



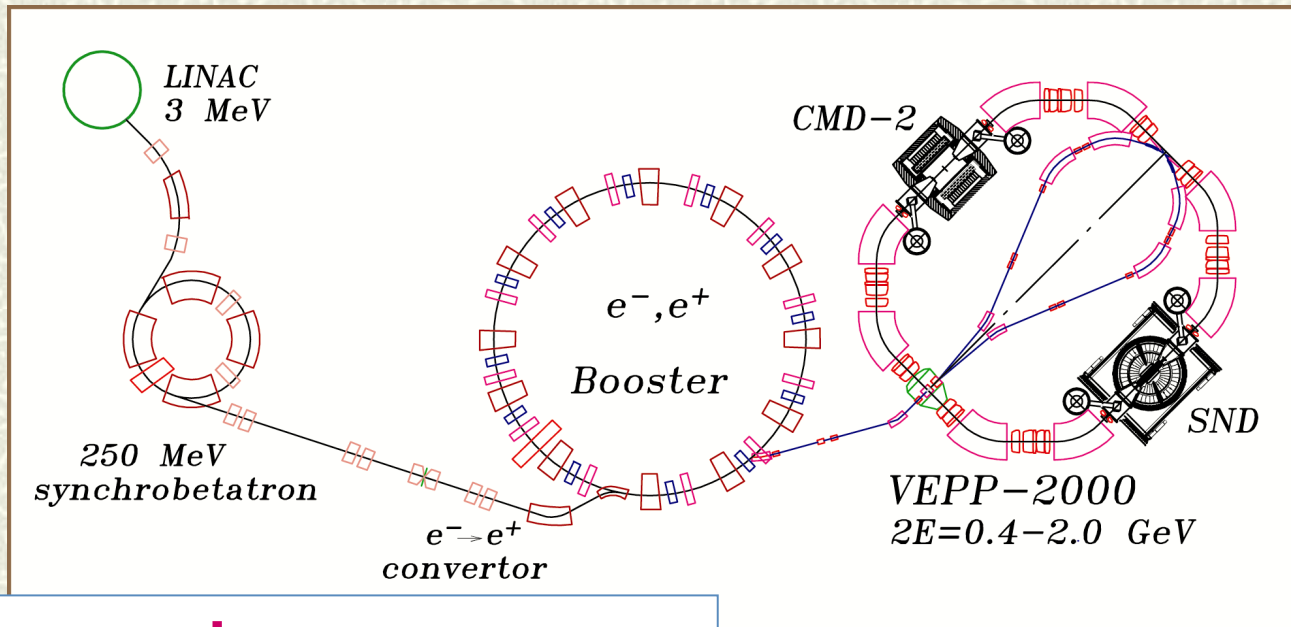
# **First SND detector results on hadron cross sections at VEPP-2000 $e^+e^-$ - collider**

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On behalf of SND  
group**

**Novosibirsk**



# VEPP-2000 Collider



## Main parameters:

- collision time – 82 ns
- beam current – 0.2 A
- bunch length – 3.3 cm
- perimeter – 24.4 m
- Energy spread – 0.7 MeV
- $\beta_x \approx \beta_z = 6.3$  cm
- $L \approx 1 \cdot 10^{32}$  (2E=2.0 GeV)
- $L = 10^{31} \text{ cm}^{-2} \text{ c}^{-1}$  (2E=1.0 GeV) 2011

## Achieved (2011):

$L \sim 0.8 \cdot 10^{31} \text{ cm}^{-2} \text{ c}^{-1}$  (2E=1.0 GeV)

$L \sim 2 \cdot 10^{31} \text{ cm}^{-2} \text{ c}^{-1}$  (2E=2.0 GeV)

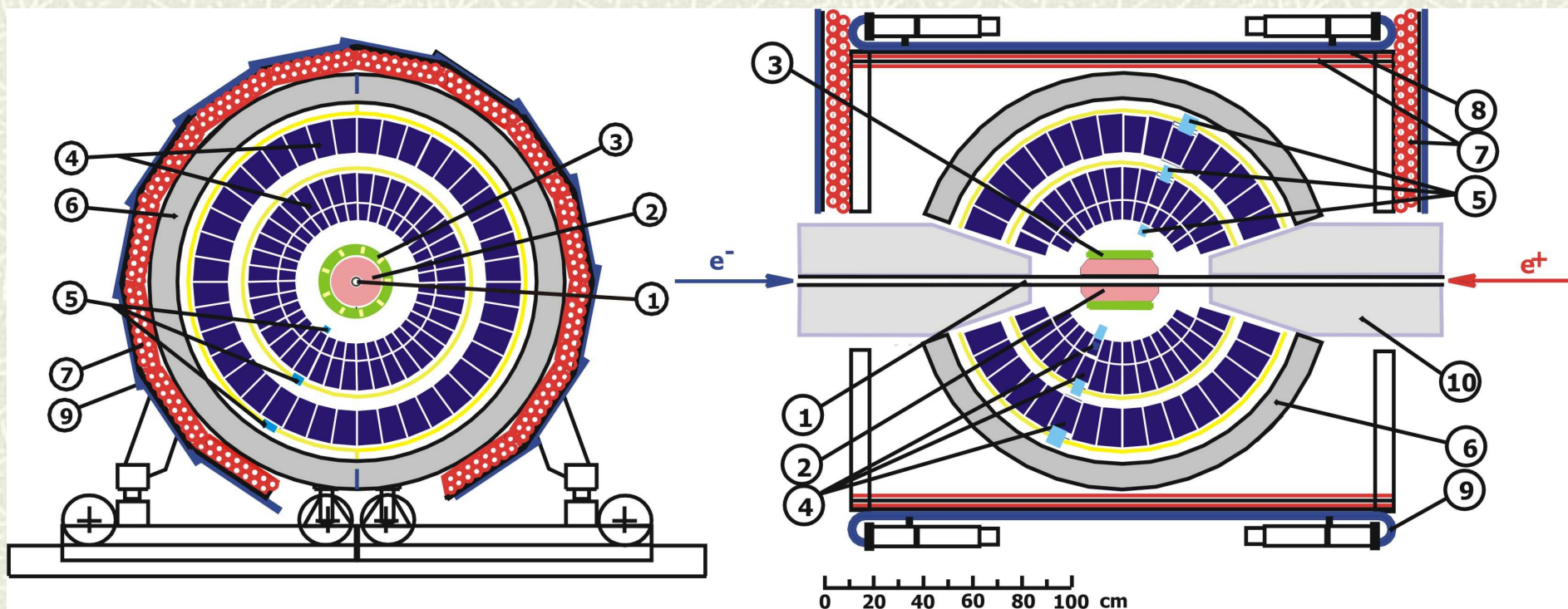
designed

$\Delta L(1 \text{ y}) = 1 \text{ fb}^{-1}$ .



# SND for VEPP-2000

NIM A449 (2000) 125-139



1 – beam pipe, 2 – tracking system, 3 – aerogel cherenkov counter , 4 – NaI(Tl) crystals, 5 – phototriodes, 6 – iron muon absorber, 7–9 – muon detector, 10 – focusing solenoids.





