

# Market risk stress-testing

Tatiana Efremova

(Prognoz Risk Lab, Prognoz; Ph.D. student, PSNRU)



**PROGNOZ**  
**RISK LAB**

Perm Winter School 2012

**Value-at-Risk** is a threshold value of loss such that the probability that the mark-to-market loss on the portfolio over the given time horizon exceeds this value is the given probability level.

Market Risk Framework Базель II / III:

- Probability: 99%
- Horizon: 10 days

VaR is applied for MRC requirements

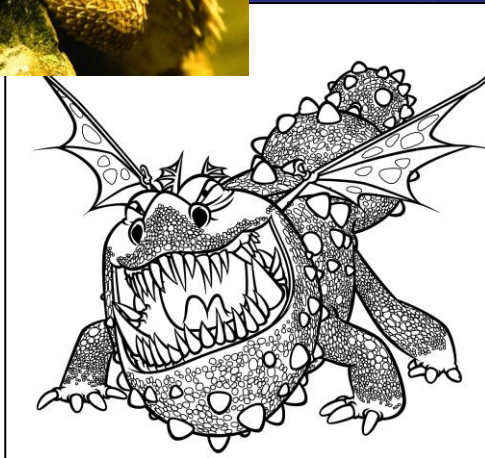


## Benefits:

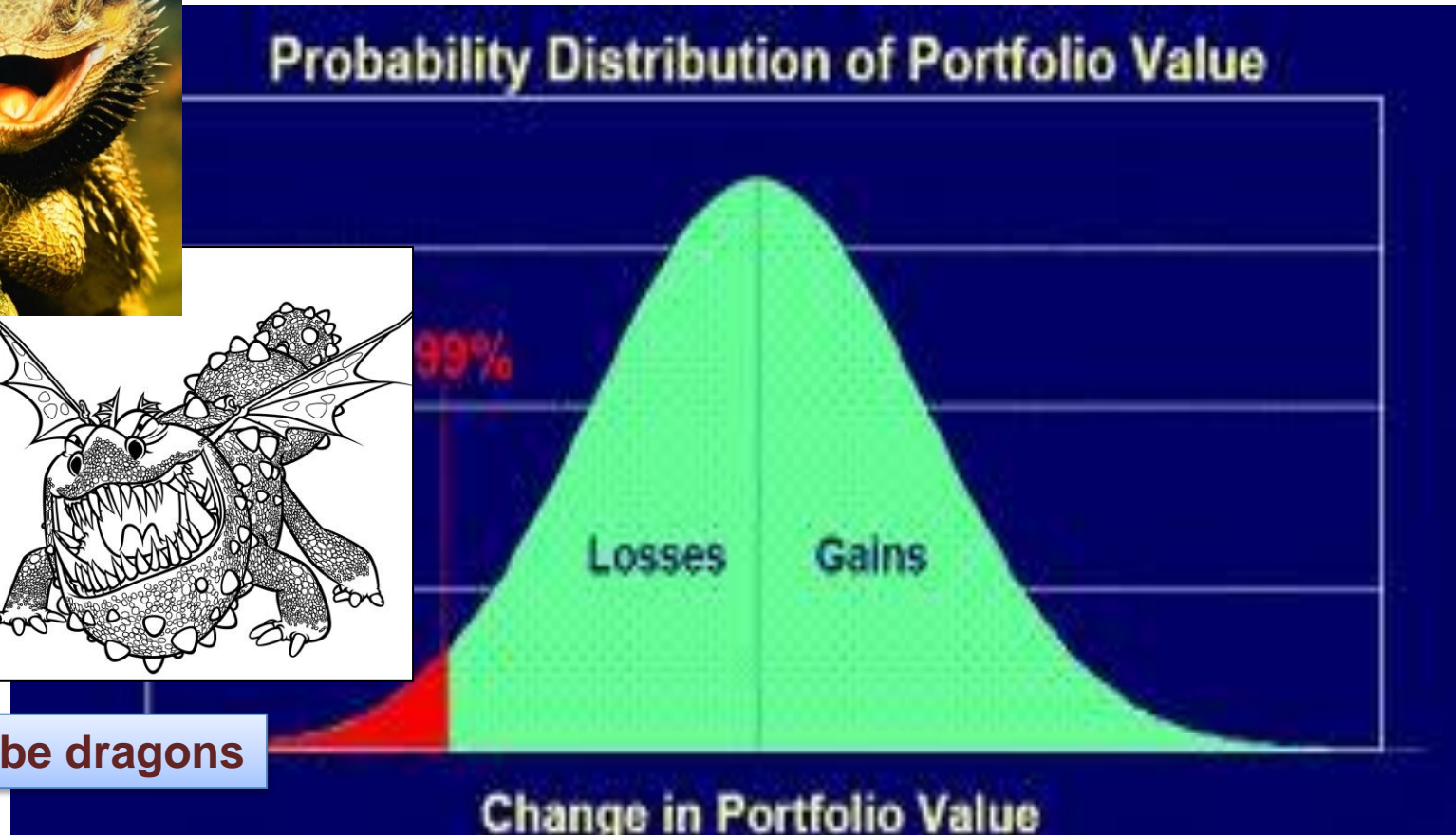
- Single value as a measure of risk
- Standard & simple measure that is easy to explain
- Compliance to supervisory requirements

## Shortcomings:

- Total uncertainty about tails
- Inefficiency before and during the crises



**Here be dragons**



Because we should be prepared to the things beyond VaR

# How to design a consistent stress-testing system?



How to set “*extreme, but plausible*” shock values for scenarios?

How to make the whole process smoother and easier?



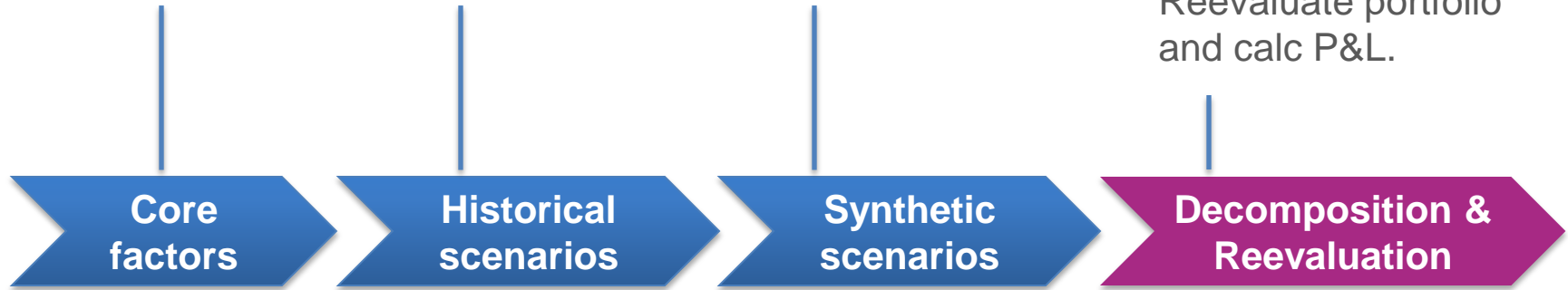
# Stress-test creation framework

Select core risk drivers relevant to portfolio structure.

