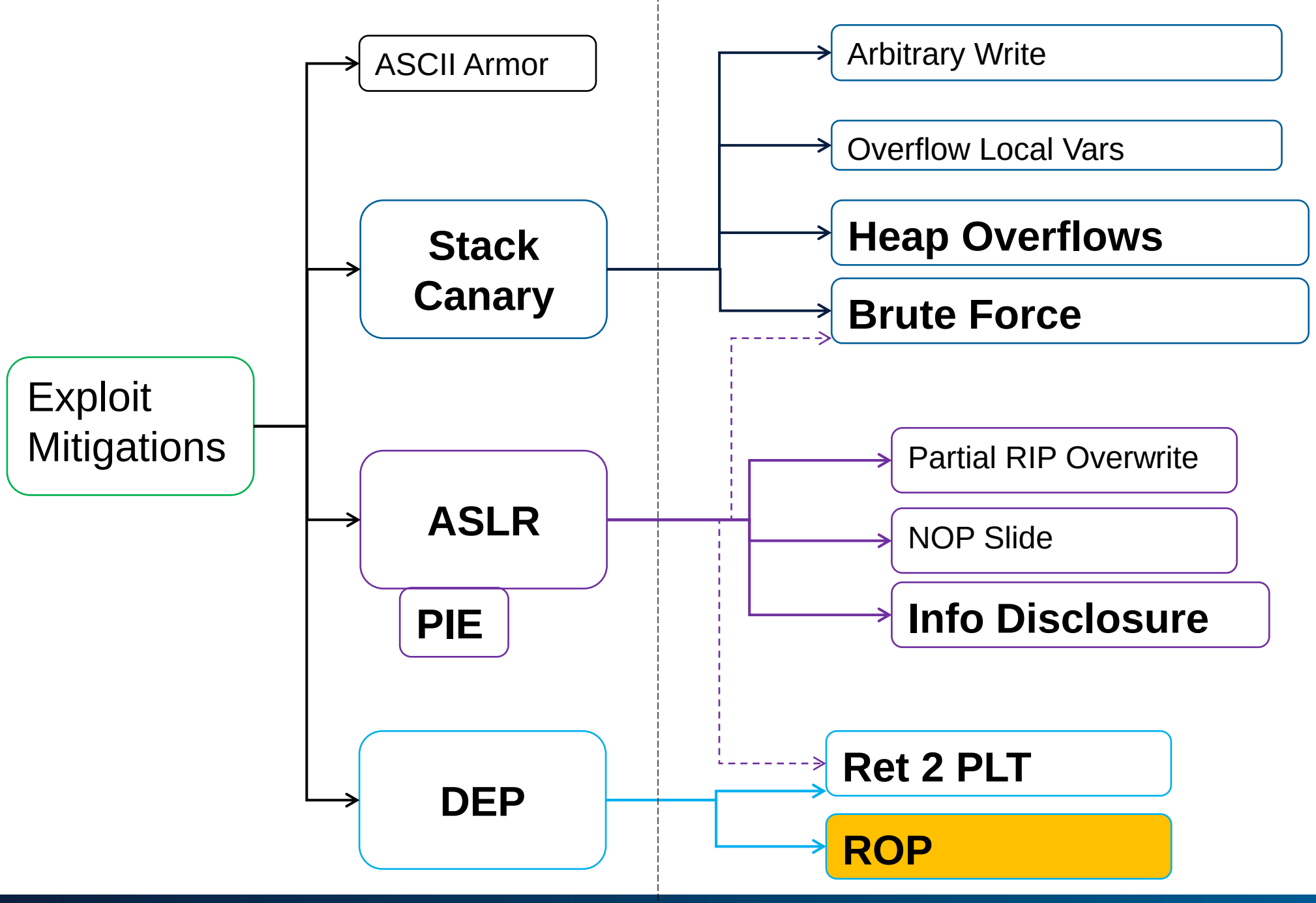
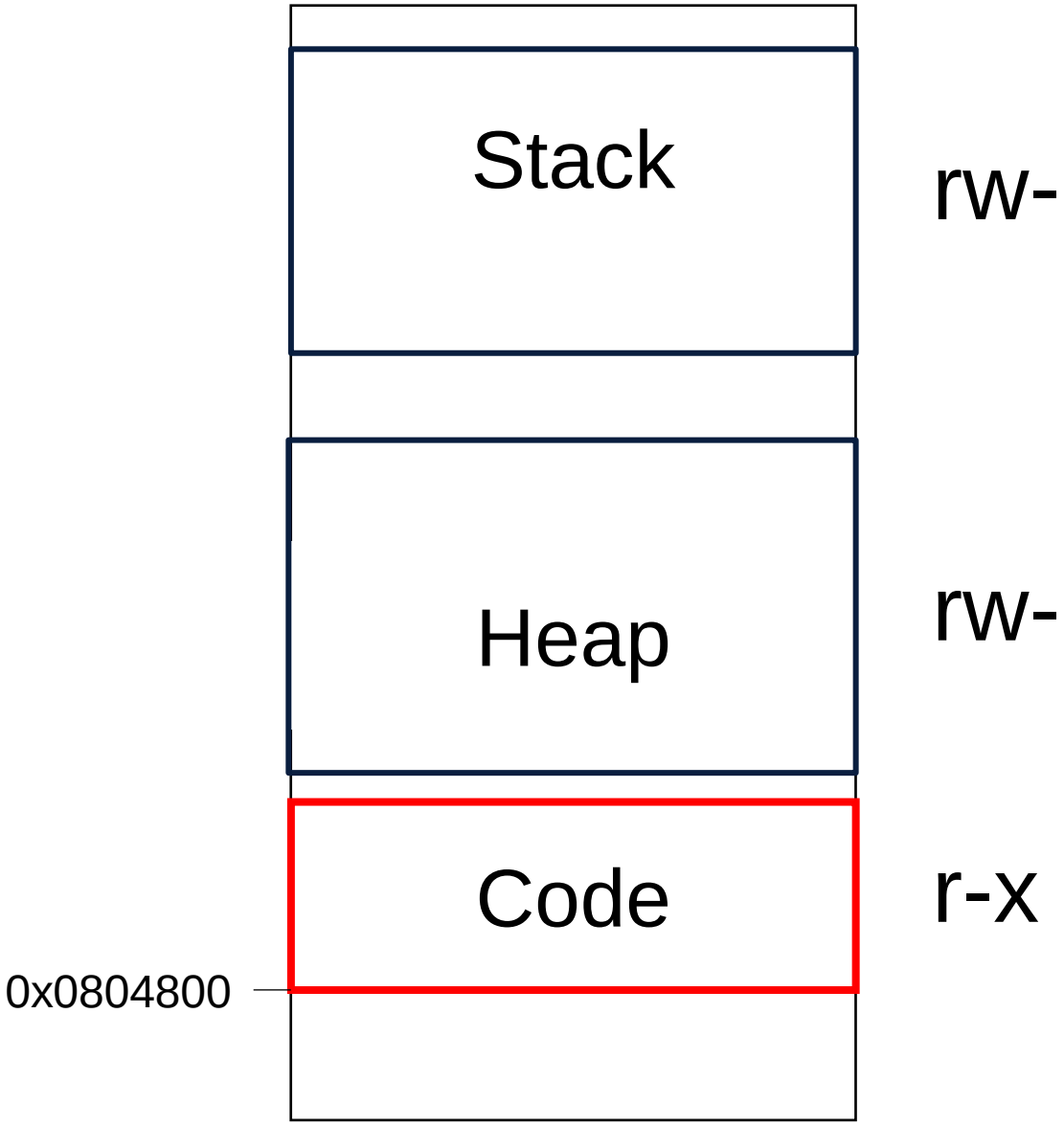
Return Oriented Programming

