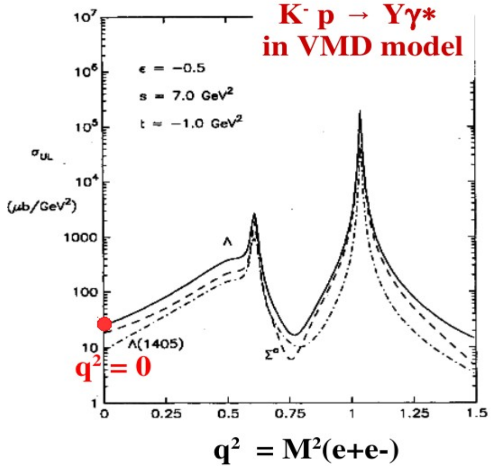
N. Salone, S. Leupold
Eur. Phys. J. A 57, 183 (2021)
O. Junker, S. Leupold et al.
Phys. Rev. C 101, 015206 (2020)



$\Sigma^* \to \Lambda e^+ e^-$

etFF of hyperons
model predictions for the Dalitz decay

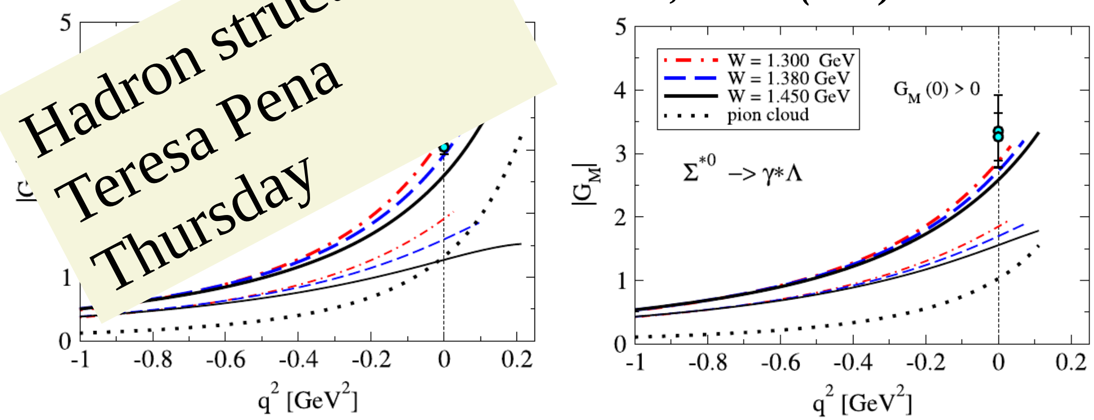
R. Williams et. al. PRC48, 1381 (1993)



VMD:
large effect of vector meson predicted

covariant spectator quark model (Σ*, Ξ*)

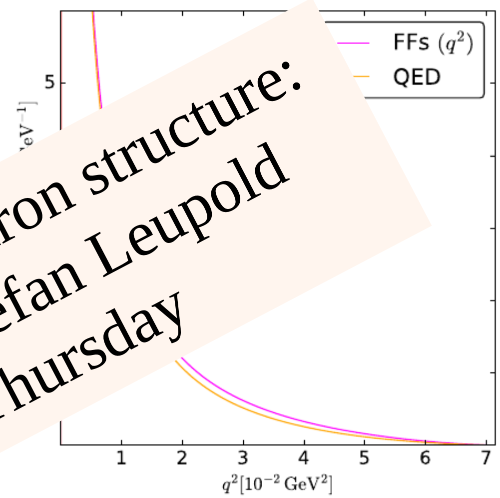
Rev. D 102, 054016 (2020)



Hadron structure:
Teresa Pena
Thursday

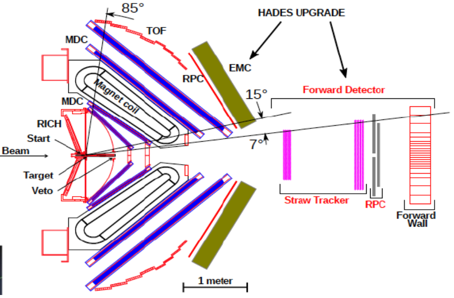
Dispersion theory

N. Salone, S. Leupold
Eur. Phys. J. A 57, 183 (2021)
O. Junker, S. Leupold et al.
Phys. Rev. C 101, 015206 (2020)



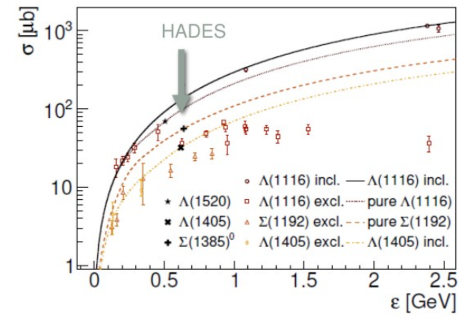
Hadron structure:
Stefan Leupold
Thursday

