π^0 Dalitz decay analysis (2007 data)

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OUTLINE

- π^0_D form factor - short introduction
- Motivation for analysis with NA62_{RK} data
- $K^{\pm} \to \pi^{\pm}\pi^0 \to \pi^{\pm} e^+ e^- \gamma$ selection
- π^0 transition form factor fit
- Summary and outlook

π^0 DALITZ DECAY: $\pi^0 \to e^+e^-\gamma$

- Kinematic variable x

$$x = \left[\frac{m_{e^+e^-}}{m_{\pi^0}}\right]^2 = \frac{(p_{e^+} + p_{e^-})^2}{m^2_{\pi^0}}$$

- Variable limits

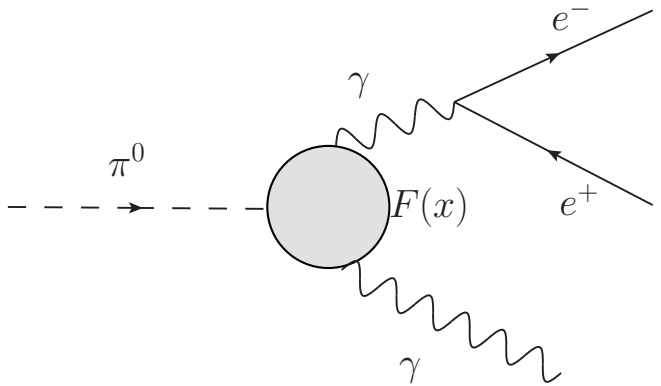
$$r^2 \leq x \leq 1,$$

$$r^2 = 4m_e^2/m^2_{\pi^0} \approx 5.73 \times 10^{-5}$$

- Decay width:

$$\frac{1}{\Gamma(\pi^0_{2\gamma})}\frac{d^2\Gamma(\pi^0_D)}{dx} = \frac{2\alpha}{3\pi}\frac{(1-x)^3}{x}\left(1+\frac{r^2}{2x}\right)\sqrt{1-\frac{r^2}{x}}\,|F(x)|^2\,(1+\delta x)$$

- Feynman diagram:



- Branching ratio:

$$BR(\pi^0_D) \approx 1.17\%$$

π^0 TRANSITION FORM FACTOR (TFF)

- TFF is expected to vary slowly in $x \in (r^2, 1)$, parametrization:

$$F(x) \approx 1 + ax$$

- a: form factor *slope*
- Expectation of *Vector Meson Dominance* model:

$$a \approx \left(\frac{m_{\pi 0}}{m_\rho}\right)^2 \approx 0.03$$

- $\pi^0 \to e^+e^-\gamma$ measurement: SINDRUM I (1992), Meijer Drees et al.

$$a \approx 0.03 \pm 0.03$$

MOTIVATION

- $\sim$ 10 million π^0_D events in NA48/2 data $\rightarrow$ Evgueni's analysis
- $\sim$ 1 million π^0_D decays in NA62$_{\mathrm{RK}}$ data
  - Minimum bias trigger (K_{e2})

  $\rightarrow$ analysis in Evgueni's footsteps (N. Lurkin, M. Koval)
- Potentially: search for U-boson (*dark photon*) in $\pi^0 \rightarrow \gamma U \rightarrow \gamma e^+ e^-$

Both analyses aim to reach uncertainty of the form factor slope measurement: $\Delta a < 0.01$

$K^{\pm} \to \pi^{\pm}\pi^0 \to \pi^{\pm}e^+e^-\gamma$ SELECTION (1)

- Detailed selection description can be found at:
  `http://mkoval.web.cern.ch/mkoval/na62/pi0/selection.html`