ROP


Exploit Mitigations
ASCII Armor
Stack Canary
ASLR
PIE
DEP
Arbitrary Write
Overflow Local Vars
Heap Overflows
Brute Force
Partial RIP Overwrite
NOP Slide
Info Disclosure
Ret 2 PLT
ROP

Exploiting: DEP - Memory Layout



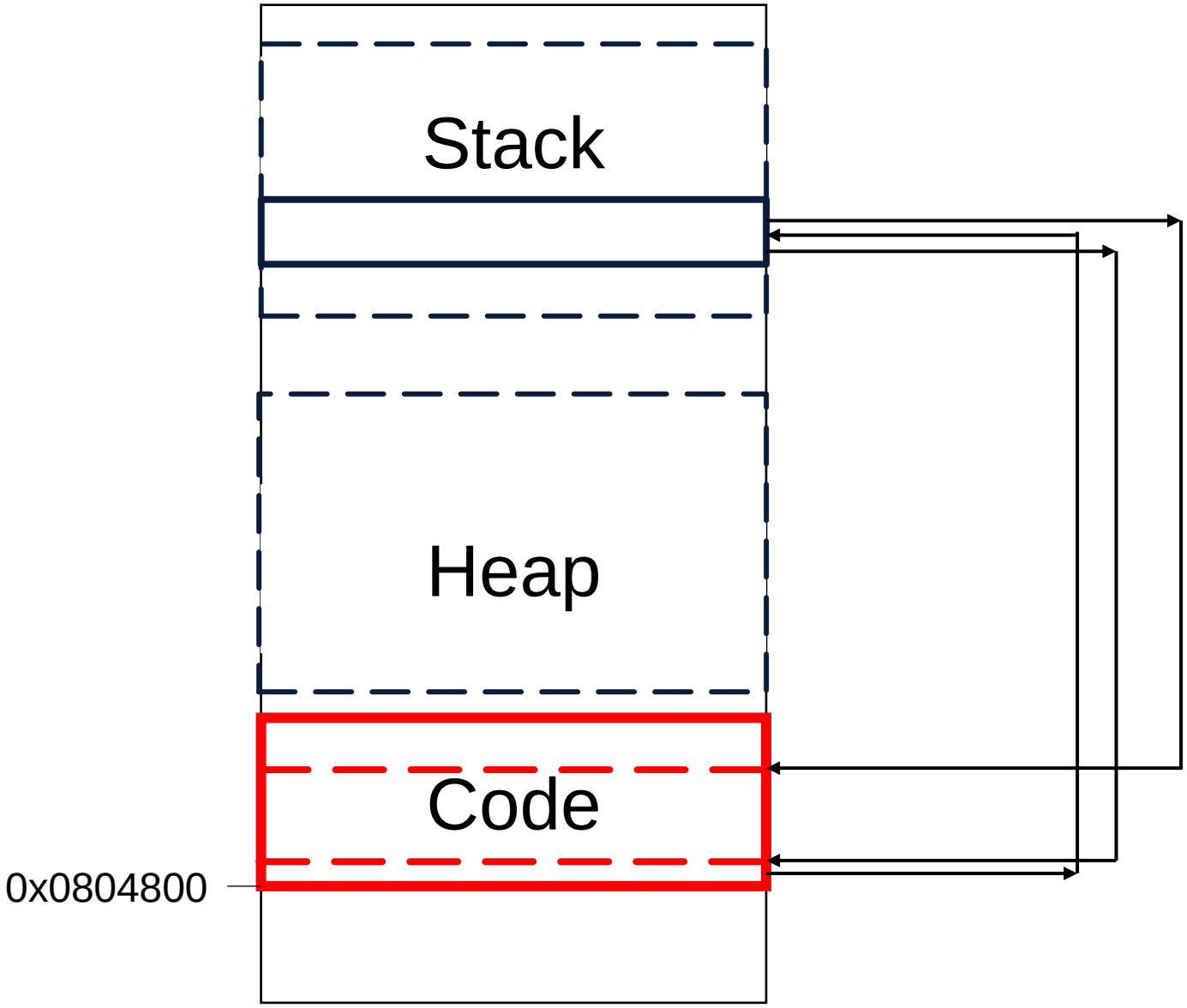
Exploiting: DEP - ROP

DEP does not allow execution of uploaded code

But what about **existing code**?

ROP: smartly put together existing code

Exploiting: DEP - Memory Layout

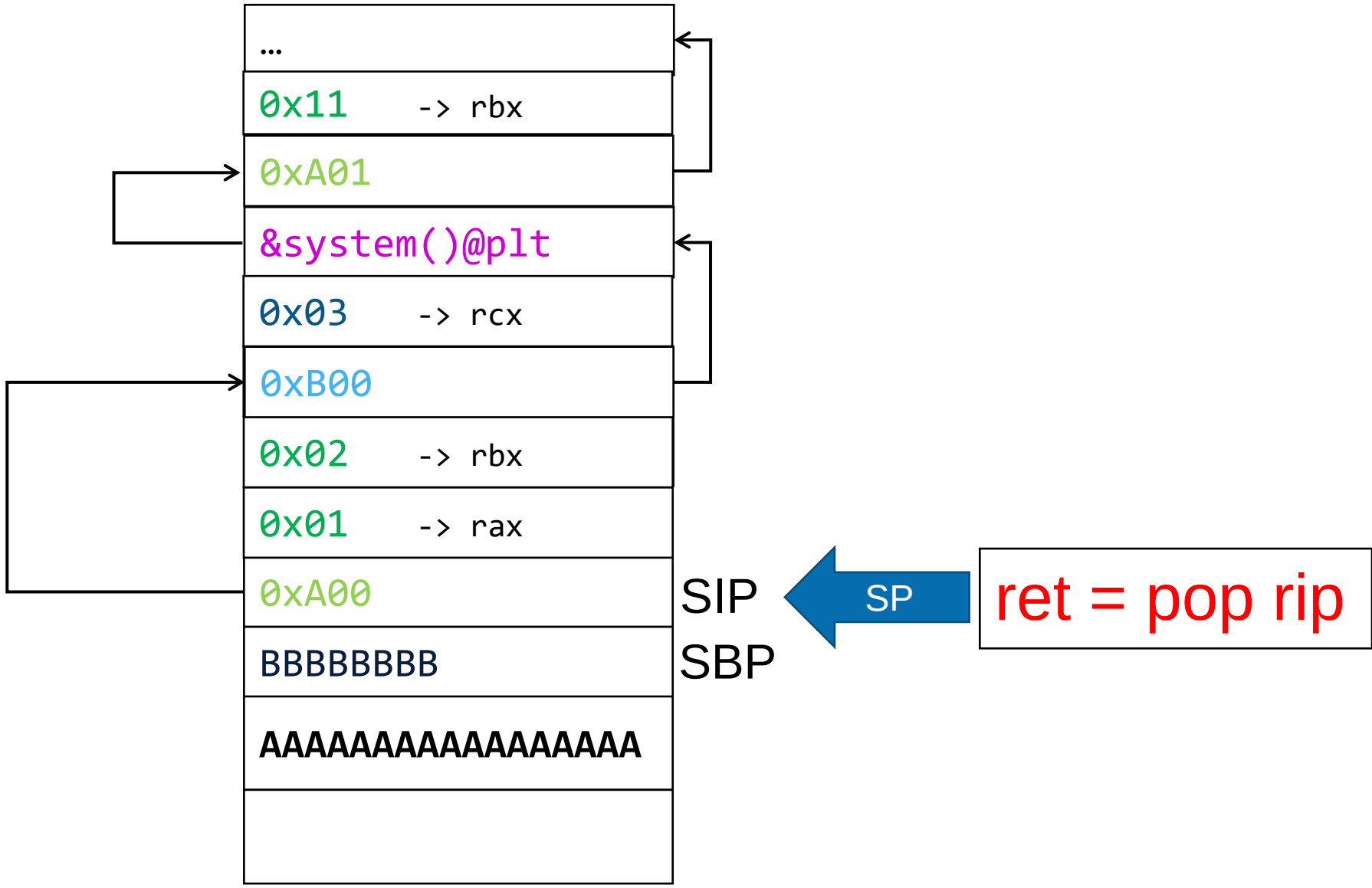


ROP In One Slide

ROP in 2 slides

```
0xB00: pop rcx
0xB01: ret
```

```
0xA00: pop rax
0xA01: pop rbx
0xA02: ret
```



ROP in 2 slides

```
payload = "AAAAAAAAAAAAAAAA"

payload += p64 (0xBBBBBBBB)
payload += p64 (0xA00)   # written on SIP
payload += p64 (0x01)
payload += p64 (0x02)
payload += p64 (0xB00)
payload += p64 (0x03)
payload += p64 (&system()@plt)
payload += p64 (0xA01)
payload += p64 (0x11)
payload += ...

print(payload)
```

ROP

Gadgets

Exploiting DEP - ROP

What is ROP?