$\Sigma^* \to \Lambda e^+ e^-$



eTFF of hyperons with HADES
pp @ 4.5GeV

HADES: Eur. Phys. J. A57, 138 (2021)

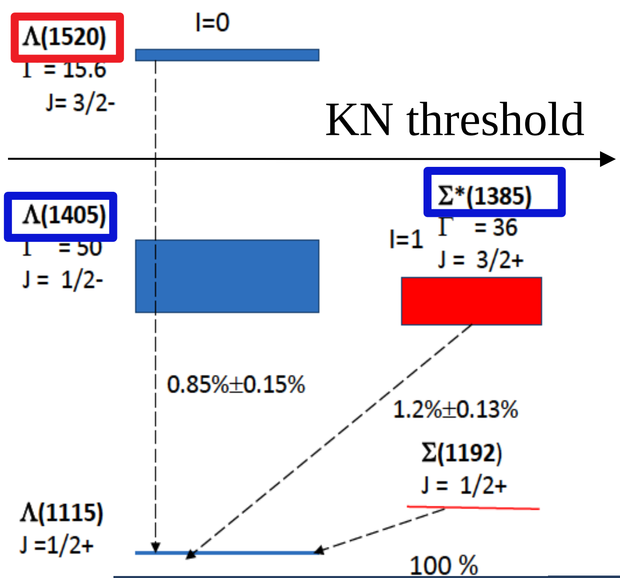


February 2022: beam time at SIS18 FAIR-Phase0

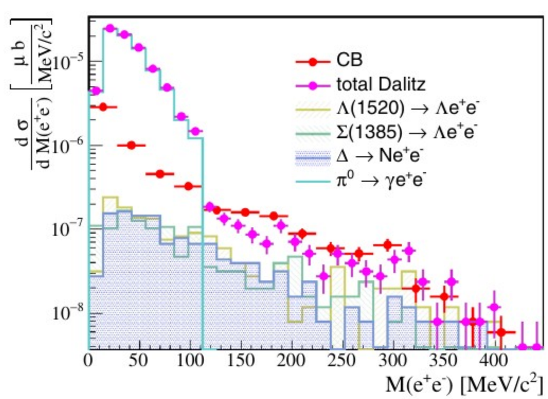
- Λ(1405), Λ(1520), Ξ production cross sec., decays,...
- Σ, Λ(1405), Λ(1520) **Dalitz decays** → attempt to measure upper limits of branching ratios (obtained luminosity L~6 pb^{-1})
- the BR important information for future measurement **@CBM** and other hyperon factories
- information on hyperon structure, role of pion/kaon cloud

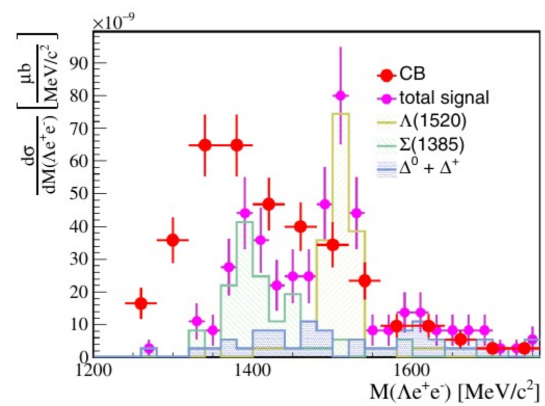
CBM@ SIS100 pp @ 30 GeV

- prod. cross sec. higher than at SIS18: σ (Σ*,Λ*) ~1 mb
- much higher luminosity