Analyze historical time series (PDF, extremes) for different horizons.

Generate “extreme, but plausible” scenarios based on EVT and copula.

Decompose core risk drivers to financial instruments pricing functions. Reevaluate portfolio and calc P&L.

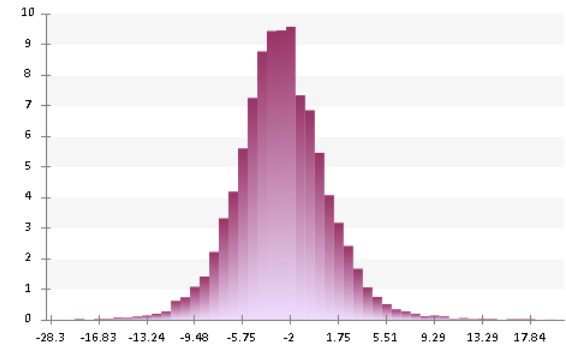
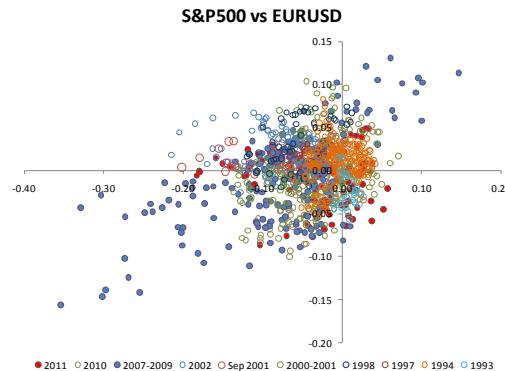
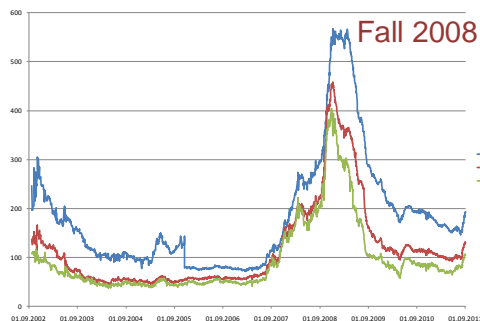


- S&P 500, MSCI
- UST....
- Bond spreads
- LIBOR
- FX
- CDS

- 1987 Black Monday
- 1997 East Asian crisis
- 1998 Russian crisis
- 2001 Dotcom crash
- 2007-20xx
- ...

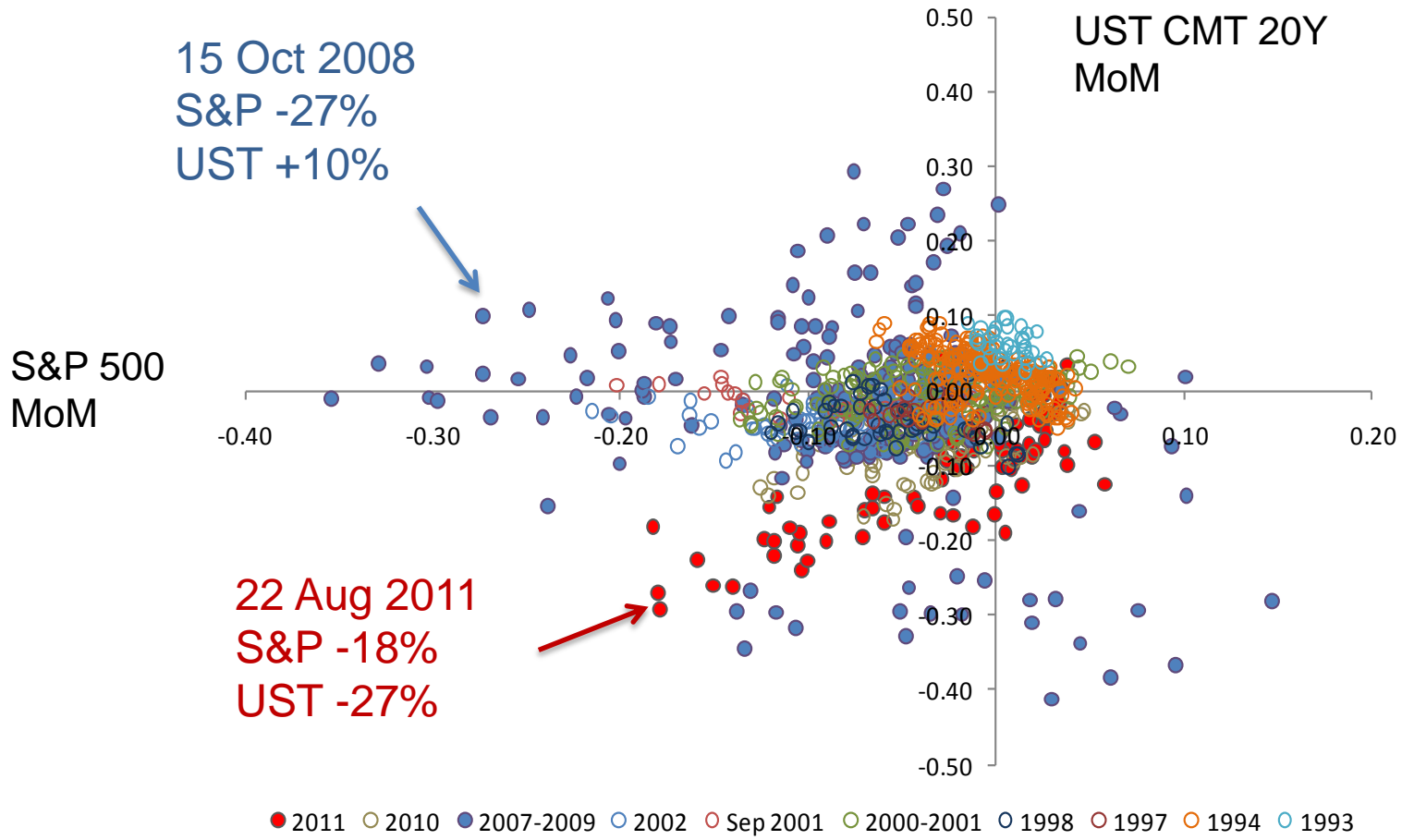
- Fat tailed marginal distr.
- Correlations & copula
- Monte-Carlo

- Decomposition (stressed betas)
- Mark-to-Market
- Loss distribution
- Reverse stress-testing



Setting historical shocks values is easy (*after 2008*). However, correlations can differ significantly in different crashes.