1. Trigger: Ke2
2. Vertex: Exactly one 3-track vertex: $N_{vtx} = 1$
   - Position: $-18\text{ m} \leq z \leq 90\text{ m}$
   - Quality: $\chi^2_{\text{max}} = 25$
3. No extra tracks in the spectrometer (see description on web)
4. Track-to-Track distance at DCH1 plane: $R_{DCH1} > 1$ cm
5. Track timing cuts: $|t_i| < 25$ ns, $|t_i - t_j| < 15$ ns
6. Track DCH radius cut: $12\text{ cm} \leq r \leq 120\text{ cm}$ for DCH1,2,4
7. Tracks in the LKr acceptance
8. Track ID in the LKr:
   - $e^{\pm}$: $0.85 \leq$ E/p ≤ 1.15
   - $\pi^{\pm}$: E/p < 0.85
9. Track separation in LKr plane: $R_{LKr} > 15$ cm

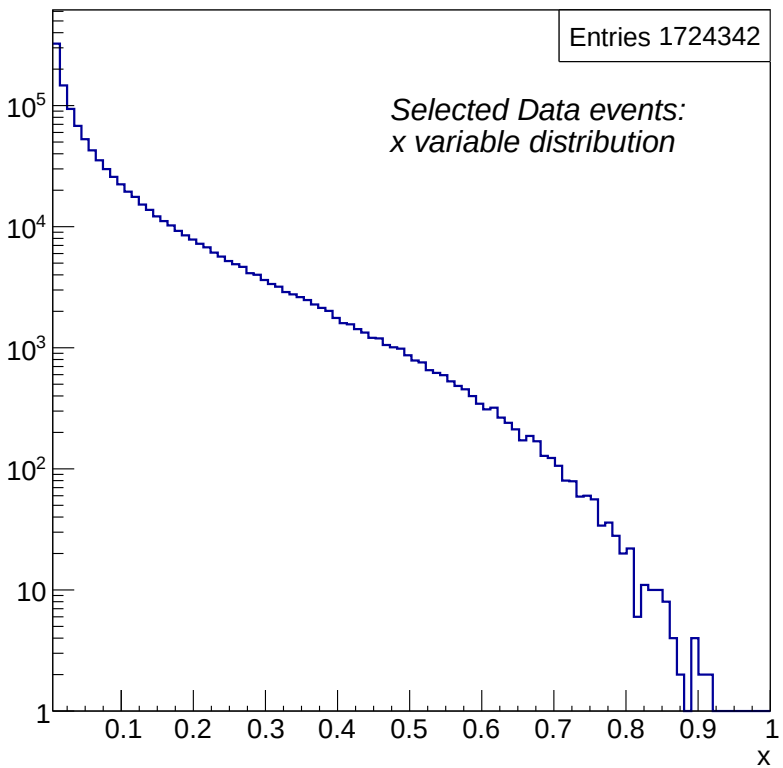
$K^{\pm} \to \pi^{\pm}\pi^0 \to \pi^{\pm}e^+e^-\gamma$ SELECTION (2)

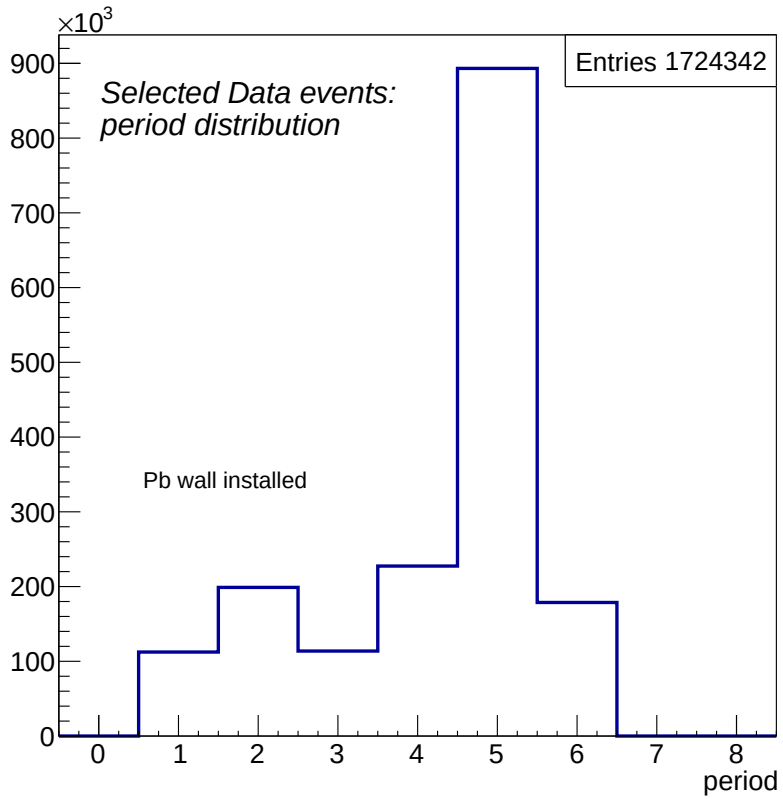
http://mkoval.web.cern.ch/mkoval/na62/pi0/selection.html