Smartly chain gadgets together to execute arbitrary code

Gadgets:

- Some sequence of code, followed by a RET

Exploiting: DEP – ROP - Gadgets

So, what is are gadgets?

- Code sequence followed by a “ret”

```
pop r15 ; ret

add byte ptr [rcx], al ; ret

dec ecx ; ret
```

Exploiting: DEP – ROP - Gadgets

```
add byte ptr [rax], al ; add bl, dh ; ret
add byte ptr [rax], al ; add byte ptr [rax], al ; ret
add byte ptr [rax], al ; add cl, cl ; ret
add byte ptr [rax], al ; add rsp, 8 ; ret
add byte ptr [rax], al ; jmp 0x400839
add byte ptr [rax], al ; leave ; ret
add byte ptr [rax], al ; pop rbp ; ret
add byte ptr [rax], al ; ret
add byte ptr [rcx], al ; ret
add cl, cl ; ret
add eax, 0x20087e ; add ebx, esi ; ret
add eax, 0xb8 ; add cl, cl ; ret
add ebx, esi ; ret
```

Exploiting: DEP – ROP - Gadgets

How to find gadgets?

- Search in code section for byte 0xc3 (=ret)
- Go backwards, and decode each byte
- For each byte:
  - Check if it is a valid x32 instruction
  - If yes: add gadget, and continue
  - If no: continue

80 00 51 02 80 31 60 00 0e 05 **c3** 20 07 dd da 23

Exploiting: DEP – ROP - Gadgets

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Exploiting: DEP – ROP - Gadgets

There will be gadgets which were not created by the compiler

- x86 instructions are not static size
- 1-15bytes
  - Unlike RISC (usually 4 byte size)
- Start parsing at the “wrong offset”

Exploiting: DEP – ROP - Gadgets

Why ret?

ret = pop eip

It "jumps" to the address at the stack location %rsp
It removes that element from the stack