# SND general parameters

## Calorimeter:

1632 NaI(Tl) crystals

VPT reading

13.5 X0

solid angle - 90% from  $4\pi$

$$\Delta\phi \times \Delta\theta = 9^\circ \times 9^\circ$$

## Tracking system:

9-layer cylindrical drift chamber  
with 24-jet type cells

solid angle - 94% from  $4\pi$

90% Ar + 10% CO<sub>2</sub> gas mixture

particle identification at  $p < 300$

MeV/c using dE/dx

## Energy resolution:

$$\frac{\sigma_E}{E} = \frac{4.2\%}{\sqrt[4]{E(\text{GeV})}}$$

## Angular resolution:

$$\sigma_\phi = \frac{0.82^\circ}{\sqrt{E(\text{GeV})}} \oplus 0.63^\circ$$

## Angular resolution:

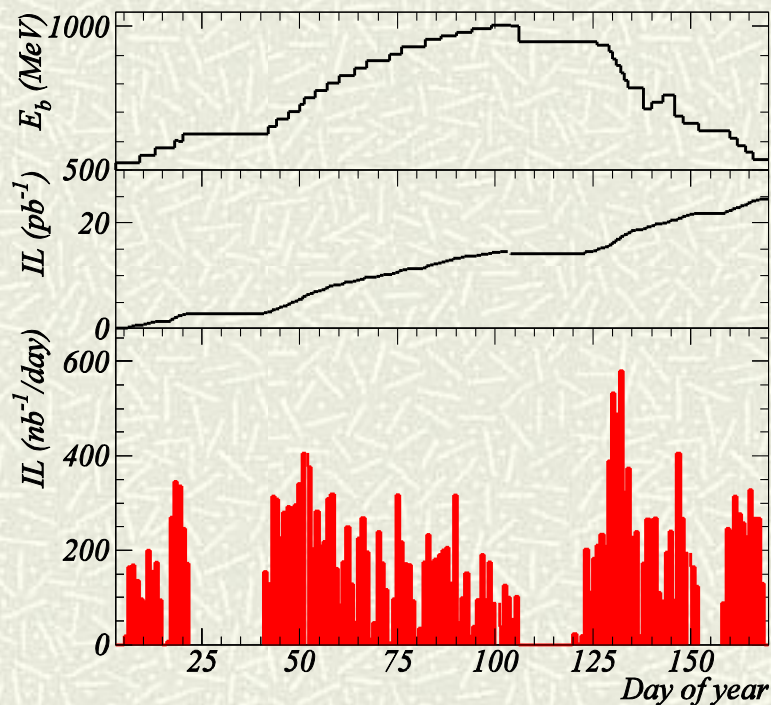
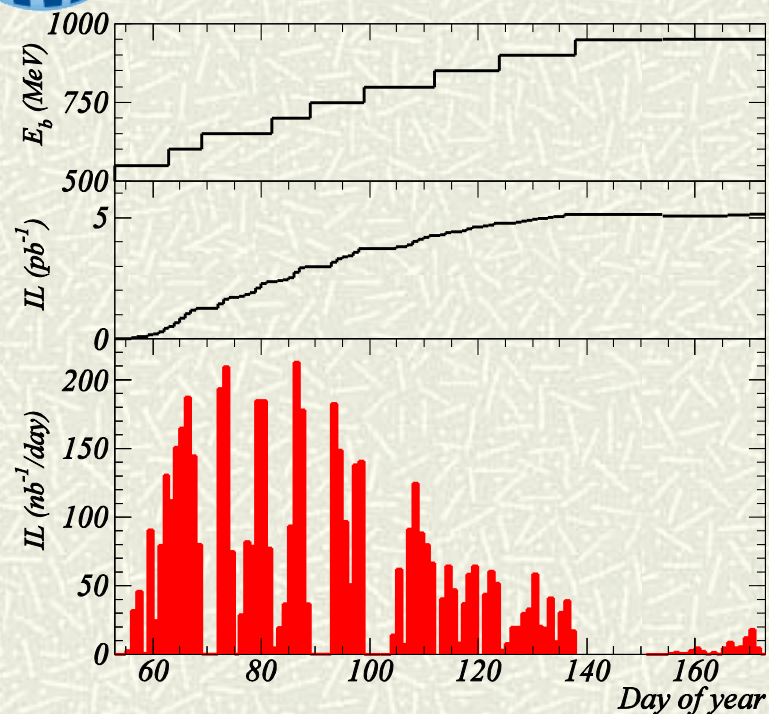
$$\sigma_\phi = 0.55^\circ \quad \sigma_\theta = 1.2^\circ$$

## Spacial resolution:

$$\sigma_R = 0.12\text{cm} \quad \sigma_z = 0.45\text{cm}$$



# Experiments 2010 and 2011



	Energy Region, GeV	Energy step, MeV	Integrated luminosity, $\text{pb}^{-1}$
scan2010	1.1-1.9	100	5
scan2011	1.05-2.0	25	25



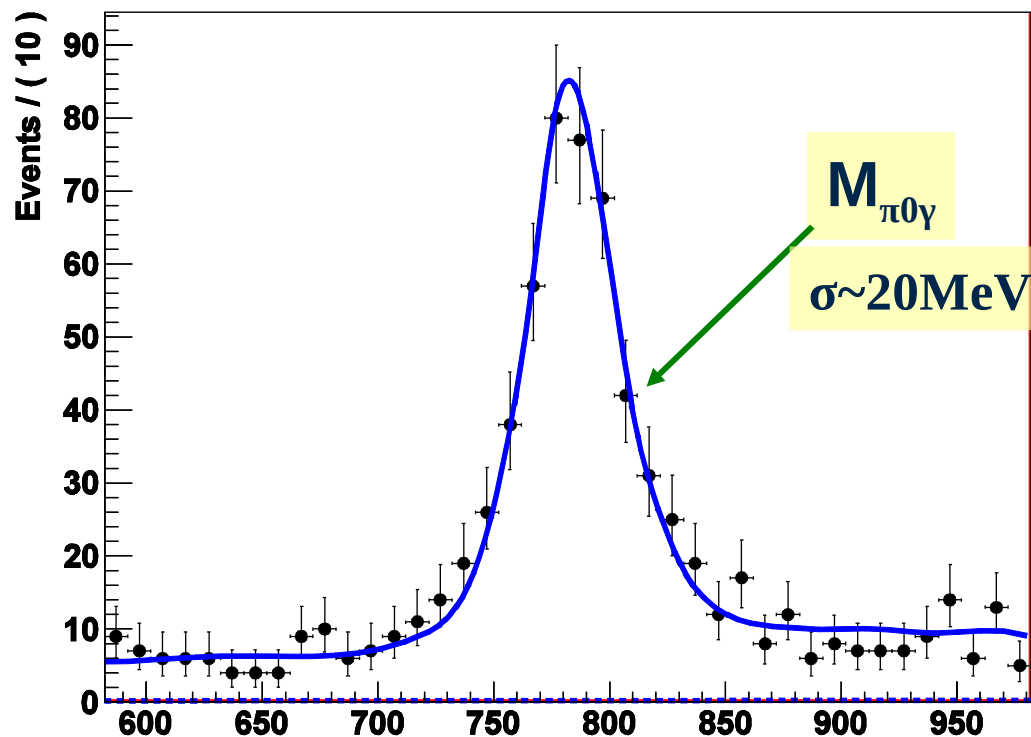
# VEPP-2000 Physical program

- ◆ 1. Precise measurement of the quantity
$$R = \sigma(e^+e^- \rightarrow \text{hadrons}) / \sigma(e^+e^- \rightarrow \mu^+\mu^-)$$
- ◆ 2. Cross section measurements of the processes of  $e^+e^-$  -annihilation into hadrons:  $e^+e^- \rightarrow 2h, 3h, 4h \dots, h = \pi, K, \eta, \dots$
- ◆ 3. Study of 'excited' vector mesons:  $\rho', \rho'', \omega', \omega'', \phi', \dots$
- ◆ 4. CVC tests: comparison of  $e^+e^- \rightarrow \text{hadrons}$  cross section with  $\tau \rightarrow \nu_\tau + \text{hadrons}$  decay spectra
- ◆ 5. Study of nucleon - antinucleon pair production  $e^+e^- \rightarrow n\bar{n}, p\bar{p}$  and nucleon electromagnetic form factors, search for NNbar resonances.
- ◆ 6. Hadron production in 'radiative return' (ISR) processes:
$$e^+e^- \rightarrow \gamma^* \gamma, \gamma^* \rightarrow \text{hadrons}$$
- ◆ 7. Two photon physics  $e^+e^- \rightarrow e^+e^- + \text{hadrons}$
- ◆ 8. Test of high order QED  $2 \rightarrow 4, 5$