10. γ cluster ID
    - Separation from the pion impact point $R_\pi > 30$ cm
    - Separation from the $e^{\pm}$ impact points $R_{e^{\pm}} > 10$ cm
    - Separation from the undeflected $e^{\pm}$ trajectories $R_{e^{\pm}\mathrm{UN}} > 20$ cm
    - Timing between LKr cluster time and DCH average time of the vertex tracks $|t_\gamma - t_{\mathrm{vtx}}| < 10$ ns
11. γ cluster conditions
    - Cluster in the LKr acceptance
    - $E_\gamma > 3$ GeV
    - Min. dead cell distance $d_{\mathrm{dead}} > 2$ cm
    - Min. radius in the first DCH plane: $r_{\mathrm{dch1}} > 13$ cm
12. Kinematic cuts
    - Momenta: $p(\pi^{\pm}, e^{\pm}) \in (5, 74)$ GeV
    - Total momentum: $p_{\mathrm{TOT}} \in (70, 78)$ GeV
    - Transverse momentum: $p_T^2 < 0.0005$ GeV^2
    - Reco π^0 mass: $|M_{ee\gamma} - M_{\pi^0}| < 0.008$ GeV
    - Reco $K^{\pm}$ mass: $0.475\ \mathrm{GeV} < M_{ee\gamma\pi} < 0.510$ GeV

$K^{\pm} \to \pi^{\pm}\pi^0 \to \pi^{\pm}e^+e^-\gamma$ SELECTION (3)

- Selection code was debugged (event by event), cooperation between Nicolas Lurkin, Evgueni Goudzovski and M.K.
- Cut values will be optimized (see Evgueni's talk)