64 bit ROP By Example

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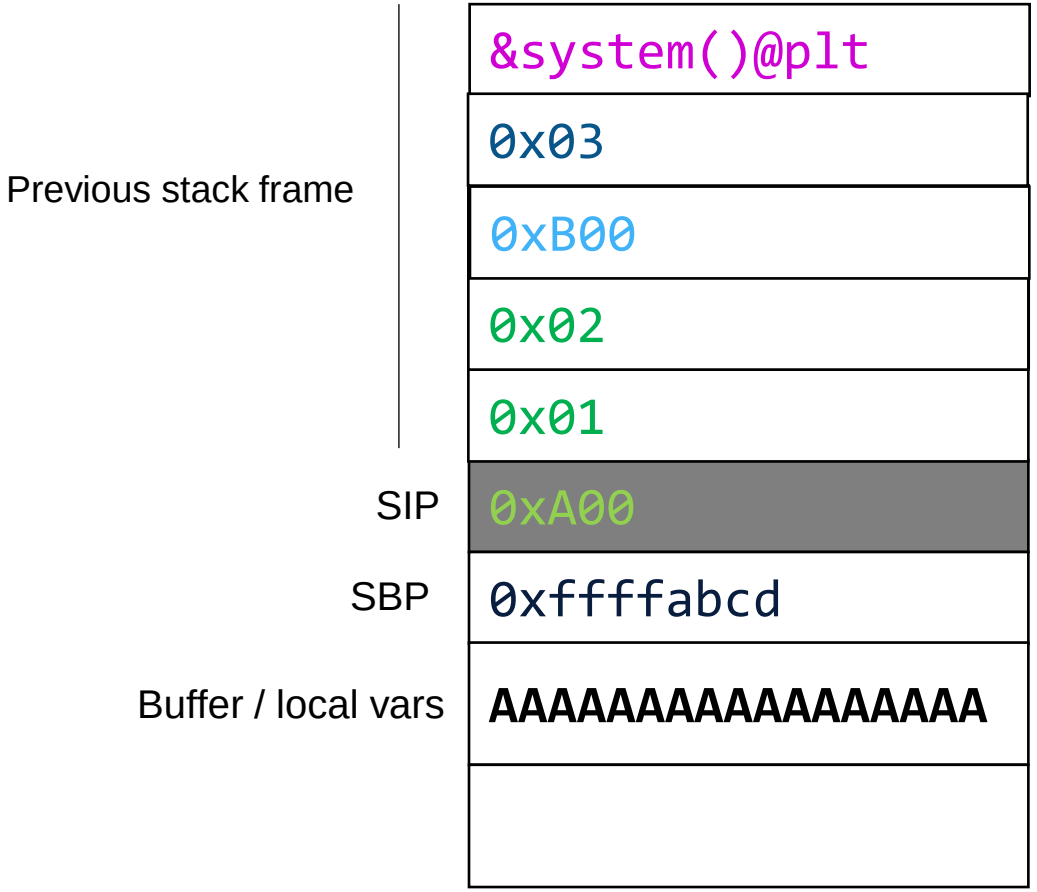