# Process $e^+e^- \rightarrow \omega\pi^0 \rightarrow \pi^0\pi^0\gamma$



## Cuts:

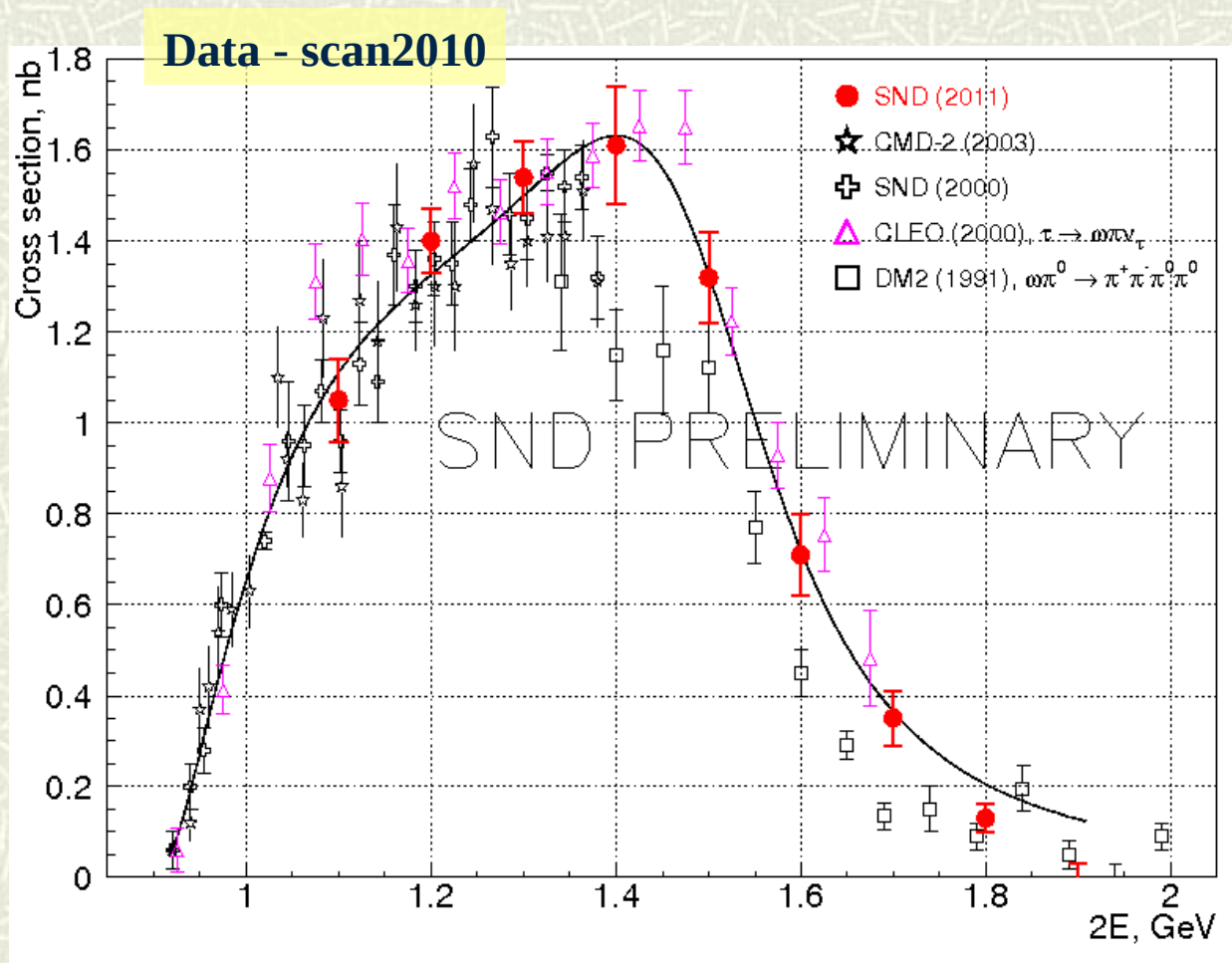
- at least 5 $\gamma$
- no charged particles
- total energy depos.  $> E_{\text{beam}}$
- kinemat. reconstruction:  
 $\chi^2_{5\gamma} < 30$ ;  $\chi^2_{\pi^0\pi^0\gamma} - \chi^2_{5\gamma} < 10$ ;  
 $|M_{\pi^0\gamma} - M_{\omega}| < 100 \text{ MeV}$

## Fitting:

sum of  $\rho(770)$  and  $\rho(1450)$



# Process $e^+e^- \rightarrow \omega\pi^0 \rightarrow \pi^0\pi^0\gamma$



## Cuts:

- at least  $5\gamma$
- no charged particles
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 $|M_{\pi^0\gamma} - M_\omega| < 100 \text{ MeV}$

## Fitting:

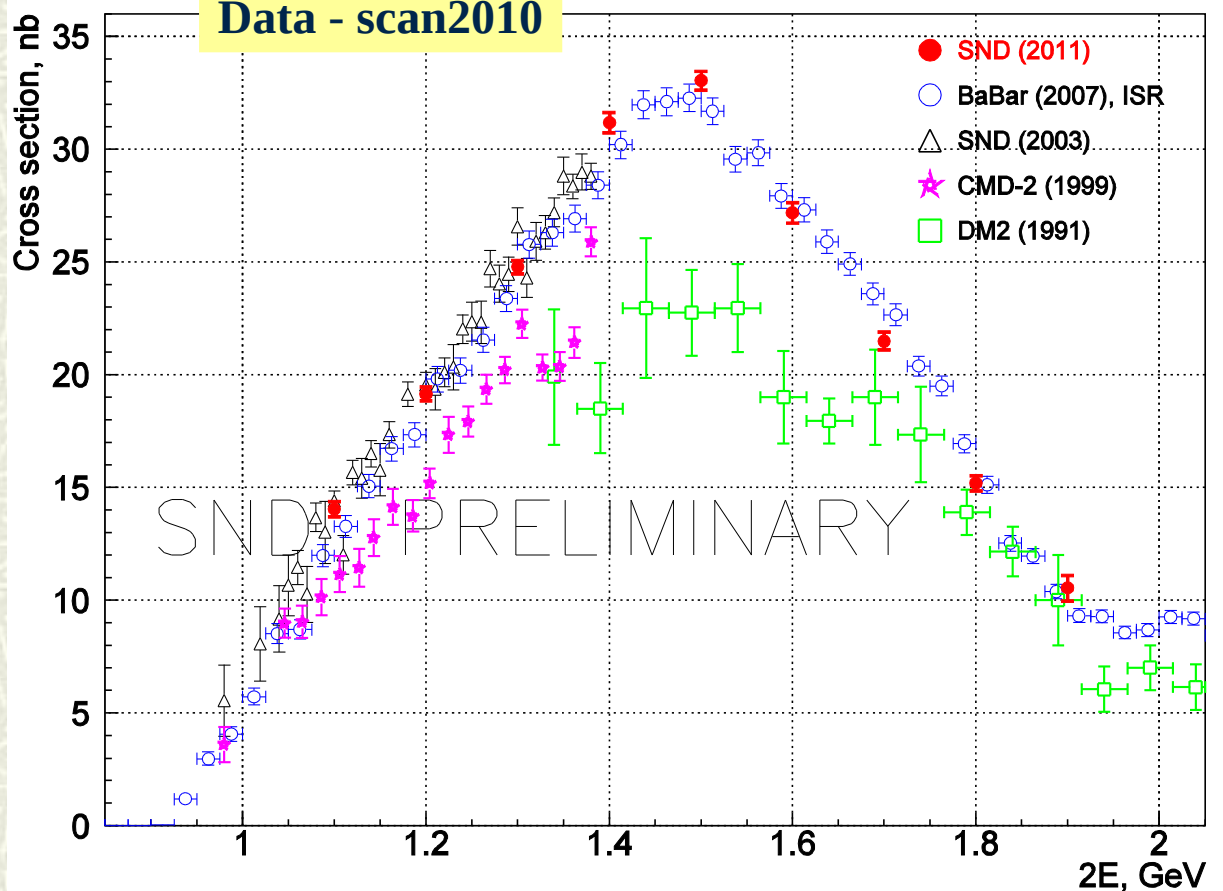
sum of  $\rho(770)$  and  $\rho(1450)$





# Process $e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0$

Data - scan2010



Only statistical errors

**Cuts:**

- at least 2 charged particles and 4 photons
  - 2 tracks are central
- kinematic reconstruction:

$$\chi^2 < 40;$$

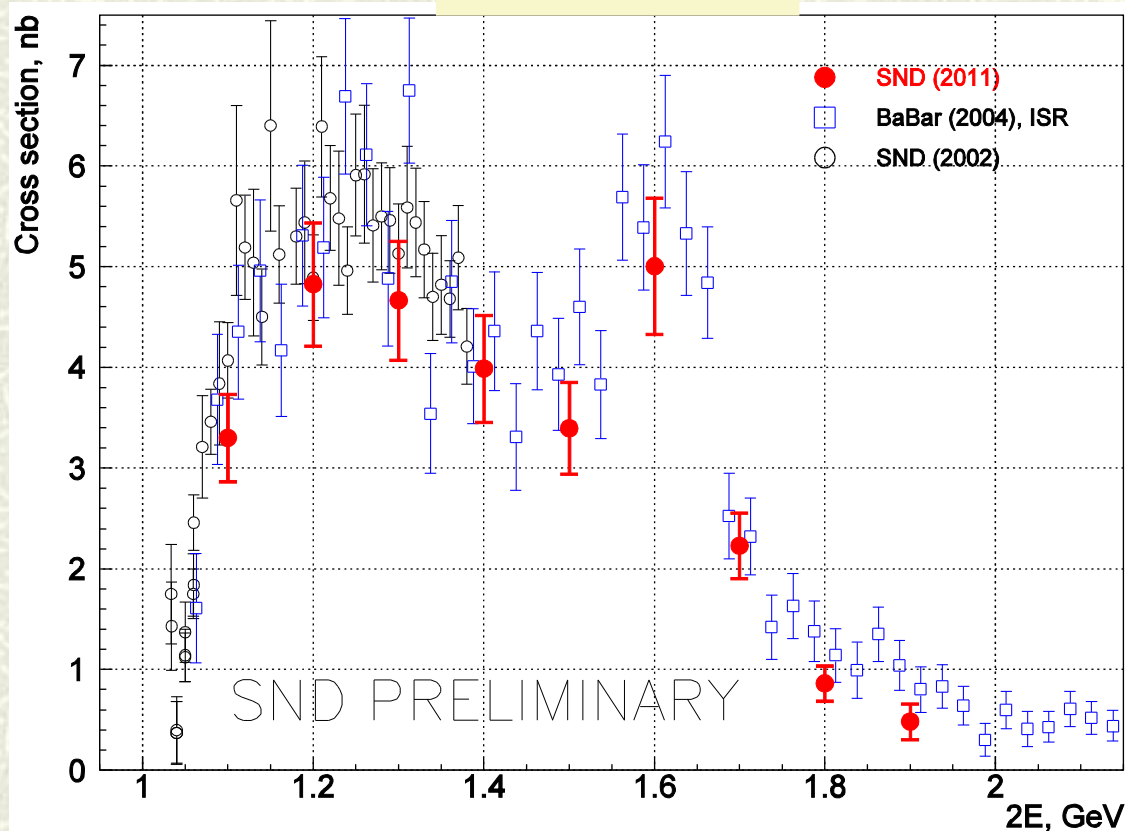
$$M_{\pi^0} \text{ in } 70\text{-}200 \text{ MeV}$$

The bump is a sum of contributions from  $\rho(770)$ ,  $\rho(1450)$  and  $\rho(1700)$  decays



# Process $e^+e^- \rightarrow \pi^+\pi^-\pi^0$

Data - scan2010



## Cuts:

– at least 2 central charged particles

– 2 or 3  $\gamma$

–  $\Delta\varphi_{\text{ch.part.}} > 10^\circ$

–  $\Delta\Omega_{\text{ch.part.}} > 40^\circ$

En.depos. of ch.part.  $< E_{\text{beam}}$

Total en.depos. –  $(0.3-0.8)E_{\text{beam}}$

Kinematic reconstruction:

interaction point -  $\chi^2_r < 40$ ;

$\pi^+\pi^-\gamma\gamma$  -  $\chi^2 < 30$ ;

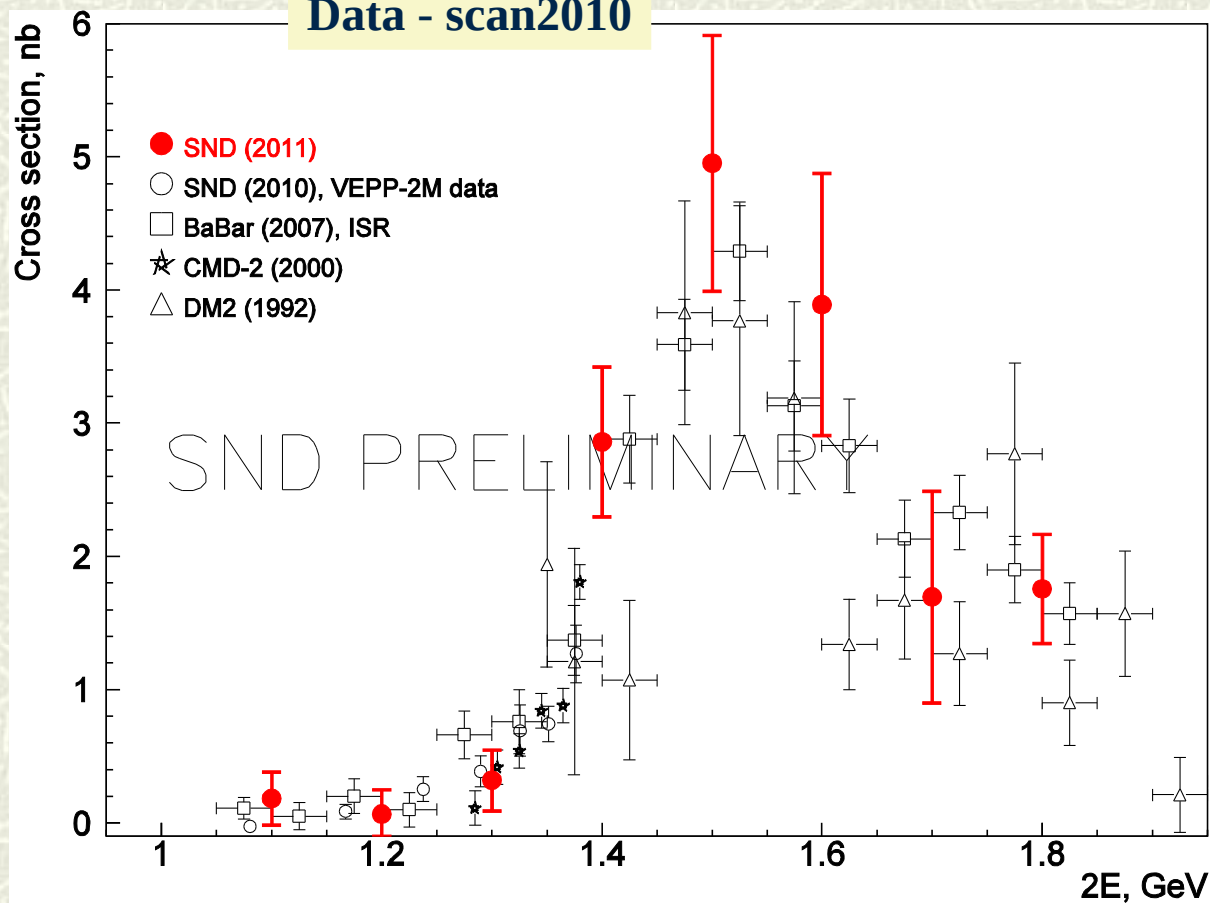
Fitting of  $M_{\pi^0}$

(effect+background)