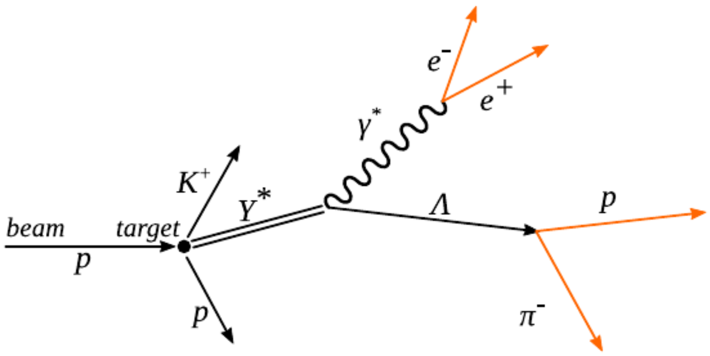
simulations with assumed L~ 11 pb^{-1}





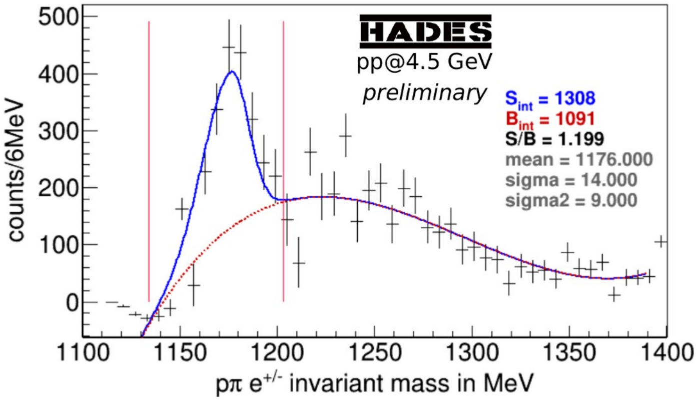
eTFF of hyperons with HADES
pp @ 4.5GeV

HADES: Eur. Phys. J. A57, 138 (2021)