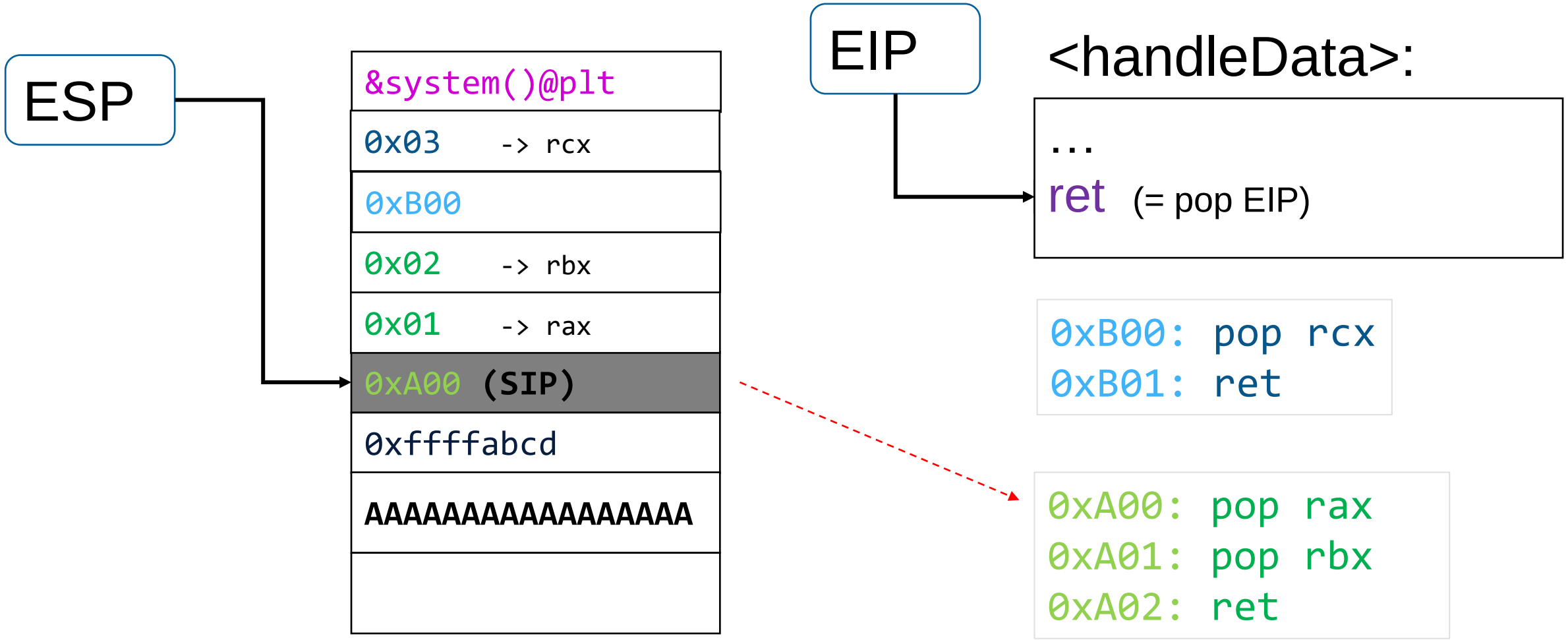
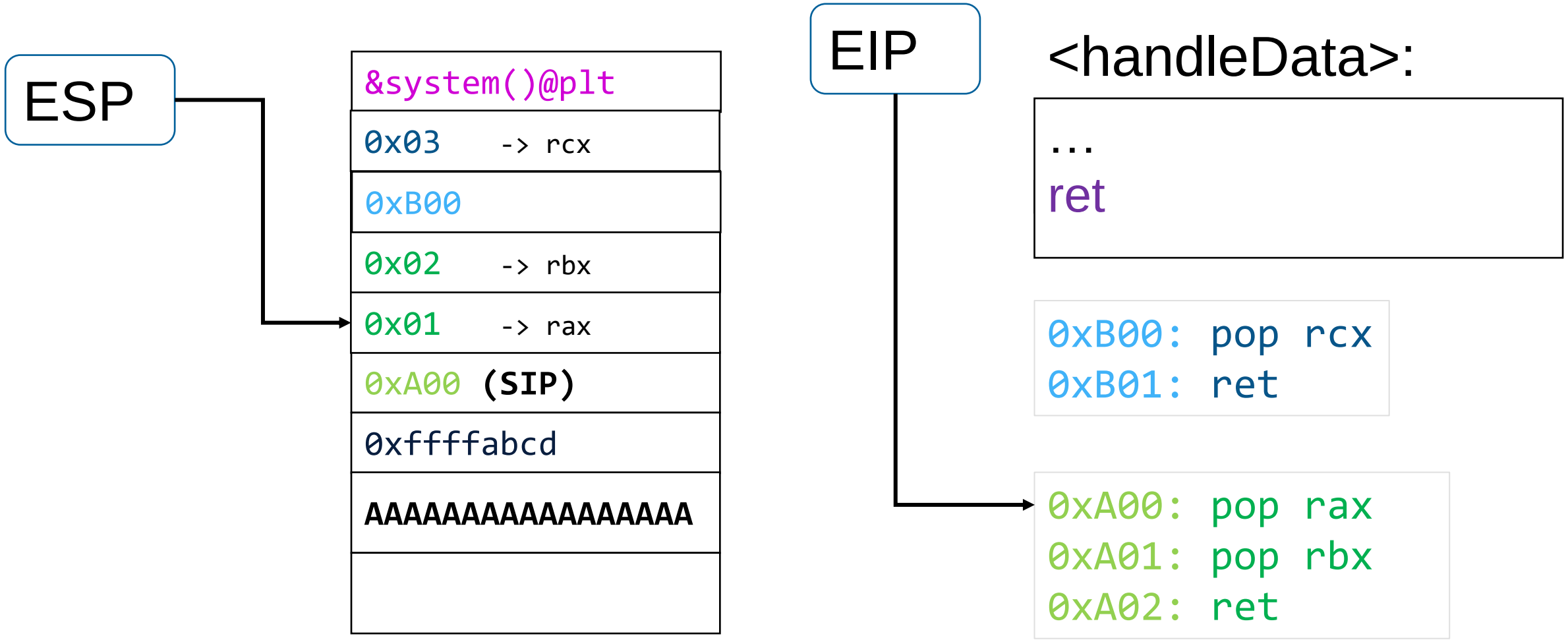