# Process $e^+e^- \rightarrow \eta\pi^+\pi^-$

Data - scan2010



## Cuts:

- 2 central charged particles
- 2 photons
- $\theta_{\text{charged}}$  ( $22.5^\circ$ - $157.5^\circ$ )
- $\theta_{\text{photon}}$  ( $36^\circ$ - $144^\circ$ )
- kinematic reconstruction
- $(\pi^+\pi^-\gamma\gamma): \chi^2 < 20$

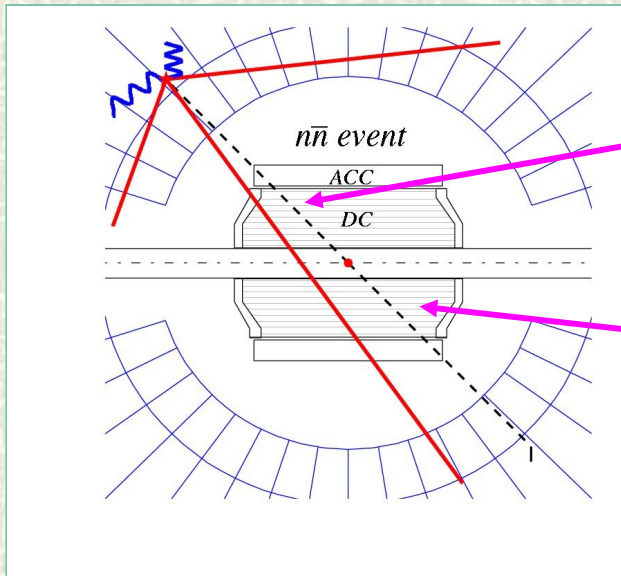




# Process $e^+e^- \rightarrow n\bar{n}$ (I)

## Picture of expected event

Cuts:



$\bar{n}$

$n$

- no central charged tracks
- no collinear clusters in calorimeter
- no signals in muon system
- signals in 3 calorimeter layers
- crystals in calorimeter are not located along one line
- no events with main en.dep. on small angles ( $\theta < 36^\circ$  or  $\theta > 144^\circ$ ) and full pulse in calorimeter directed into small angles
- limitations on cluster quality and total pulse in calorimeter
- total en.dep in the range 1.0-1.8GeV
- cosmic suppression using event time

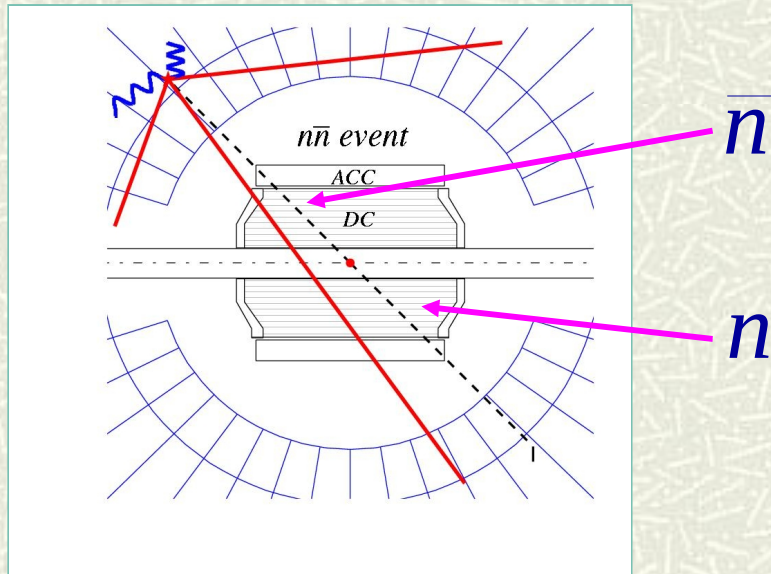
### Events features:

- No signal from  $n$
- “star” from annihilation point of  $\bar{n}$  in Cherenkov counters or calorimeter



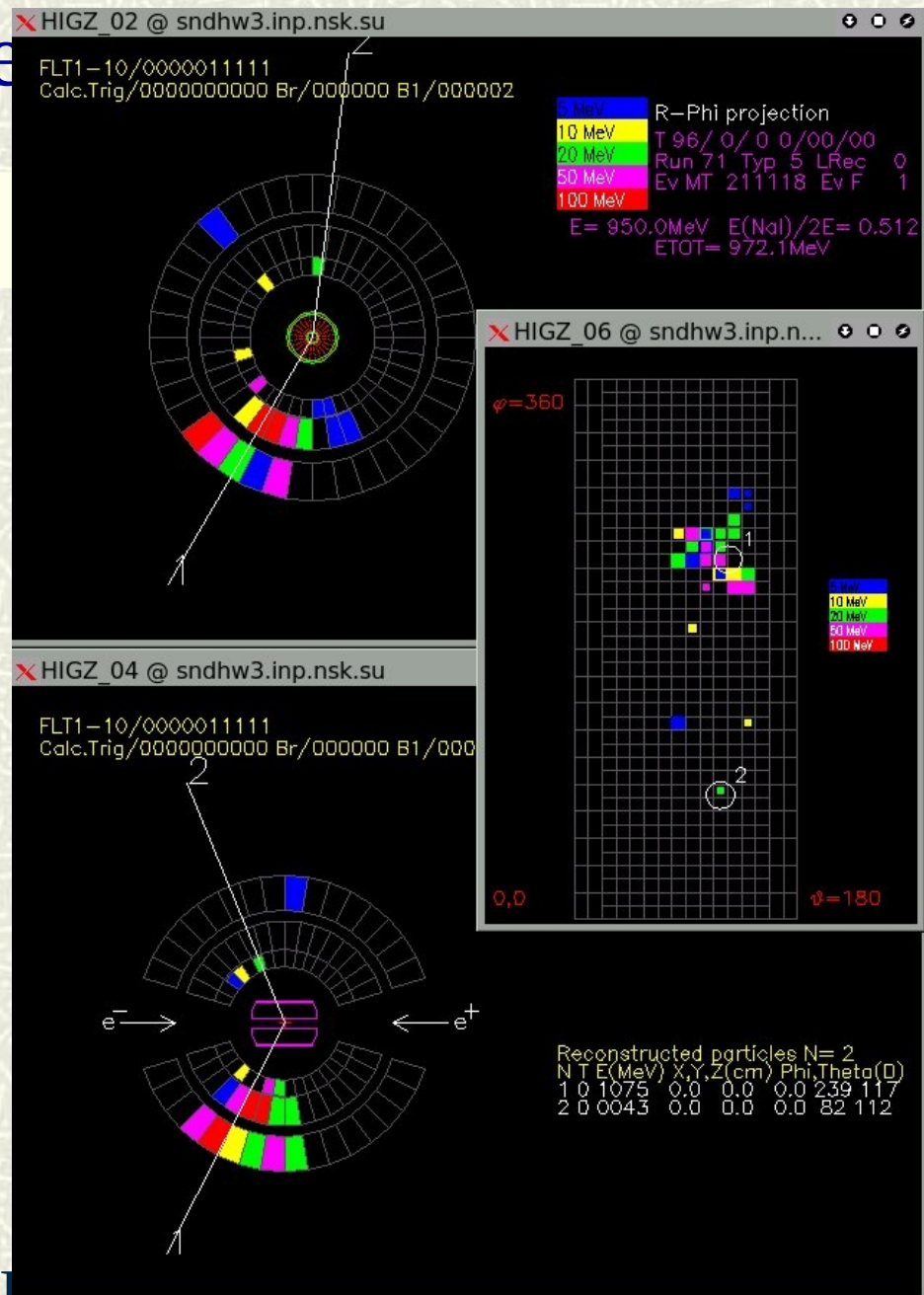
# Process e

## Picture of expected event



### Events features:

- No signal from  $n$
- “star” from annihilation point of  $\bar{n}$  in Cherenkov counters or calorimeter