## S&P500 vs UST20



*Solnik, Boucrelle, LeFur (1996); Longin, Solnik (1999); Sornette (2005)*

Two aspects to be captured:

- Risk factors extreme values to provide **stress** tests (McNeil (1999))
- Correlations to provide **coherent** stress tests
  - Stress factor/ stress correlation matrix (Gauthier (2010), Bender, Lee, Stefek (2010))
  - Parametric scenarios construction on copulas

Copula (mathematical basis was provided by Sklar (1959) ) is

$$F(x_1, \dots, x_N) = C(F_1(x_1), \dots, F_N(x_N)),$$

$$F(x_1, \dots, x_N) = P(X_1 \leq x_1, \dots, X_N \leq x_N) \text{ and } F_i(x_i) = P(X_i \leq x_i), i = \overline{1, N}$$

$F_i$  - marginal distribution function,

C – copula function.

- Elliptic copulas
  - Produced by elliptical distributions (Gaussian, t-Student...)
- Archimedean copulas (Clayton, Gumbel, Frank...)
  - Have nice analytical form (NOT like elliptic copulas)

$$C(u_1, \dots, u_n) = \varphi(\varphi^{-1}(u_1) + \dots + \varphi^{-1}(u_n)) \quad (u_i = F(x_i))$$

Tail dependence:

$$\tau^L = \lim_{q \rightarrow 0^+} Pr[F_1(Y_1) \leq q \mid \dots \mid F_n(Y_n) \leq q]$$

$$\tau^U = \lim_{q \rightarrow 1^-} Pr[F_1(Y_1) > q \mid \dots \mid F_n(Y_n) > q]$$



For hypothetical portfolio consisted of stocks and corporate bonds,  
4 risk factors were chosen:

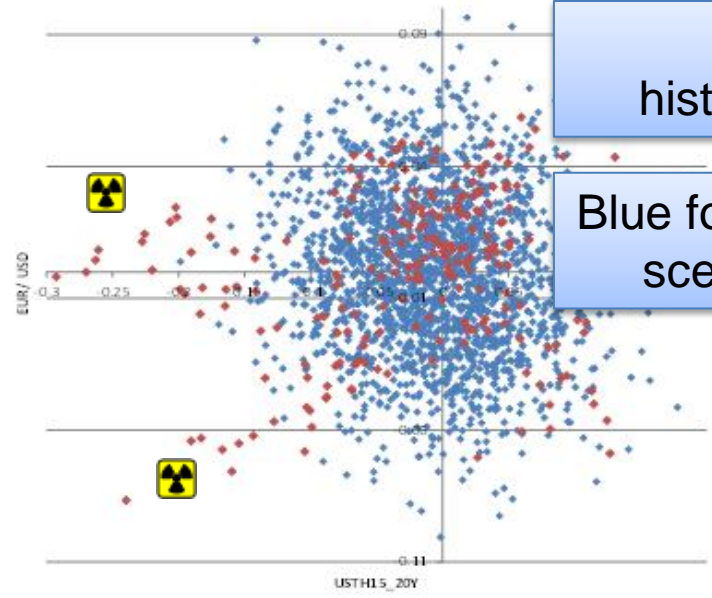
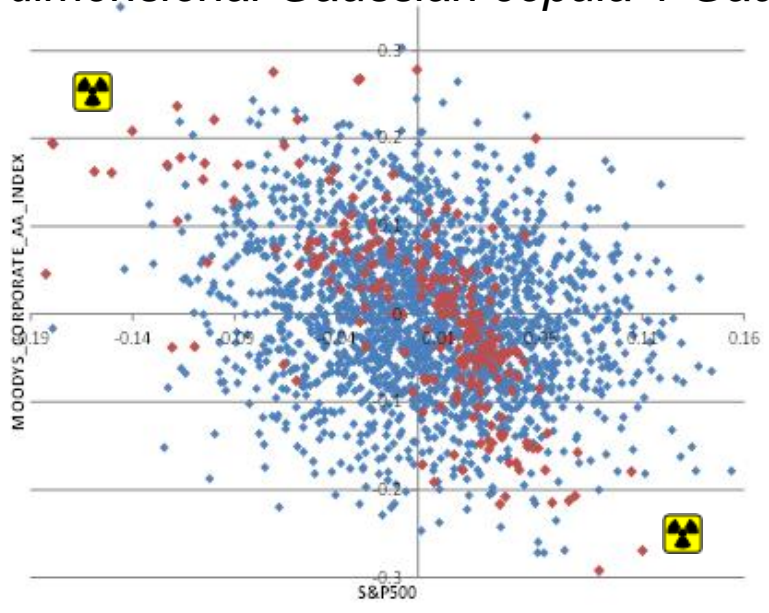
- S&P500,
- EUR/USD,
- 20-years US Treasuries yield,
- Moody's AA-spread