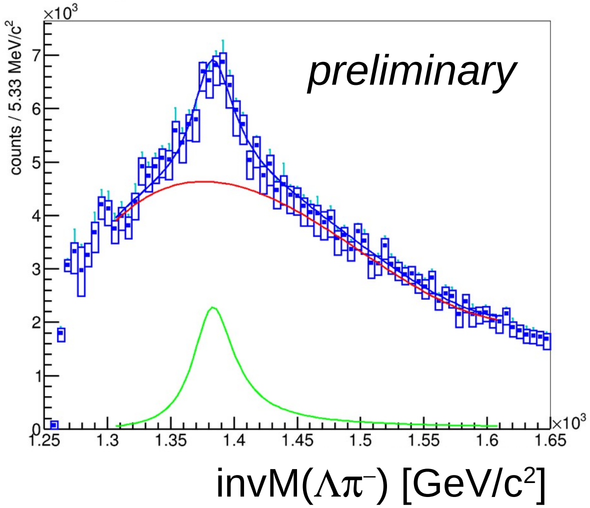
Jana Riger, *PhD*

$\Sigma^0(1192) \rightarrow \Lambda\gamma^*$ Dalitz decay

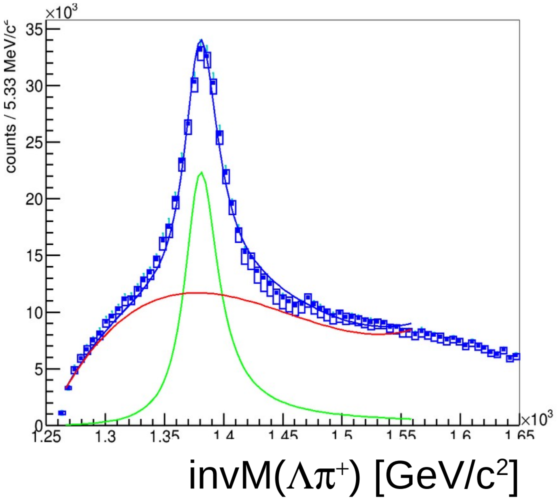


Konrad Sumara, *PhD*

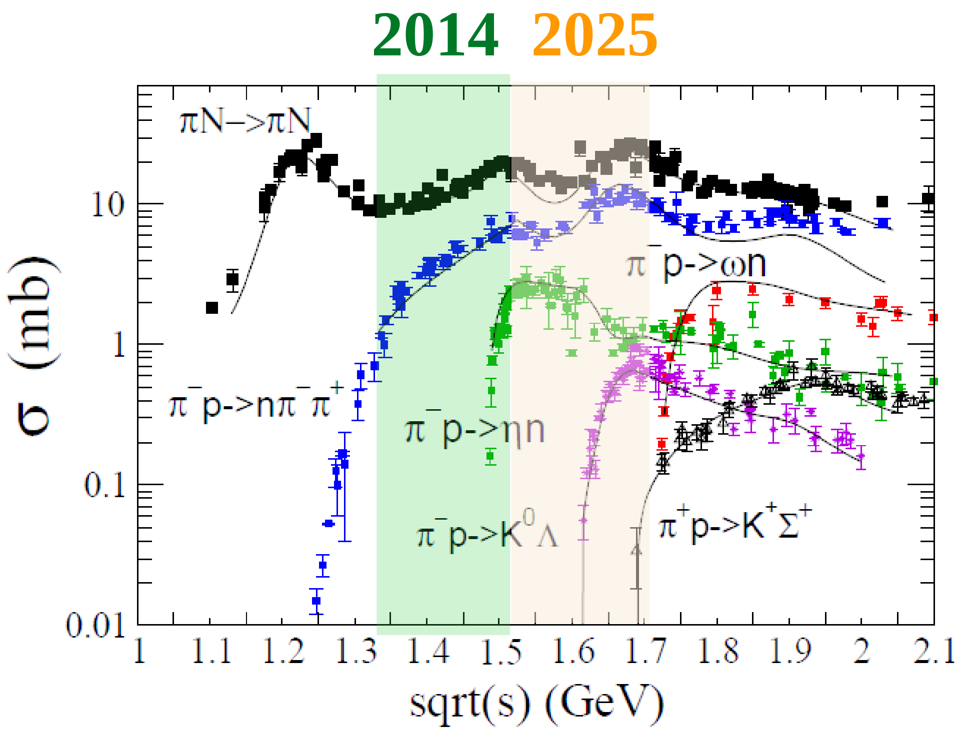
$\Sigma^{*-}(1385) \rightarrow \Lambda\pi^-$



$\Sigma^{*+}(1385) \rightarrow \Lambda\pi^+$



OUTLOOK
HADES Physics Program with Pion Beams
explore the 3rd resonance region $\sqrt{s} = 1.7$ GeV/c²



High statistics beam energy scan: continuation and extension to 3rd resonance region

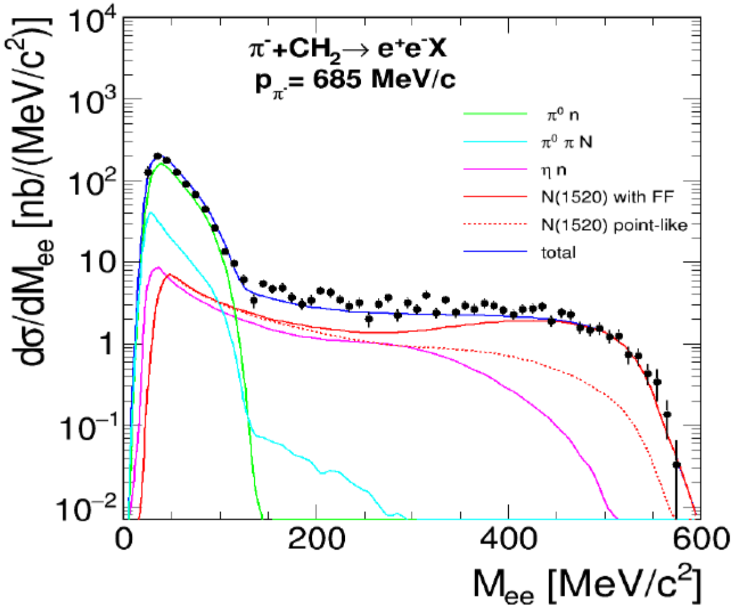
1) **Baryon-meson couplings:**
   - → ππN, ωn, ηn, $K^0\Lambda$, $K^0\Sigma$, … including neutral mesons (ECAL),
   - → ρR couplings S31(1620), D33(1700), P13(1720),..
2) **Time-like em. baryon transitions**
   - → $\pi^- p$ → ne+e-,
   - → test of VMD for ρ and ω,
   - → spin-density matrix elements,
3) **Cold nuclear matter studies:**
   - → ω absorption
   - → ρ spectral function
   - → strangeness production

Summary

- HADES & **pion beam** is an unique tool to understand in details baryon-ρ couplings:
  → significant off-shell contribution originating from N(1520)D_{13} shown by combined PWA (D_{13}(1520) coupling to ρ-N: 12+/-2 %),
  → improved knowledge of baryon resonances- meson (ρ) couplings (new BR measurements),
  → very new information on electromagnetic baryon transitions in the time-like region,
- First test of Vector Dominance Model below 2π threshold and time-like electromagnetic transition form factor models
  → important inputs for medium effects of ρ meson calculations
- Studies of etFF of hyperons in pp@ 4.5 GeV.
- Proposal for pion beam experiment in 2025 in the third resonance region.
- Studies of hyperon structure @CBM.