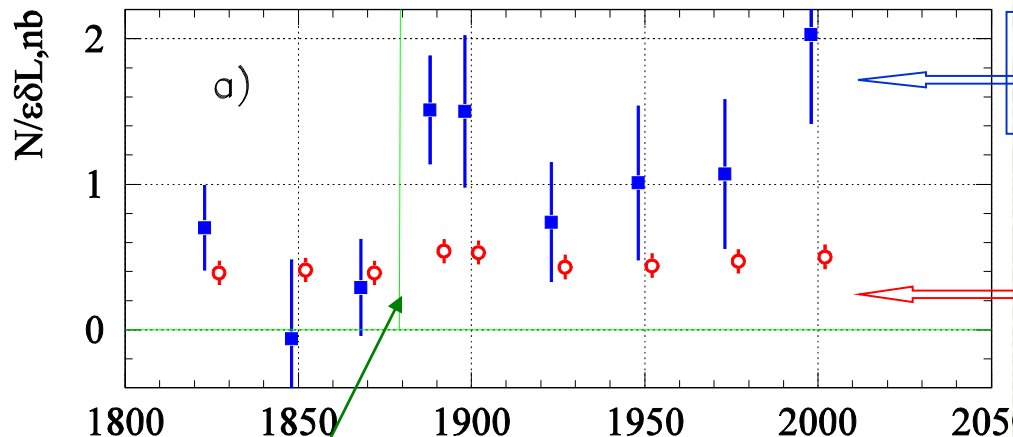






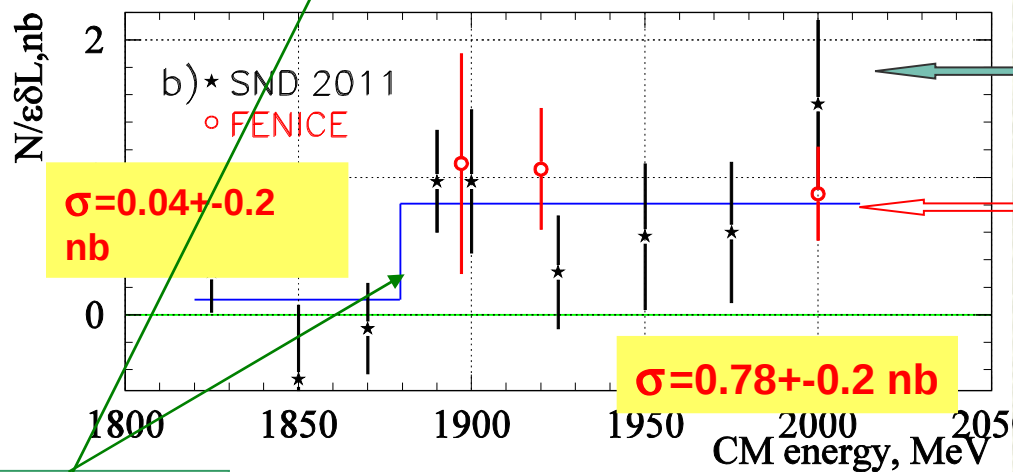
# Process $e^+e^- \rightarrow n\bar{n}$ (II)

$e^+e^- \rightarrow n\bar{n}$ , SND, 2011



After cosmic suppression using event time (effect + phys. background)

Calculated background from physical processes ( $pp + \gamma\gamma\gamma$ )



SND preliminary cross section

FENICE data

Physical background –  
1 –  $e^+e^- \rightarrow \gamma\gamma\gamma$ ,  $\sigma \sim 0.4$  nb,  
2 –  $e^+e^- \rightarrow p\bar{p}$ ,  $\sigma \sim 0.03$  nb

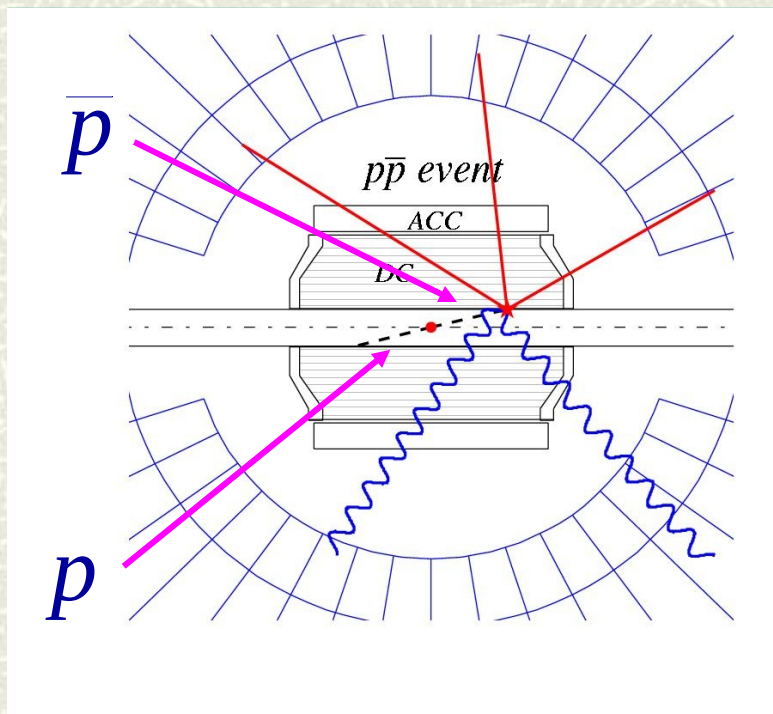
threshold





# Process $e^+e^- \rightarrow p\bar{p}$ (I)

Picture of expected event at the threshold



Events features (at the threshold):

- No signal from  $\bar{p}$
- “star” from annihilation point of at vacuum tube for  $\bar{p}$

Events features (above the threshold):

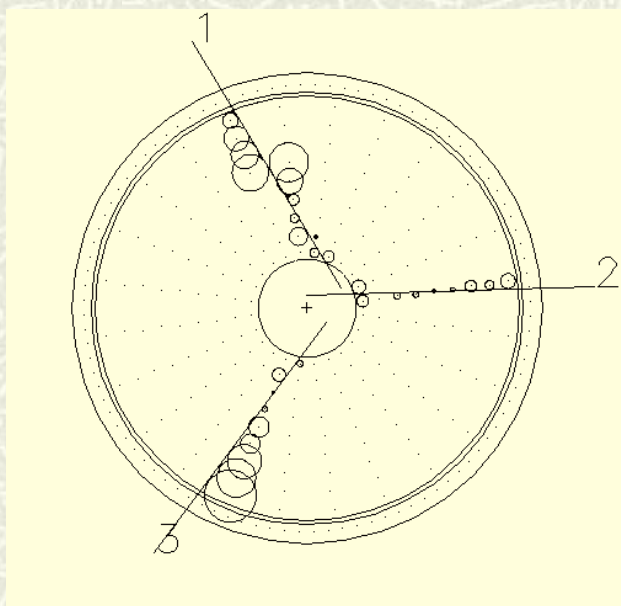
- charged track and no energy deposition for  $p$
- charged track and “star” from annihilation point in Cherenkov counter for  $\bar{p}$



# Process $e^+e^- \rightarrow p\bar{p}$ (II)

## Cuts(at the threshold):

- 3 or more charged particles with common point on vacuum tube
- total en. deposition  $> 650\text{MeV}$