1-month window worst returns,  
Crisis sample November'07 – March'09

# Stress scenarios validity

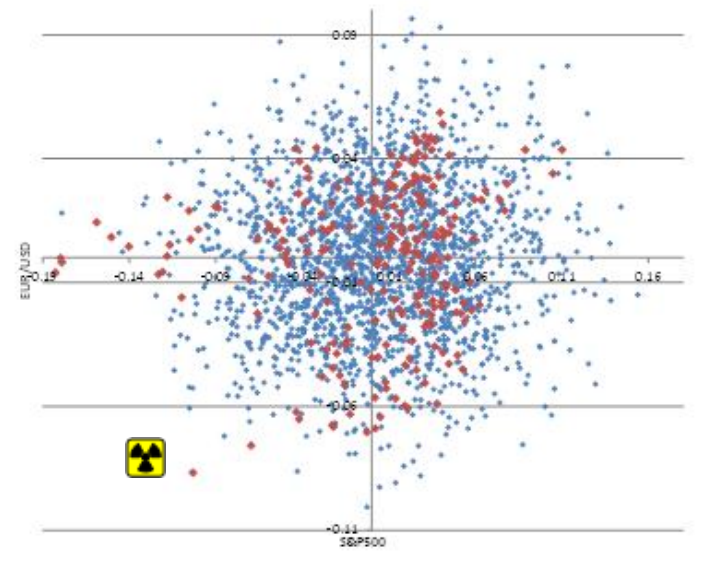
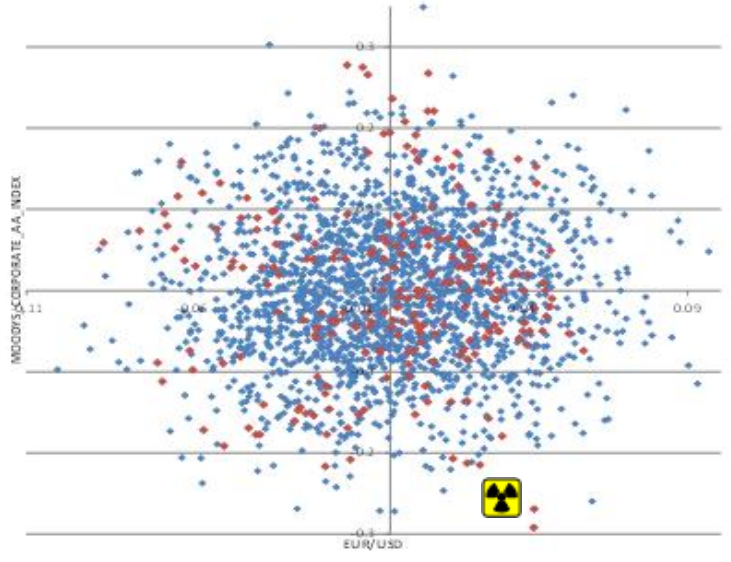
## Good Old Classics: multinormality