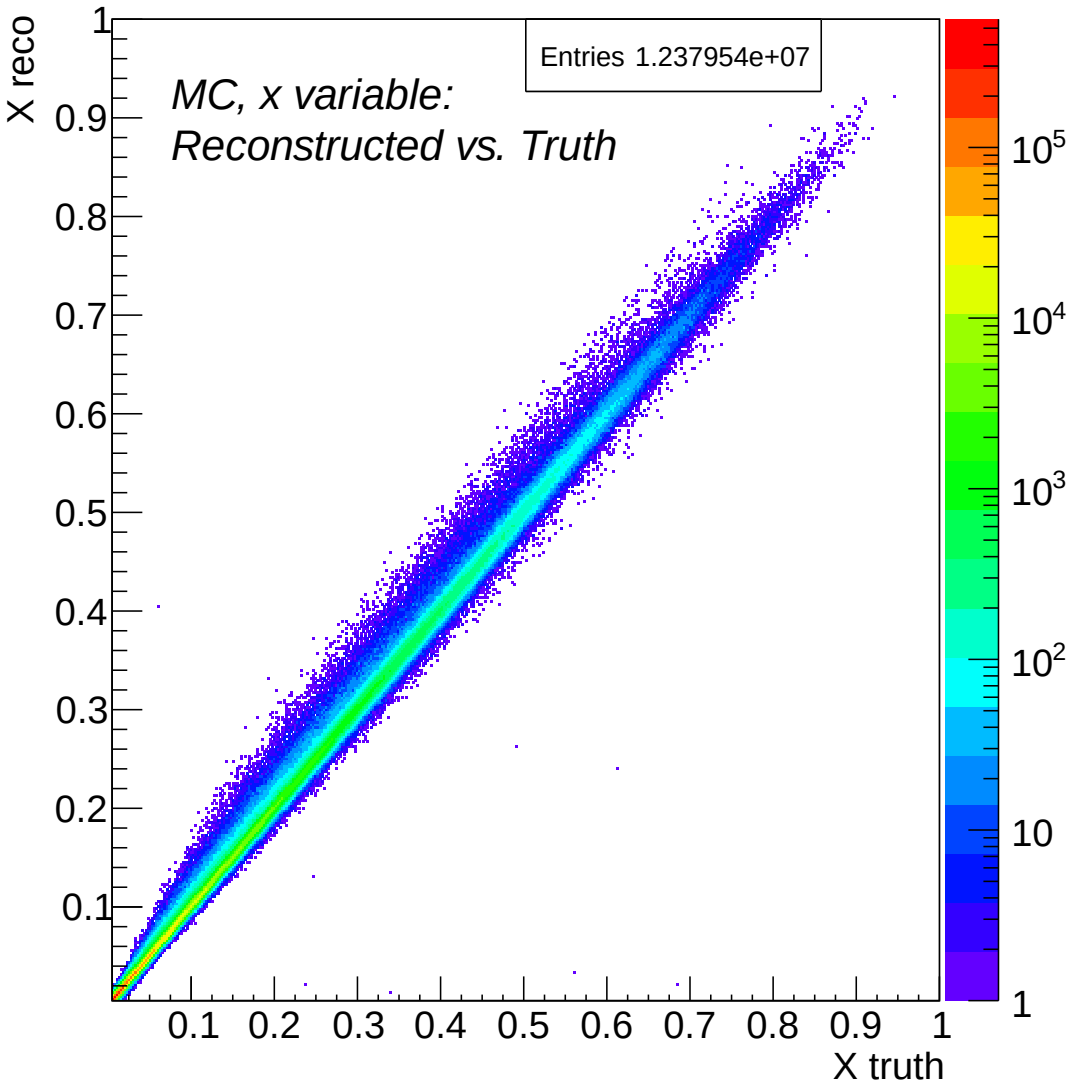
USED MONTE CARLO SAMPLES

1. $K^{\pm} \to \pi^{\pm}\pi^0_D(\gamma)$ KLOE IB generator
   - 447 million events
   - Prague radiative corrections to π^0_D
   - *mc.2007.k2pigd.kloe.pi0d.radcor.prague.list*
2. $K^{\pm} \to \pi^0_D\mu^{\pm}\nu(\gamma)$ KLOE IB generator
   - 119 million events
   - Prague radiative corrections to π^0_D
   - *mc.2007.km3gd.kloe.pi0d.radcor.prague.list*

See Evgueni's talk from 5. 6. 2014 for detailed discussion of radiative corrections.