## Cuts(above the threshold):

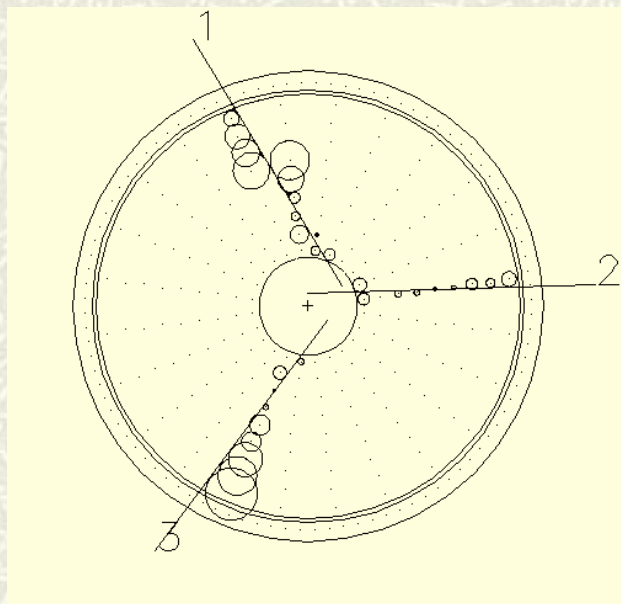
- 2 or more charged particles
- 2 central collinear tracks with large  $dE/dx$  in tracking system and  $36^\circ < \theta < 144^\circ$
- total en. deposition  $> 650\text{MeV}$
- distribution of energy deposition in calorimeter is not located along one line



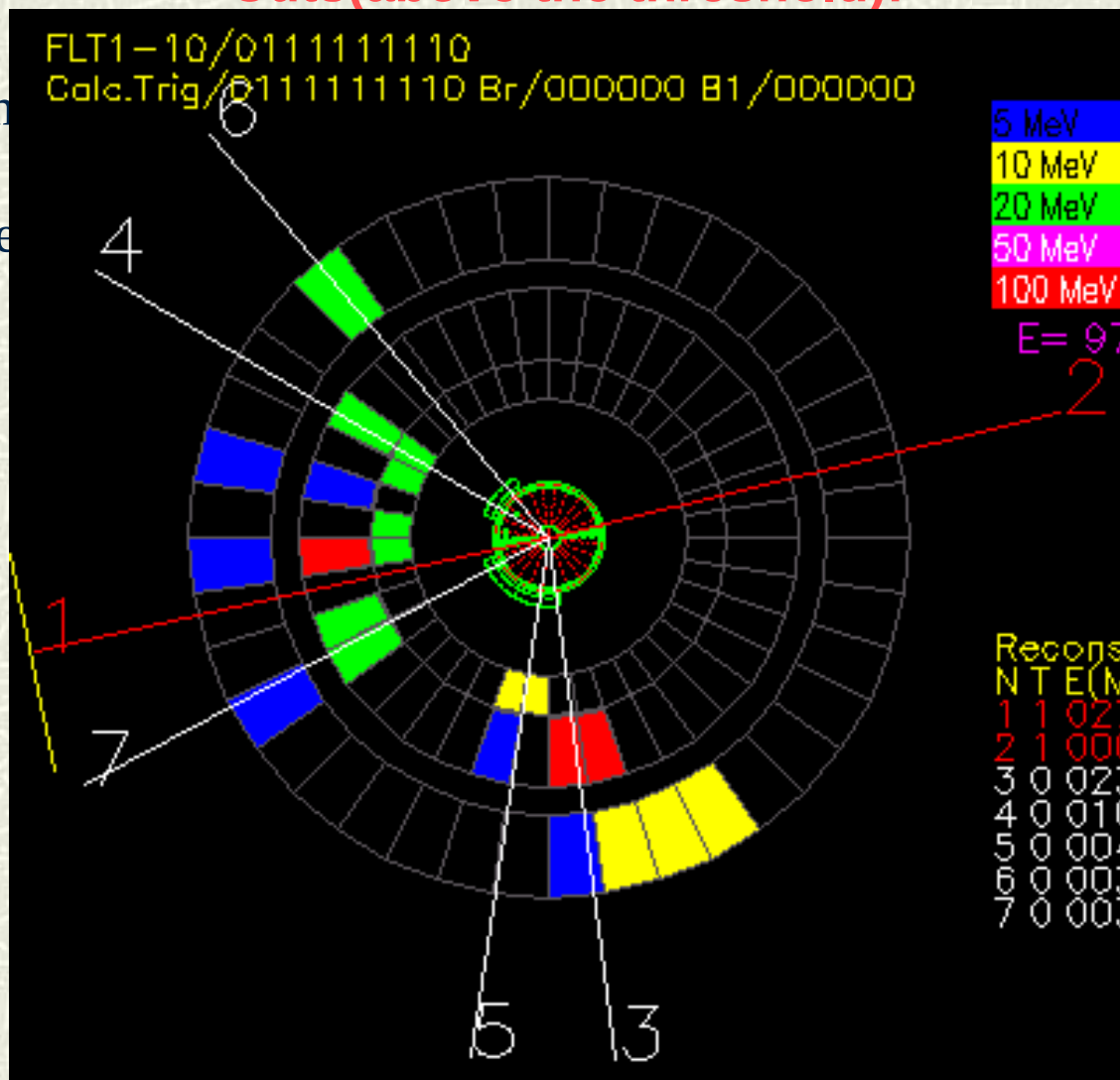
# Process $e^+e^- \rightarrow p\bar{p}$ (II)

## Cuts(at the threshold):

- 3 or more charged particles with common point on vacuum tube
- total en. deposition > 650MeV



## Cuts(above the threshold):



23.07.2011





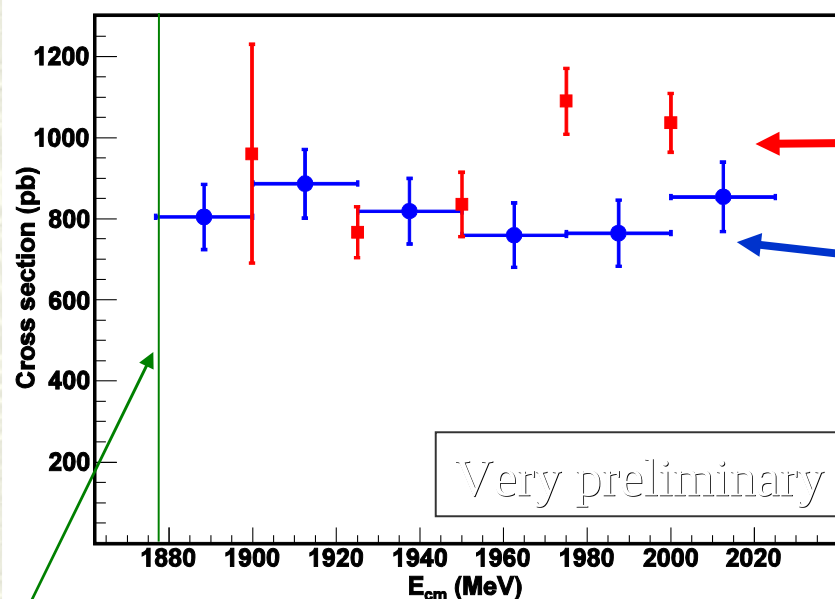
# Process $e^+e^- \rightarrow p\bar{p}$ (III)

Data - scan2010+scan2011(part.)

Registration efficiency  $\sim 40\%$   
Background  $\sim 6\%$   
(estimated using the same cuts below threshold)

SND preliminary cross section

Babar data



threshold

Only statistical errors!  
Systematic errors are under study.