*4-dimensional Gaussian copula + Gaussian marginals*

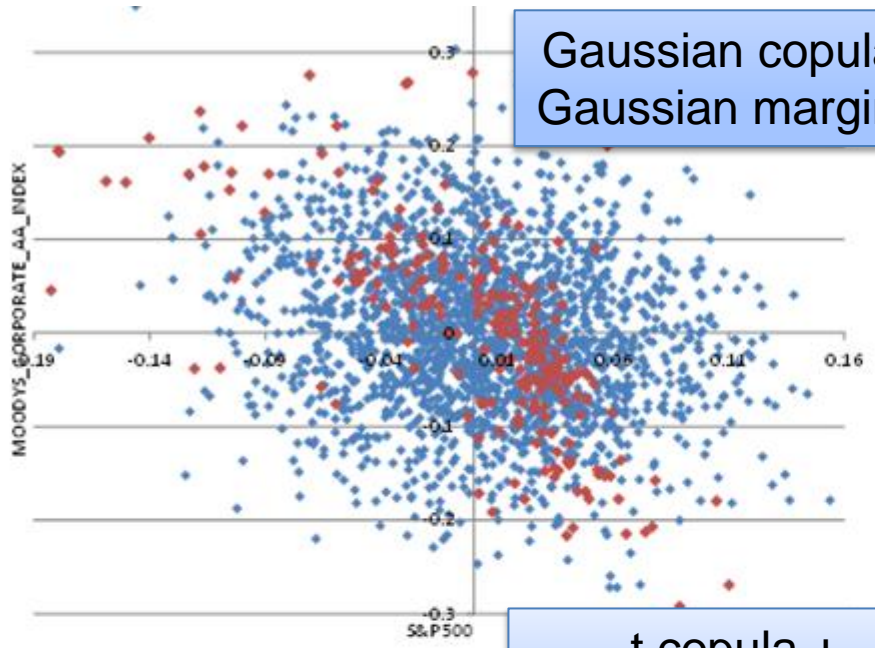


Red for historical values

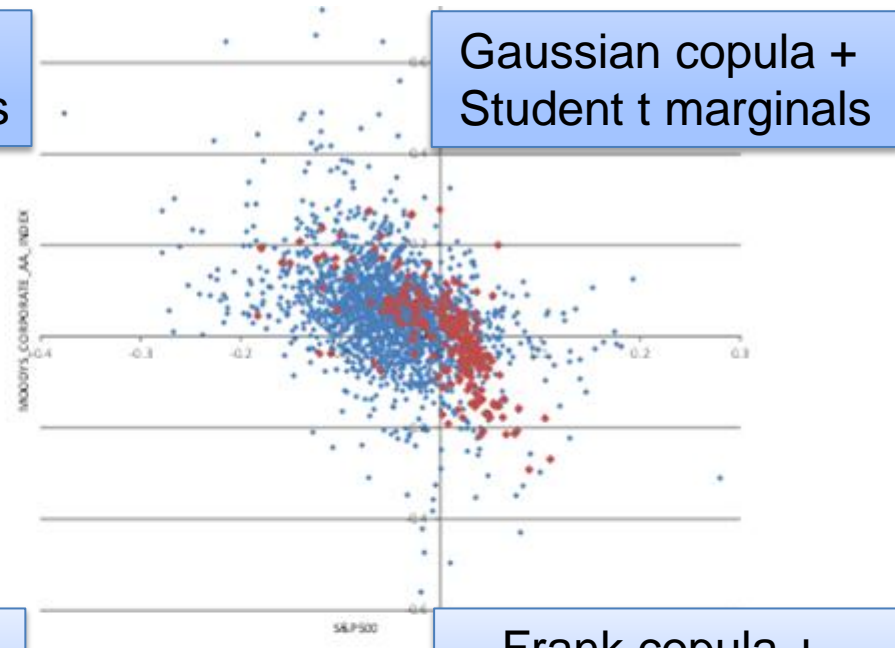
Blue for (hypothetical) scenario values



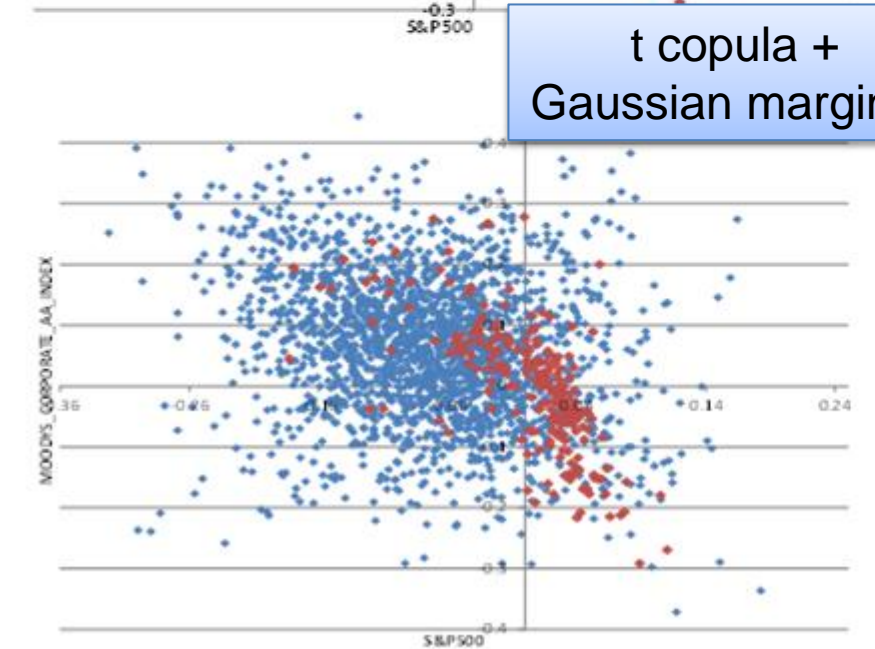
## A little bit closer to real data (dimension "S&P500 vs AA spread")



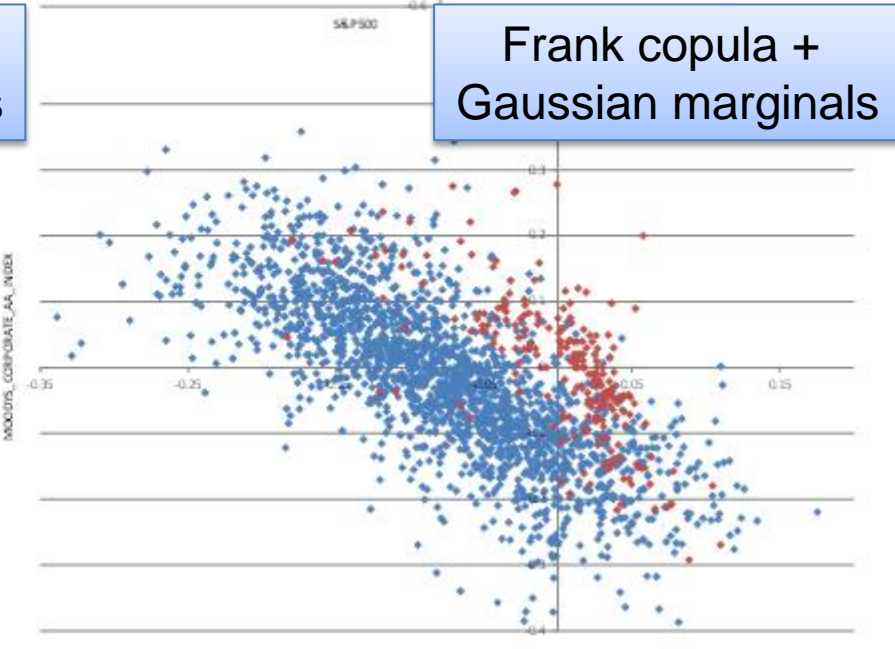
Gaussian copula + Gaussian marginals



Gaussian copula + Student t marginals



t copula + Gaussian marginals



Frank copula + Gaussian marginals

Multiple goodness-of-fit tests ( $H_0: C = \{C_\theta, \theta \in \Theta\}$ )

Including Cramer-von Mises statistic and other distance criteria between estimated copula and

- empirical copula (Genestand Remillard(2008)),
- copula kernel estimator (Hong and Li (2002), Chen and Huang (2007) )

*From scenarios towards risk measures*

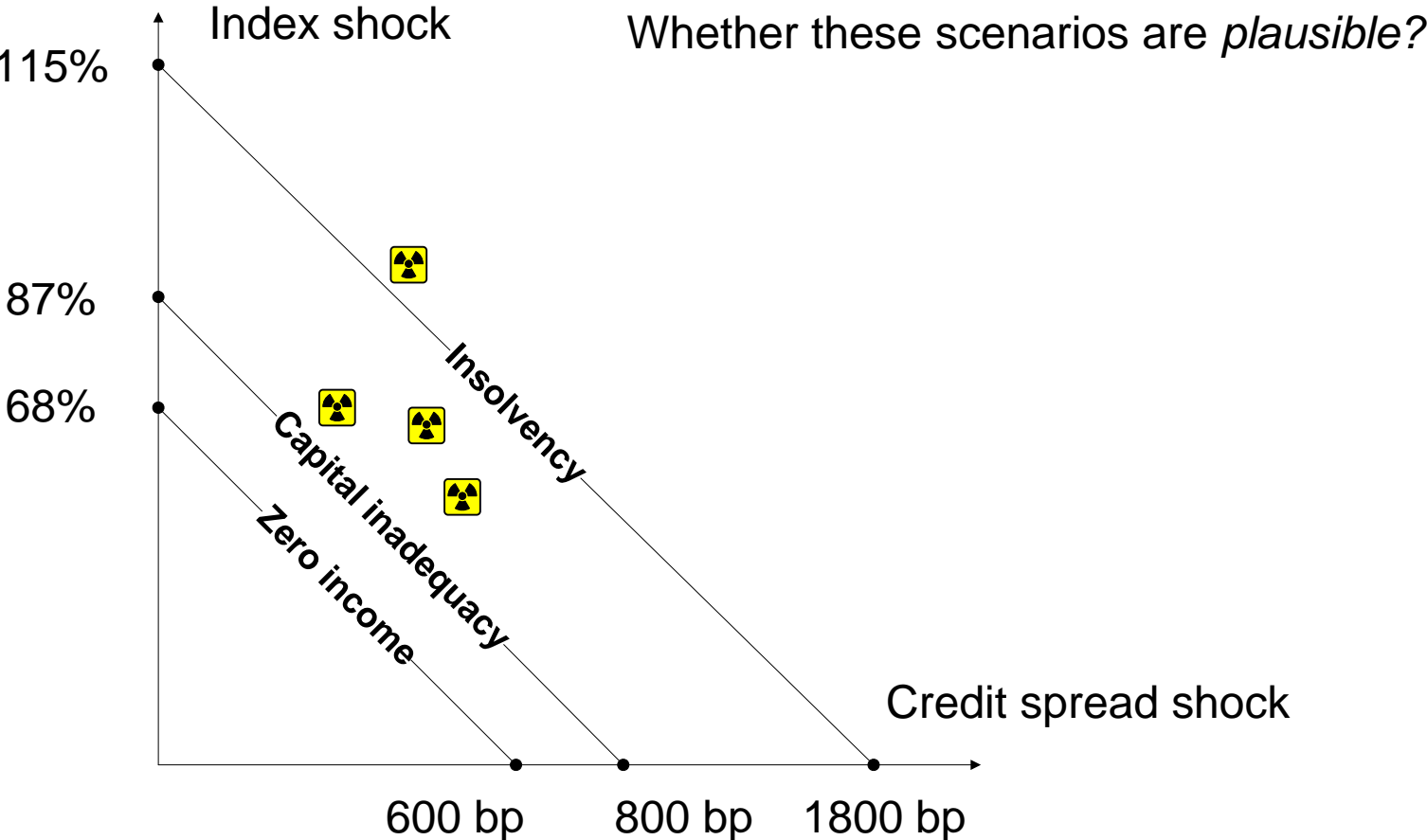
Use pricing functions mechanism  $V = f(r_1, \dots, r_n, b_1, \dots, b_n)$