View of the stack
After stack overflow
Before ret

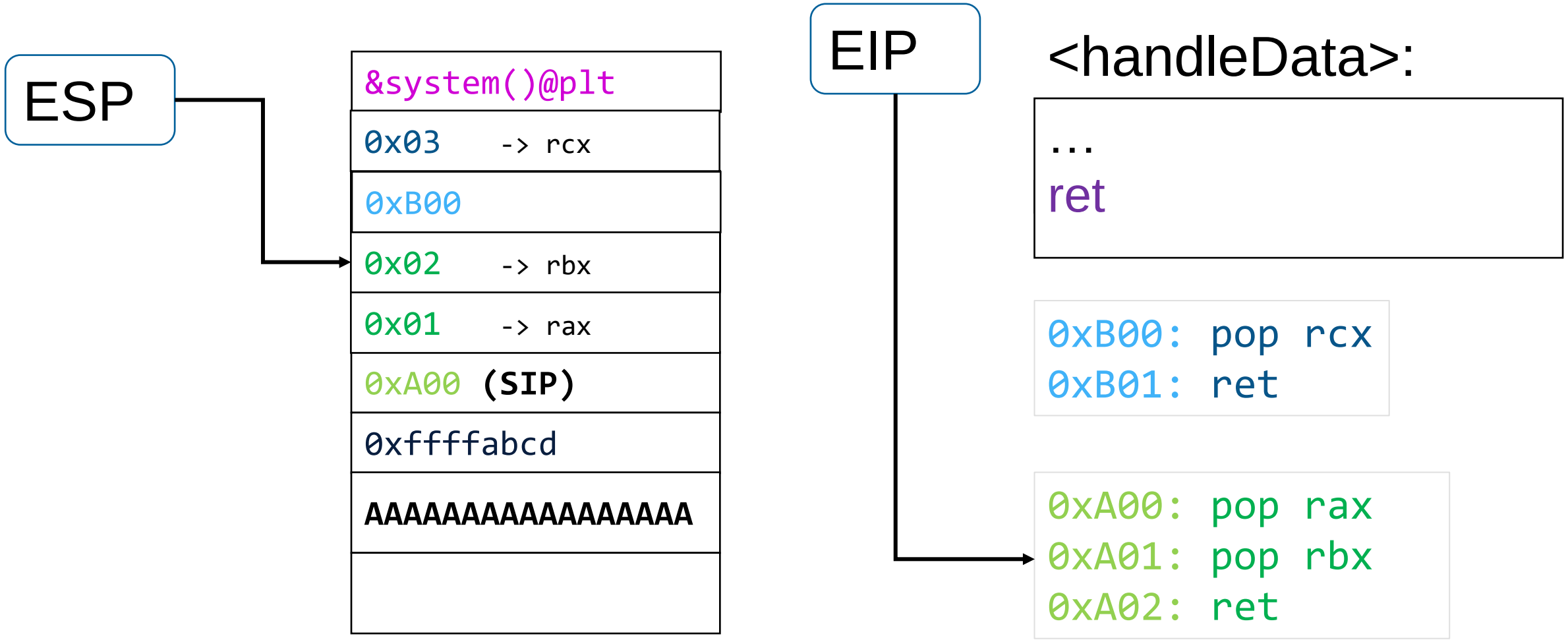
64 bit ROP By Example



64 bit ROP By Example



64 bit ROP By Example