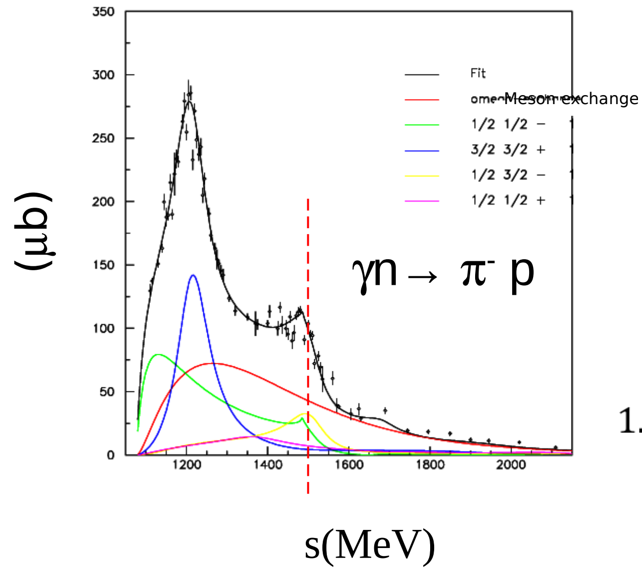
Thank You for Your Attention !

Inclusive e+e- cocktail
Fixing cocktail ingredients



$\pi^- p \to n\pi^0$ [9 mb] (SAID)
$\pi^- p \to n\pi^0\pi^0$ [1.9 mb] (L.-B.)
$\pi^- p \to p\pi^0\pi^-$ [4.0 mb] (L.-B.)
$\pi^- p \to n\eta$ [0.83 mb] Arndt et al., PRC**72** (2005) 045202

Dalitz Decay BR
π^0: 0.012
η: 0.006

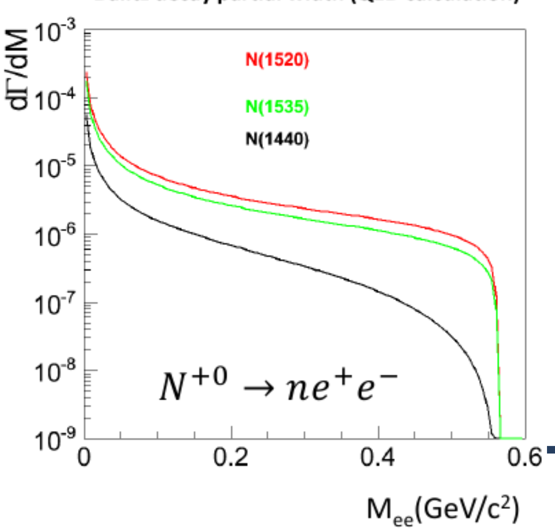


Bonn-Gatchina PWA

N(1520) to π^-p→γn: 21%
N(1535) to π^-p→γn: 15%

$$\sigma(\pi^- p \to n e^+ e^-) \sim$$
$$1.35\ \alpha\ \sigma(\pi^- p \to n\gamma) = 2\ \mu b$$