V for asset value, while f for pricing functions dependent on

$r_i$  for i-th risk factor and  $b_i$  for pricing model coefficient estimation

- Profit & loss due to risk factors scenario dynamics,
- VaR and ES based on multivariate scenario,
- Risk profile decomposition

*From worst-case events towards scenarios*





## Prognoz.Market Risk

PROGNOZ

Monitor Risk Factors Scenarios Hide

### Scenario parameters

**S&P 500:** 1218

Scenario value, %: 0.00

**UST 20Y:** 2.73%

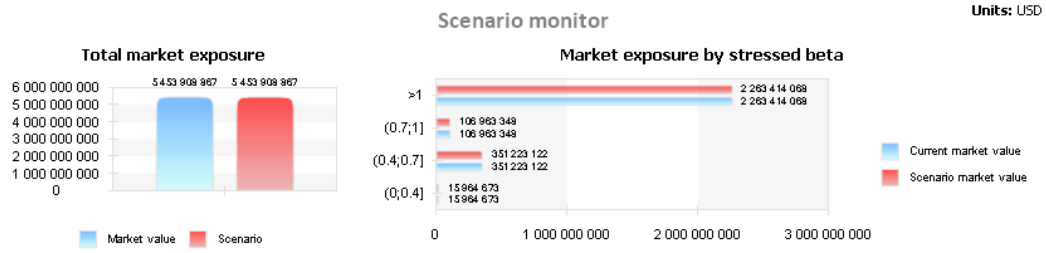
Scenario value, %: 0.00

**AA Spread:** 114 bp

Scenario value, %: 0.00

**EUR/USD:** 1.3703

Scenario value, %: 0.00



### Health monitor

**P&L:** --

**P&L, %:** --

**Loss Limit, %:** 10.0

---