RESPONSE MATRIX

Standard selection applied to $K^{\pm} \to \pi^{\pm}\pi^0_D(\gamma)$ sample



FORM FACTOR FITTING METHOD

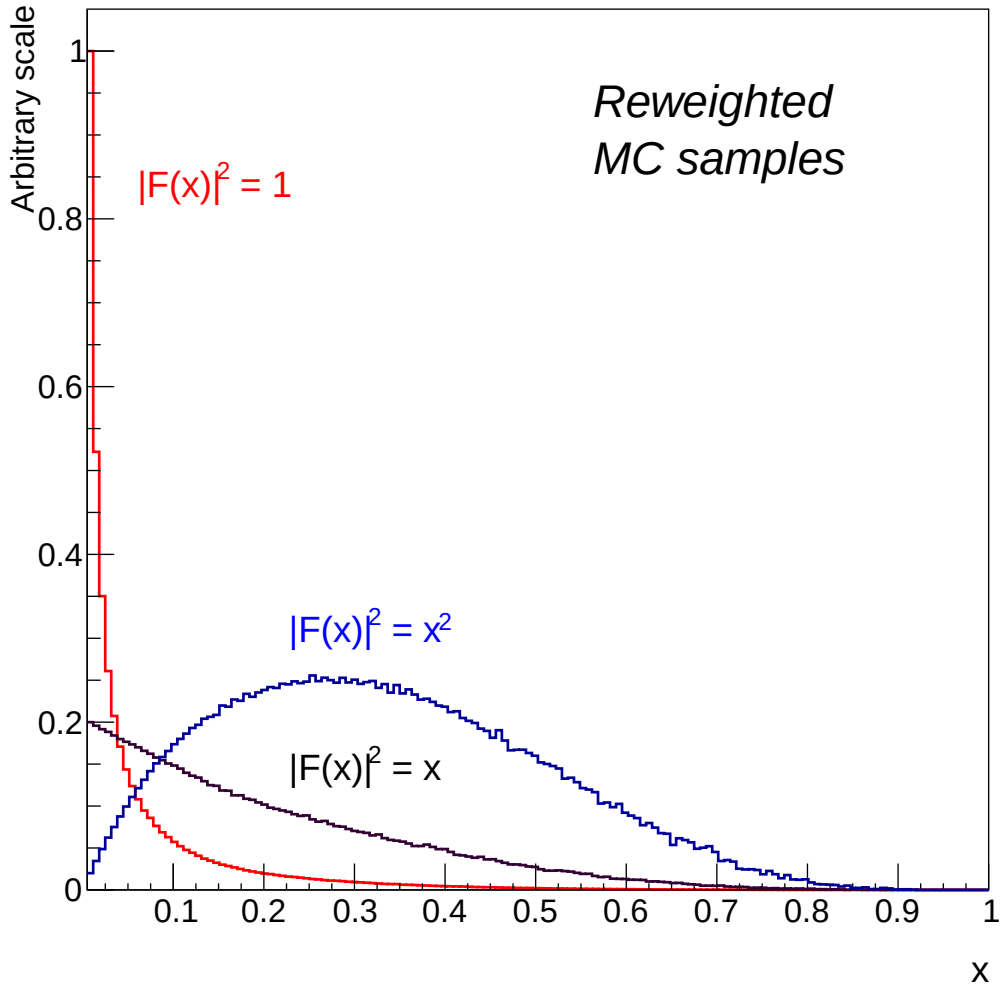
- *Re-weighting* $\rightarrow$ 3 independent MC samples with different FF:

$$|F(x)|^2 = \{1, x, x^2\}$$

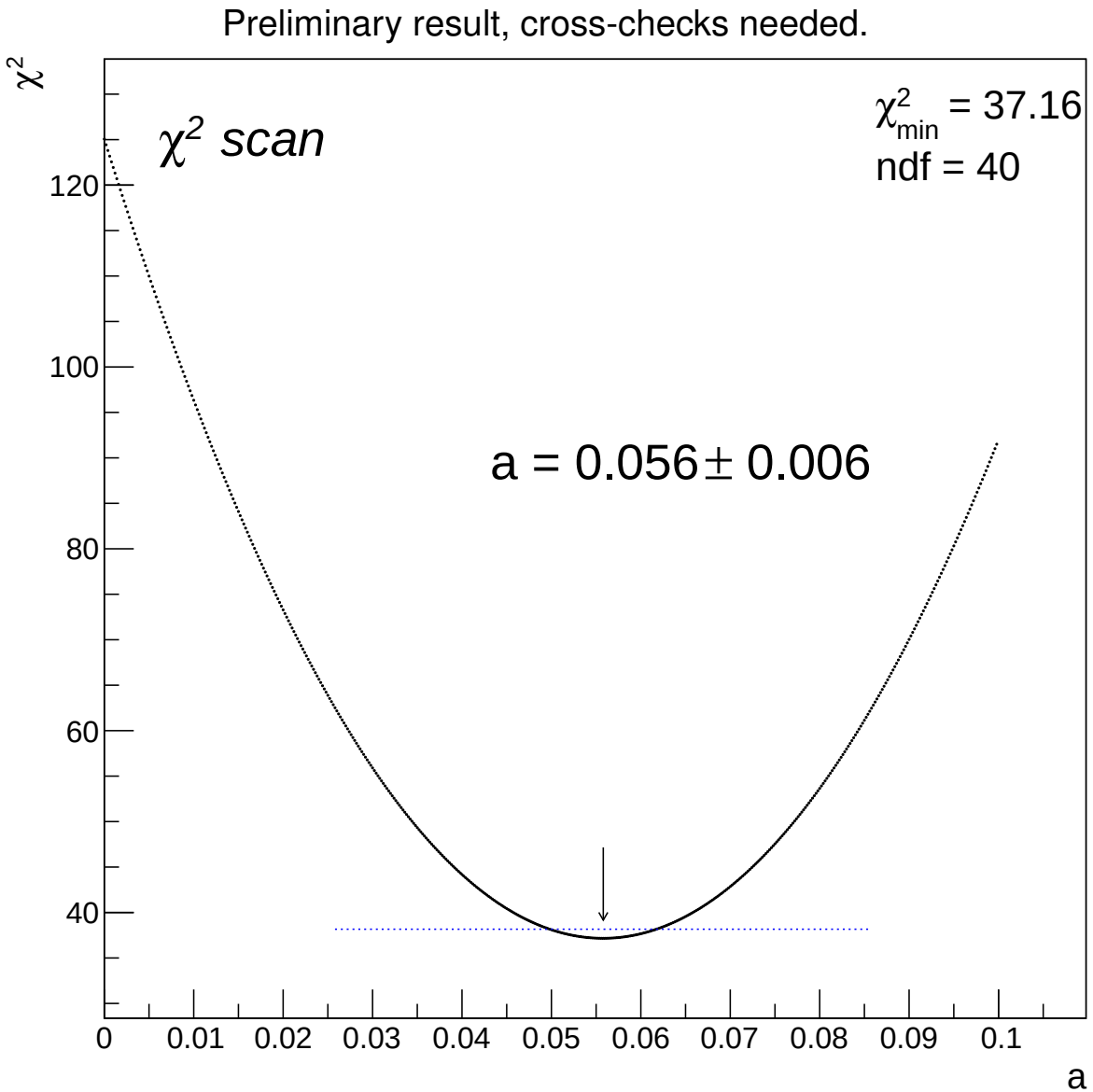
- Reconstructed x histograms re-binned into (almost) equipopulous bins
- Fit performed by scanning of a-values, looking at χ^2: data vs. linear combination of the samples