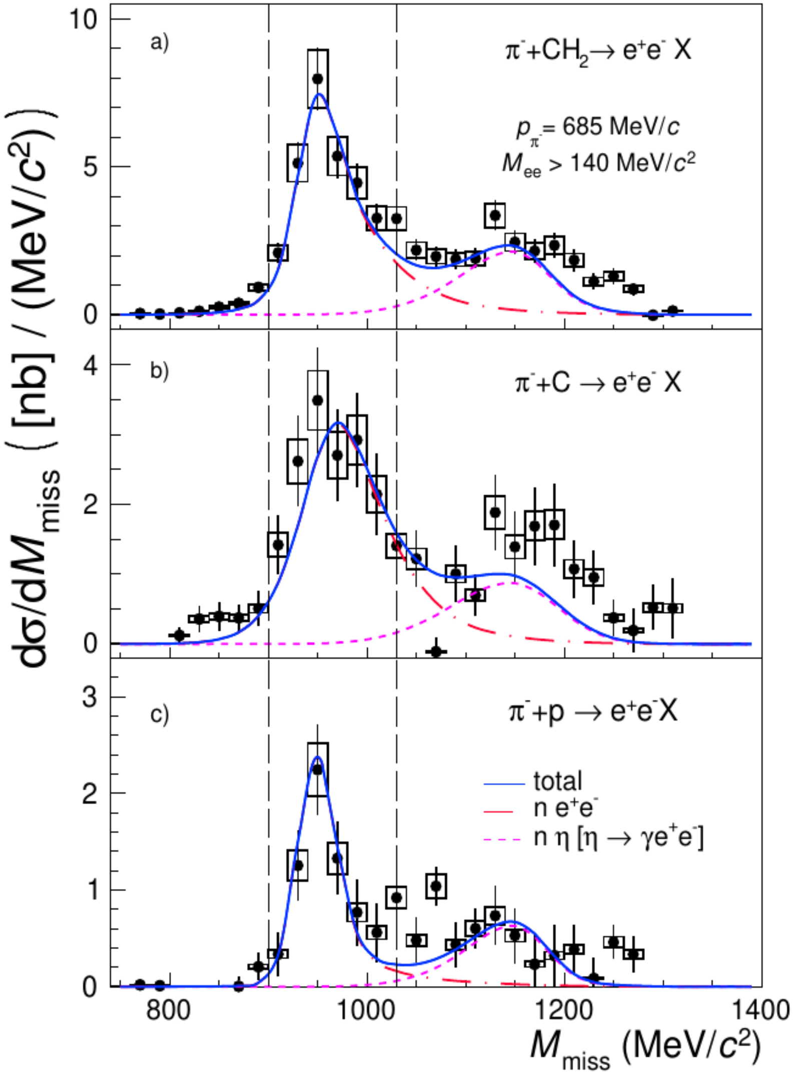
Dalitz decay partial width (QED calculation)



input for $\pi^- p \to \gamma^*(e^+e^-)n$
QED Dalitz decay contribution

Selection of quasi-free $\pi^- p \rightarrow ne^+e^-$

HADES coll. arXiv:2205.15914 [nucl-ex]



- cut on **invMe$^+$e$^-$** >140 MeV (above π^0 mass)
- missing mass cut on $\mathbf{M_{miss}}$ (η removed)

- **π^-C** simulations using Pluto (qfs participant-spectator model)
- production cross sec. on C for: π^0, η, ρ, γ deduced from the scaling: $R_{C/H} = \sigma_C/\sigma_H$

- **CH_2** target:

$$\left(\frac{d\sigma}{dM_{ee}}\right)_{CH_2} = \left(\frac{d\sigma}{dM_{ee}}\right)_C + 2\left(\frac{d\sigma}{dM_{ee}}\right)_H$$

PDG Verification

ρN coupling not present in PDG since 2016

$\Gamma(\,N(1520) \to \Delta(1232)\pi\,,\, S\!-\!wave)/\Gamma_{total}$

VALUE (%)	DOCUMENT ID
12.1 ± 2.1	ADAMCZEWSKI- 2020

$\Gamma(\,N(1520) \to \Delta(1232)\pi\,,\, D\!-\!wave)/\Gamma_{total}$

VALUE (%)	DOCUMENT ID
6 ± 2	ADAMCZEWSKI- 2020

$\Gamma(\,N(1520) \to N\rho\,,\, S{=}3/2\,,\, S\!-\!wave)/\Gamma_{total}$

VALUE (%)	DOCUMENT ID
11.8 ± 1.9	ADAMCZEWSKI- 2020

$\Gamma(\,N(1520) \to N\rho\,,\, S{=}1/2\,,\, D\!-\!wave)/\Gamma_{total}$

VALUE (%)	DOCUMENT ID
0.4 ± 0.2	ADAMCZEWSKI- 2020

$\Gamma(\,N(1520) \to N\sigma\,)/\Gamma_{total}$

VALUE (%)	DOCUMENT ID
7 ± 3	ADAMCZEWSKI- 2020

$\Gamma(\,N(1535) \to \Delta(1232)\pi\,,\, D\!-\!wave)/\Gamma_{total}$

VALUE (%)	DOCUMENT ID
3 ± 1	ADAMCZEWSKI- 2020

$\Gamma(\,N(1535) \to N\rho\,,\, S = 1/2)/\Gamma_{total}$

VALUE (%)	DOCUMENT ID
2.7 ± 0.6	ADAMCZEWSKI- 2020

$\Gamma(\,N(1535) \to N\rho\,,\, S{=}3/2\,,\, D\!-\!wave)/\Gamma_{total}$

VALUE (%)	DOCUMENT ID
0.5 ± 0.5	ADAMCZEWSKI- 2020