**Liquid assets:** 5 454 mln. USD

**30d net outflow:** 4 850 mln. USD

**LCR, %:** 88.93

**Limit, %:** 100.0

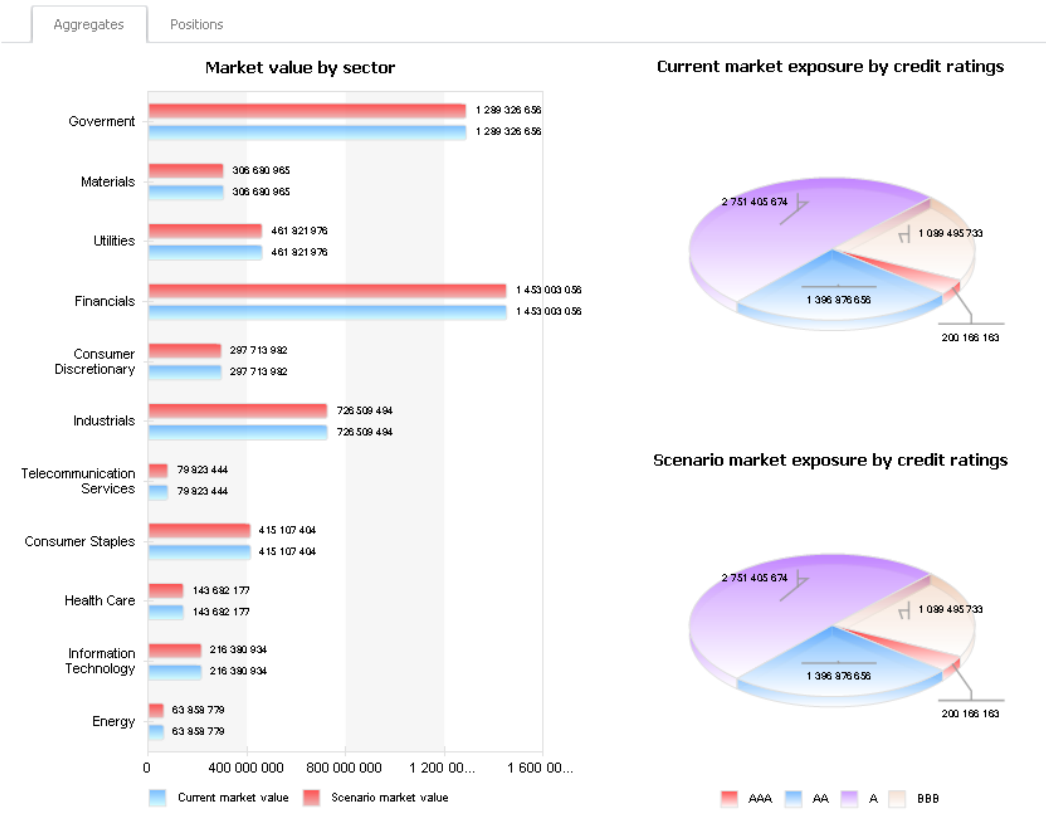
---

**Capital:** 1 000 mln. USD

**RWA:** 5 800 mln. USD

**Capital Ratio, %:** 17.24

**Limit, %:** 8.0

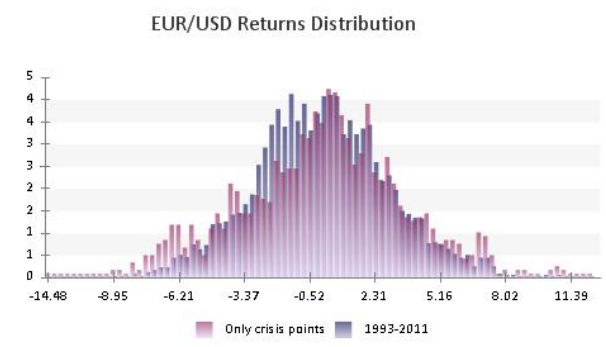
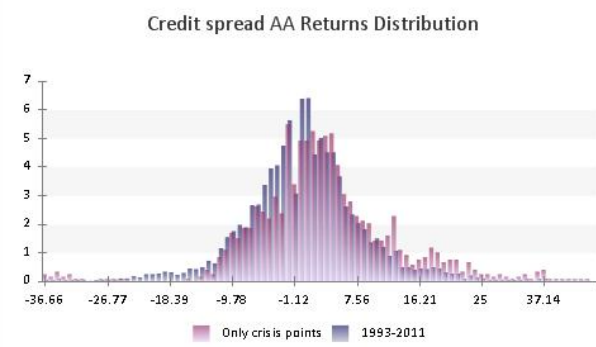
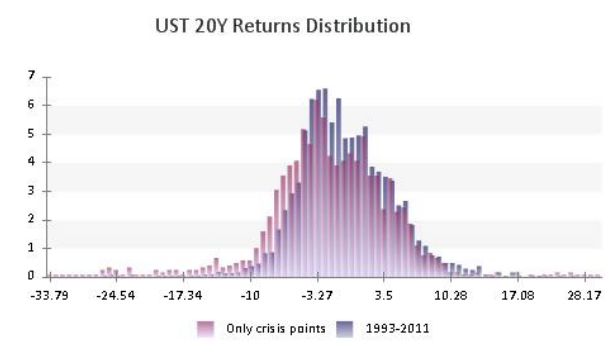
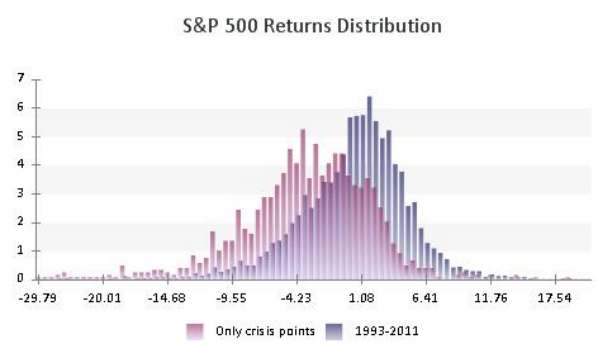


Reset

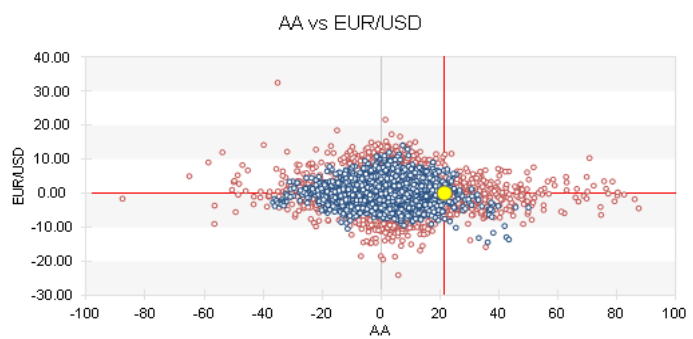
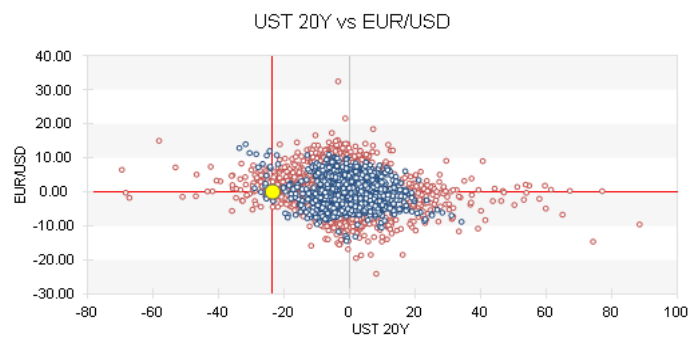
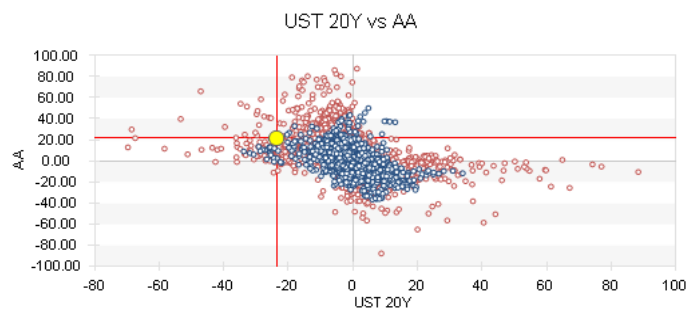
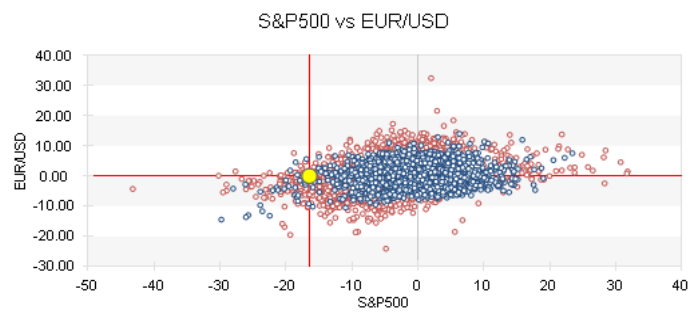
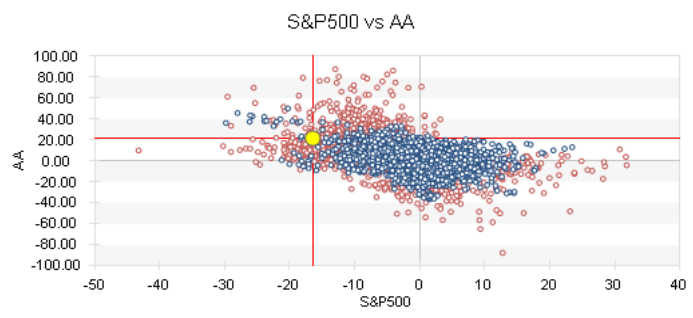
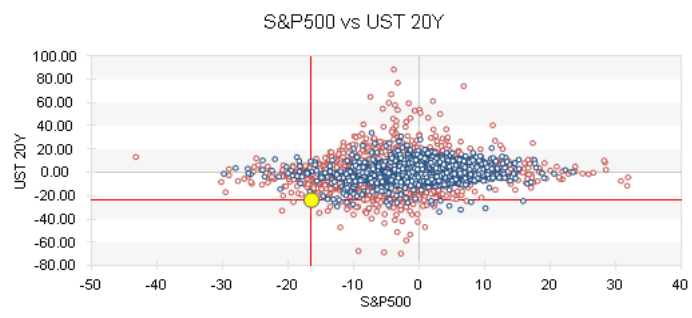
### Parameters