$$|F(x)|^2 = (1 + ax)^2$$
$$= 1 + 2ax + a^2x^2$$

- Fit in range $0.005 \leq x \leq 1$

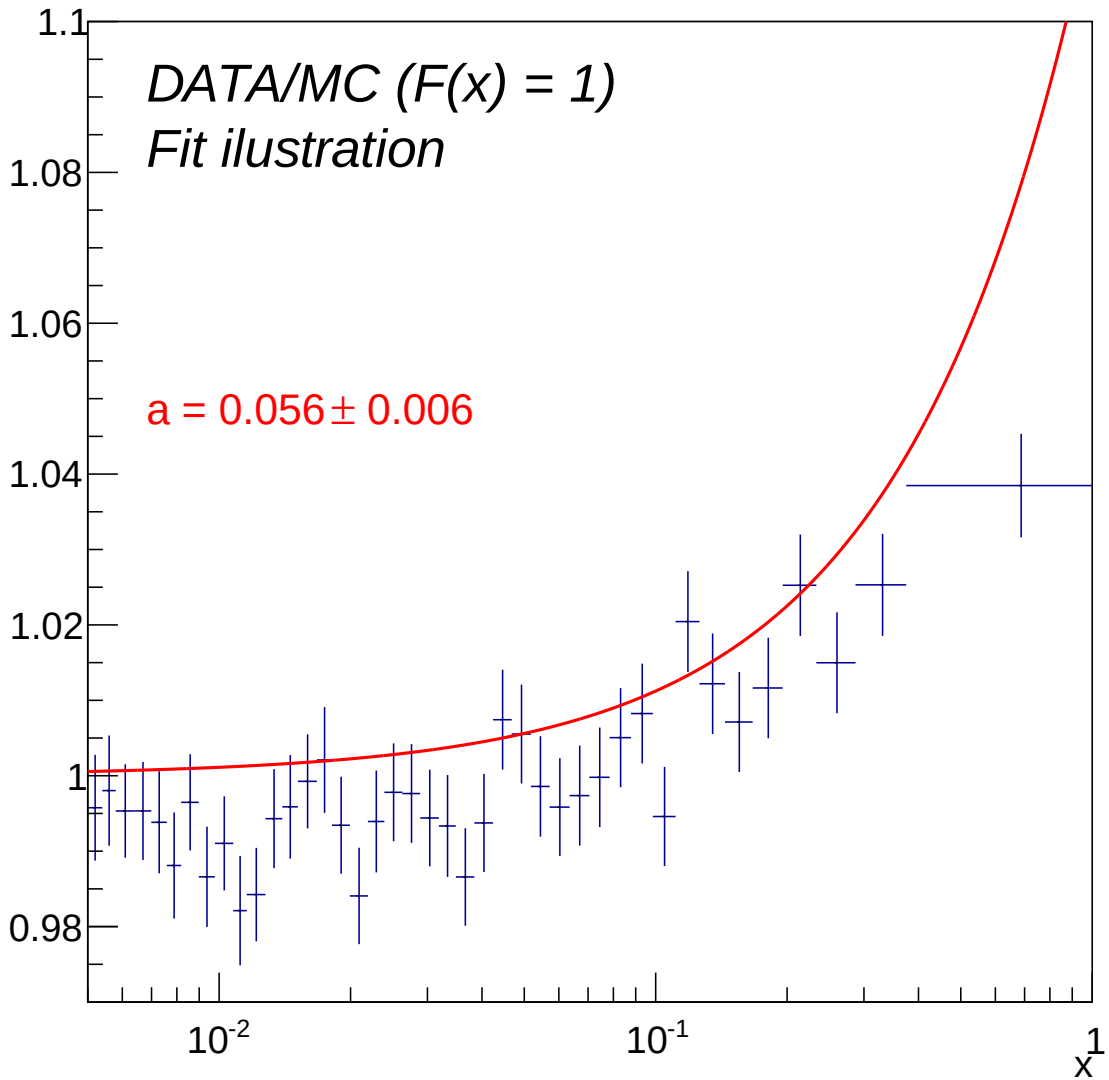


BEST FIT RESULT



DATA/MC BEST FIT

Preliminary result, cross-checks needed.



SUMMARY AND OUTLOOK

- π^0 Dalitz decay analysis with NA62_{RK} data started (N. Lurkin, M. Koval)
- Goal: π^0 transition form factor measurement
- $K^{\pm} \to \pi^{\pm}\pi^0 \to \pi^{\pm}e^+e^-\gamma$ selection developed and debugged
- Fitting procedure built

Next steps

- Check of the fit procedure
- Stability of the cuts in selection (see Evgueni's talk today)