# Conclusions & Plans

1. First data runs were performed on VEPP-2000 with SND detector (approximately 30 nb collected at the energy range 1.05 – 2.0 GeV)
2. Preliminary results on different hadron cross sections were obtained ( $e^+e^- \rightarrow \omega\pi^0, \pi^+\pi^-\pi^0, \pi^+\pi^-\pi^0\pi^0, \eta\pi^+\pi^-, n\bar{n}, p\bar{p}$ )
3. The results are in agreement with previous measurements
4. Obtaining results based on full available statistics (30 pb<sup>-1</sup>)
5. More hadron processes to study ( $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-, K_S K_L, \eta\gamma$ , etc )
6. Analyses of systematical errors from all detector systems.
7. New run for  $e^+e^- \rightarrow n\bar{n}, p\bar{p}$  study with higher luminosity and with smaller energy step (5 points with 25 MeV step  $\rightarrow$  25 points with 5 MeV step)

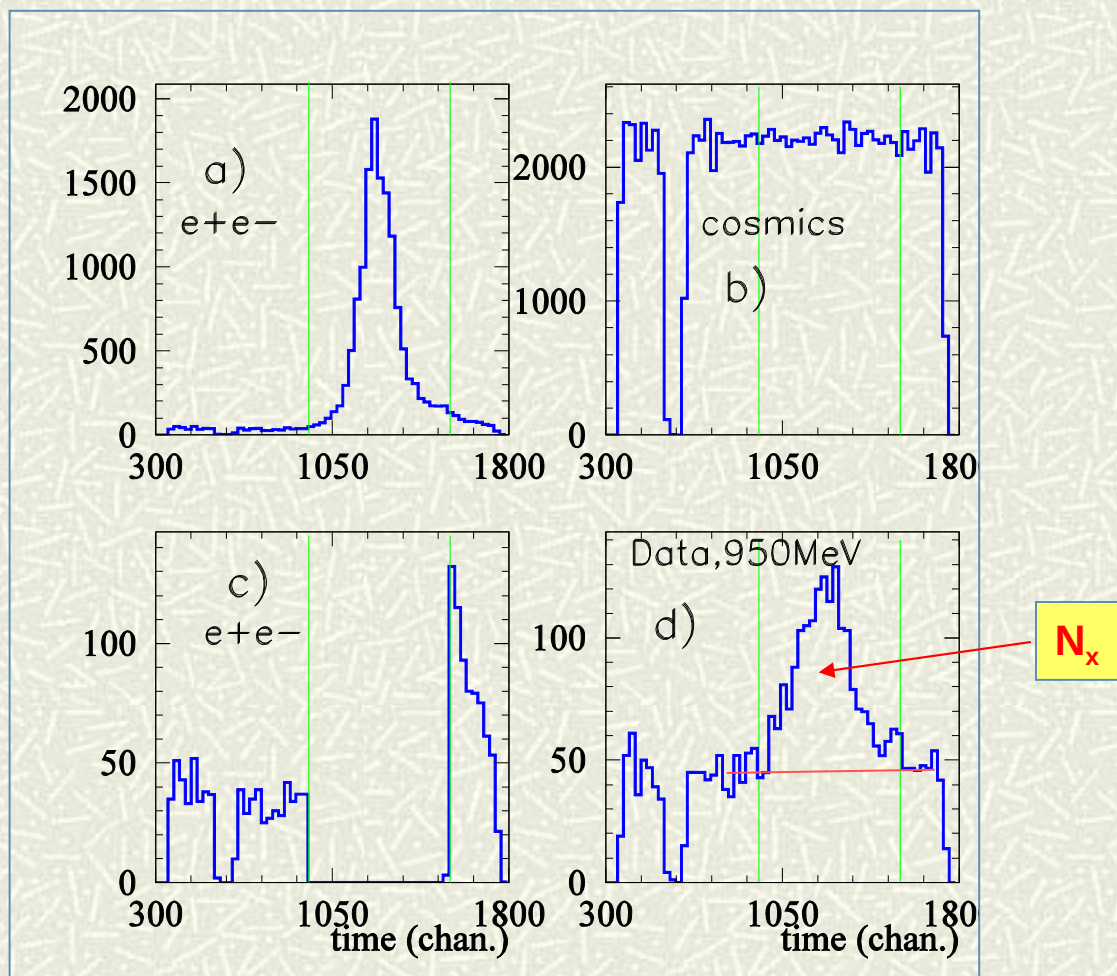


**Thank you**



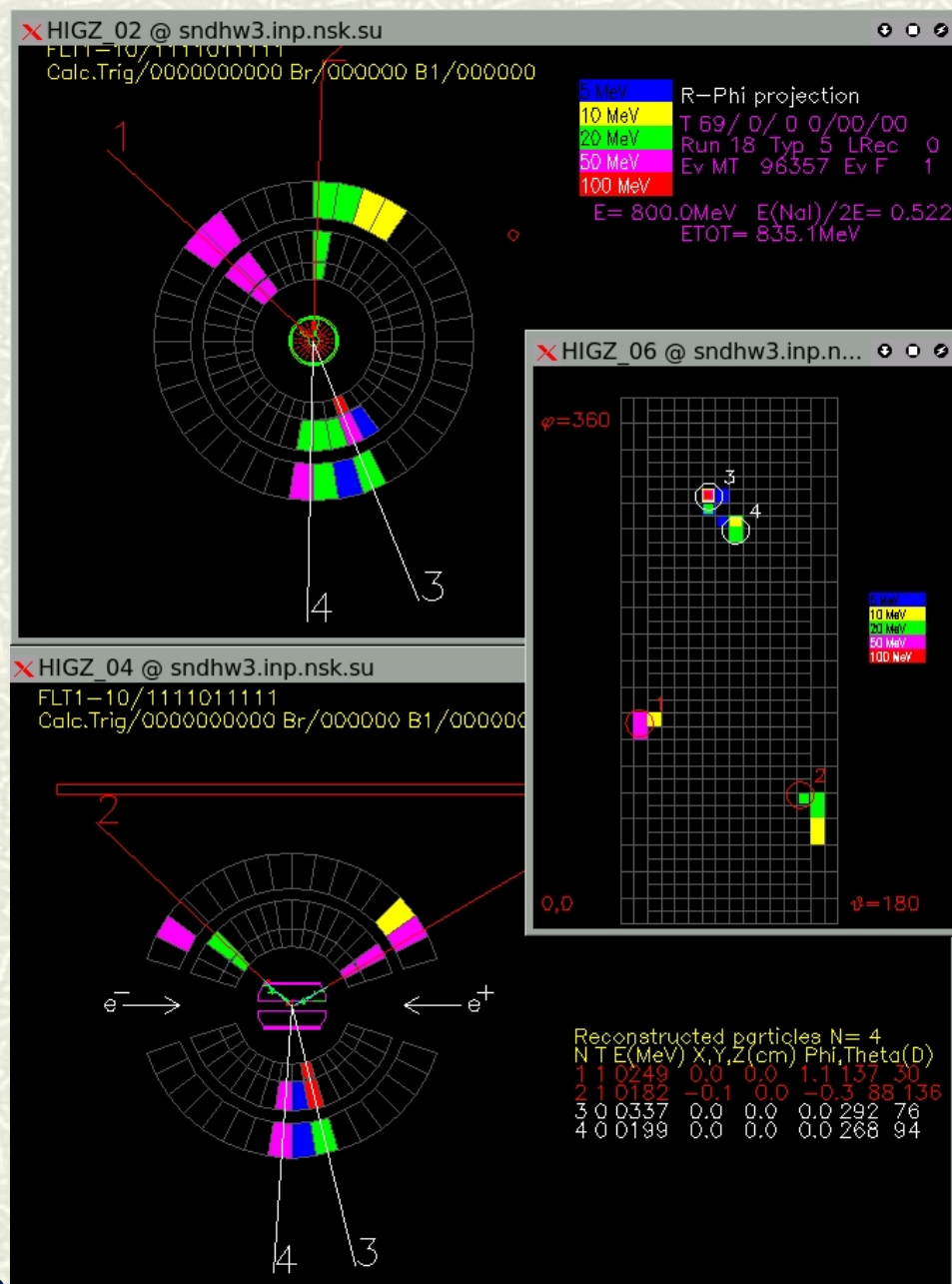


# Cosmic suppression using event time





# Typical view of $e^+e^- \rightarrow \pi^+\pi^-\pi^0$ event



23.07.2011

EPJ-HEP 2011