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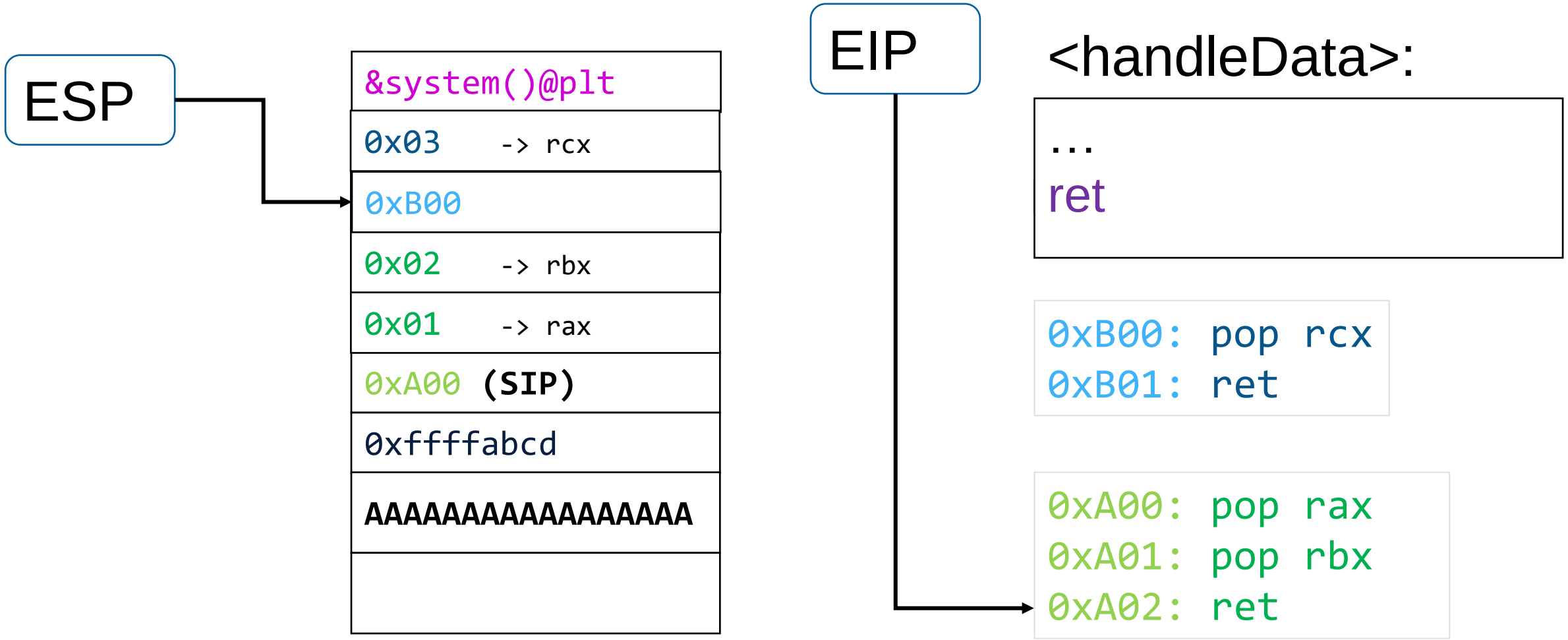
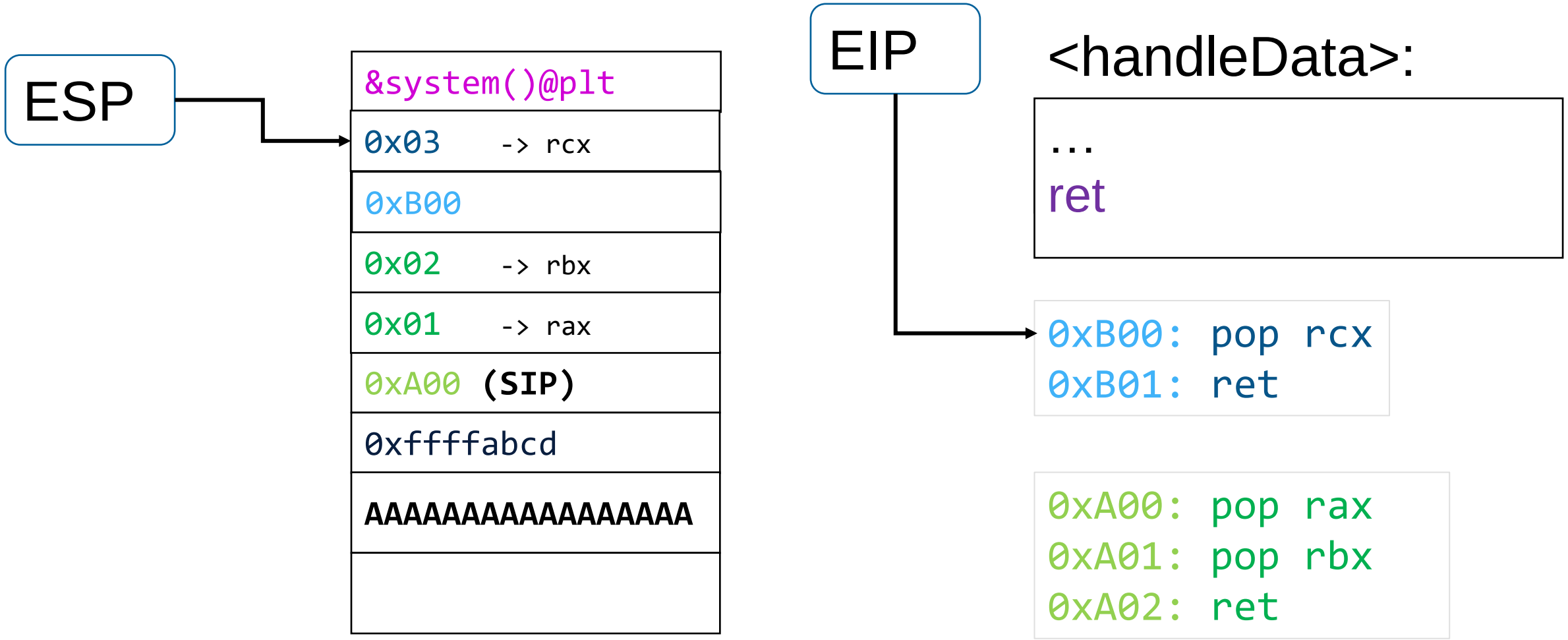
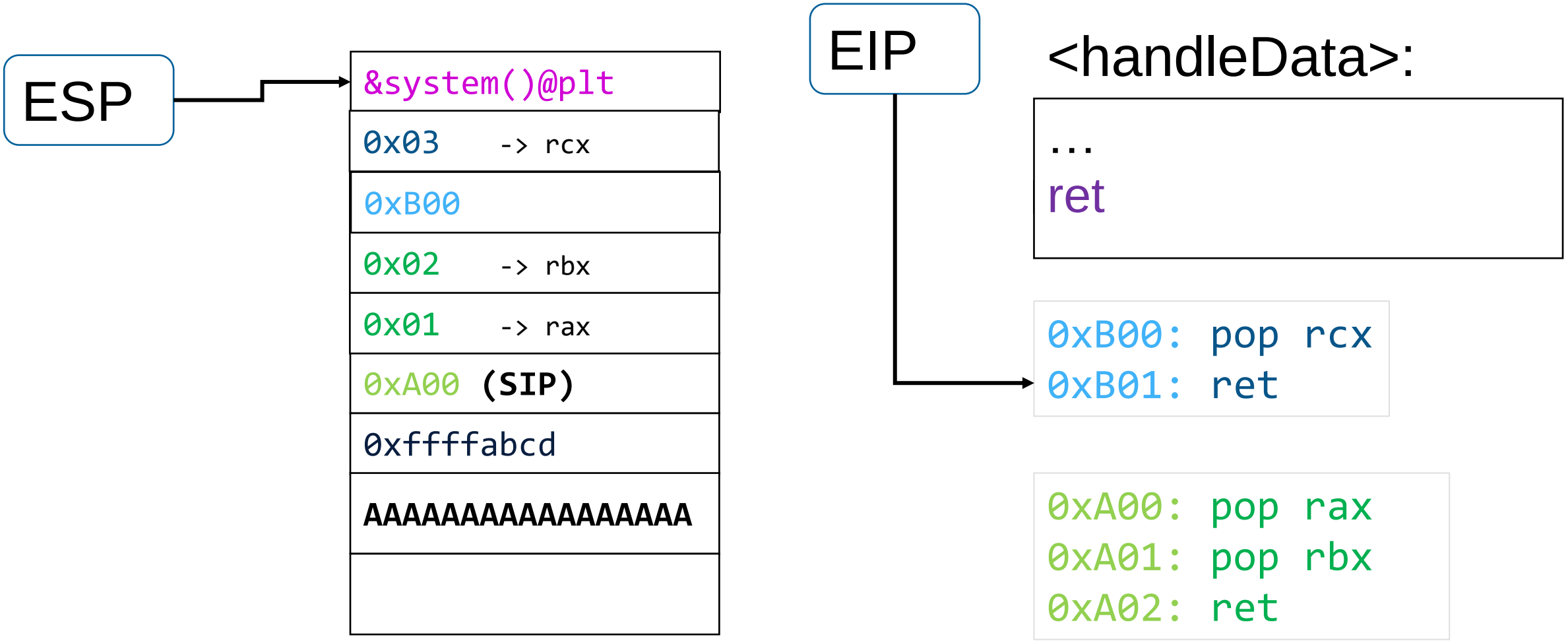