Number of buckets:

### Core Risk Drivers



Selected point: [22.08.2011](#)  
**S&P500:** -16.45%  
**UST 20Y:** -23.66%  
**AA:** 21.50%  
**EUR/USD:** -0.01%  
  
Filter:   
Loss Level: 5.6



○ Historical data ○ Scenario data

○ Historical data ○ Scenario data

## Prognoz.Market Risk

PROGNOZ

### Scenario parameters

**S&P 500:** 1218 --> 1018 (-200)

Scenario value, %: -16.45

---

**UST 20Y:** 2.73% --> 2.08% (-65 bp)

Scenario value, %: -23.66

---

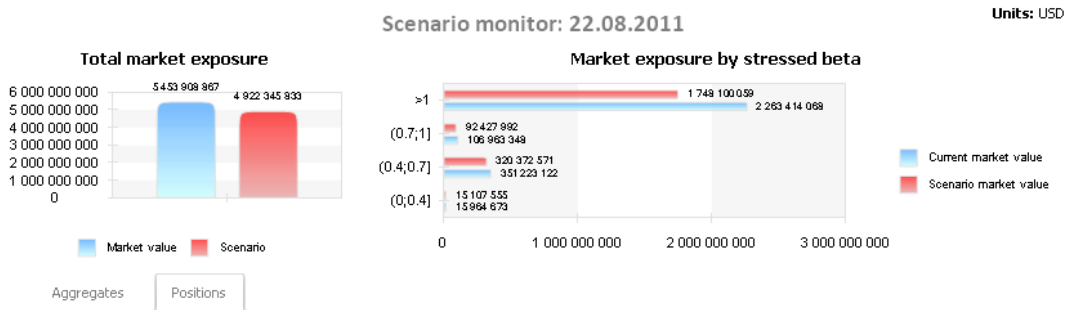
**AA Spread:** 114 bp --> 139 bp (+25 bp)

Scenario value, %: 21.50

---

**EUR/USD:** 1.3703 --> 1.3702 (-0.0001)

Scenario value, %: -0.01



Security	Sector	Credit Rating	Beta	Market Value, USD	Scenario Market Value, USD	P&L, USD	P&L, %
<b>Portfolio</b>				<b>1.25</b>	<b>5 453 908 867</b>	<b>4 922 345 833</b> ↓	<b>-531563034</b> ↓ <b>-9.75%</b>
ABBOTT LABORATORIES	Health Care	AA	0.48	31 929 351	29 418 113	-2 511 238	-7.86
AMAZON.COM INC	Consumer Discretion...	A	0.80	7 982 413	6 925 929	-1 056 484	-13.24
AMERICAN ELECTRIC POWER	Utilities	BBB	1.07	63 858 744	52 644 573	-11 214 172	-17.56
APPLE INC	Information Technology	NR	0.98	15 964 641	13 397 187	-2 567 453	-16.08
AT&T INC	Telecommunication...	A	0.54	47 894 059	43 650 756	-4 243 303	-8.86
BANK OF AMERICA CORP	Financials	A	1.45	319 293 755	243 342 989	-75 950 766	-23.79
BOEING CO/THE	Industrials	A	1.24	227 010 731	180 601 847	-46 408 884	-20.44
Bank of America 5.625 07/01/20...	Financials	A	0.86	103 531 000	114 133 573	10 602 573	10.24
Barclays 5.2 07/10/2014	Financials	AA	1.00	110 050 000	109 001 741	-1 048 259	-0.95
Brazil 7.125 01/20/2037	Government	BBB	0.68	122 700 000	128 860 468	6 160 468	5.02
CATERPILLAR INC	Industrials	A	1.72	284 381 887	204 084 392	-80 297 496	-28.24
CHEVRON CORP	Energy	AA	1.13	47 894 052	39 017 109	-8 876 944	-18.53
CITIGROUP INC	Financials	A	1.76	266 318 629	189 343 225	-76 975 403	-28.90
COCA-COLA CO/THE	Consumer Staples	A	0.61	23 947 035	21 543 203	-2 403 832	-10.04
COMCAST CORP-CLASS A	Consumer Discretion...	BBB	1.09	95 788 129	78 660 221	-17 127 907	-17.88
Canada 2.375 09/10/2014	Government	AAA	0.87	104 378 000	100 758 908	-3 619 092	-3.47
DU PONT (E.I.) DE NEMOURS	Materials	A	1.35	258 786 877	201 166 442	-57 620 435	-22.27
EXELON CORP	Utilities	BBB	1.26	243 126 860	192 787 490	-50 339 370	-20.70
EXXON MOBIL CORP	Energy	AAA	0.59	15 964 727	14 408 815	-1 555 912	-9.75
GENERAL ELECTRIC CO	Industrials	AA	1.26	215 116 876	170 564 543	-44 552 332	-20.71
GOOGLE INC-CL A	Information Technology	AA	0.71	3 192 887	2 817 383	-375 504	-11.76
Goldman Sachs 5 10/01/2014	Financials	A	0.86	107 266 000	108 016 872	750 872	0.70
Hartford 5.375 03/15/2017	Financials	BBB	0.68	106 899 000	108 829 602	1 930 602	1.81
Hungary 6.375 03/29/2021	Government	BBB	0.68	105 000 000	113 764 429	8 764 429	8.35
IBM 5.7 09/14/2017	Information Technology	A	0.86	117 400 000	113 685 017	-3 714 983	-3.16
INTL BUSINESS MACHINES C...	Information Technology	A	0.95	15 964 657	13 466 124	-2 498 533	-15.65
Israel 5.125 03/26/2019	Government	A	0.86	108 183 000	110 477 439	2 294 439	2.12
Italy 5.25 09/20/2016	Government	A	0.86	109 718 000	110 709 965	991 965	0.90

### Health monitor

**P&L:** -532 mln. USD  
**P&L, %:** -9.75  
**Loss Limit, %:** 10.0

---

**Liquid assets:** 4 922 mln. USD  
**30d net outflow:** 4 850 mln. USD  
**LCR, %:** 98.53  
**Limit, %:** 100.0

---

**Capital:** 1 000 mln. USD  
**RWA:** 5 800 mln. USD  
**Capital Ratio, %:** 8.08  
**Limit, %:** 8.0

Reset

Questions?

Thank you  
for your attention

[efremova@prognoz.ru](mailto:efremova@prognoz.ru)