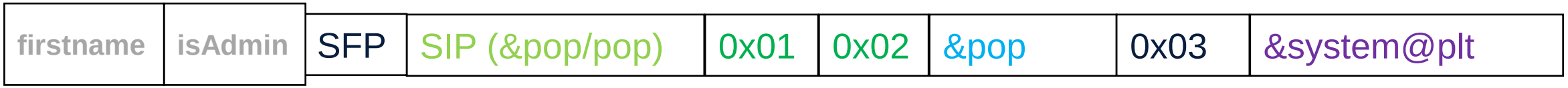
64 bit ROP By Example



64 bit ROP By Example



64 bit ROP By Example



Stack grows down

Writes go up

ROP By Example

call/ret’s can be chained!

Arbitrary code execution with no code uploaded

“Shellcode” consists of:

- Addresses of gadgets
- Arguments for gadgets (addresses, or immediates)
- NOT: assembler instructions

Finding gadgets: ropper

$ **ropper**
(ropper)> **file challenge16**
[INFO] Load gadgets from cache
[LOAD] loading... 100%
[LOAD] removing double gadgets... 100%
[INFO] File loaded.

(challenge16/ELF/x86_64)> **search pop rbx;**
[INFO] Searching for gadgets: pop rbx;

[INFO] File: challenge16
0x000000000044b431: pop rbx; adc eax, 0xc6e8fffd; ret 0xfffc;
0x000000000047f177: pop rbx; add rax, qword ptr [rdx + 8]; pop rbp; pop r12; jmp rax;
0x00000000004492a6: pop rbx; and eax, 0x7ff80000; ret;
0x000000000046be26: pop rbx; and eax, 0xc; pop rbp; pop r12; ret;
0x00000000004491fb: pop rbx; cmove rax, rdx; ret;
0x000000000044928b: pop rbx; cmovne rax, rdx; ret;
0x000000000415af5: pop rbx; jmp rax;

ROP: Conclusion

ROP: Conclusion

Ret2libc / ret2got / ret2plt

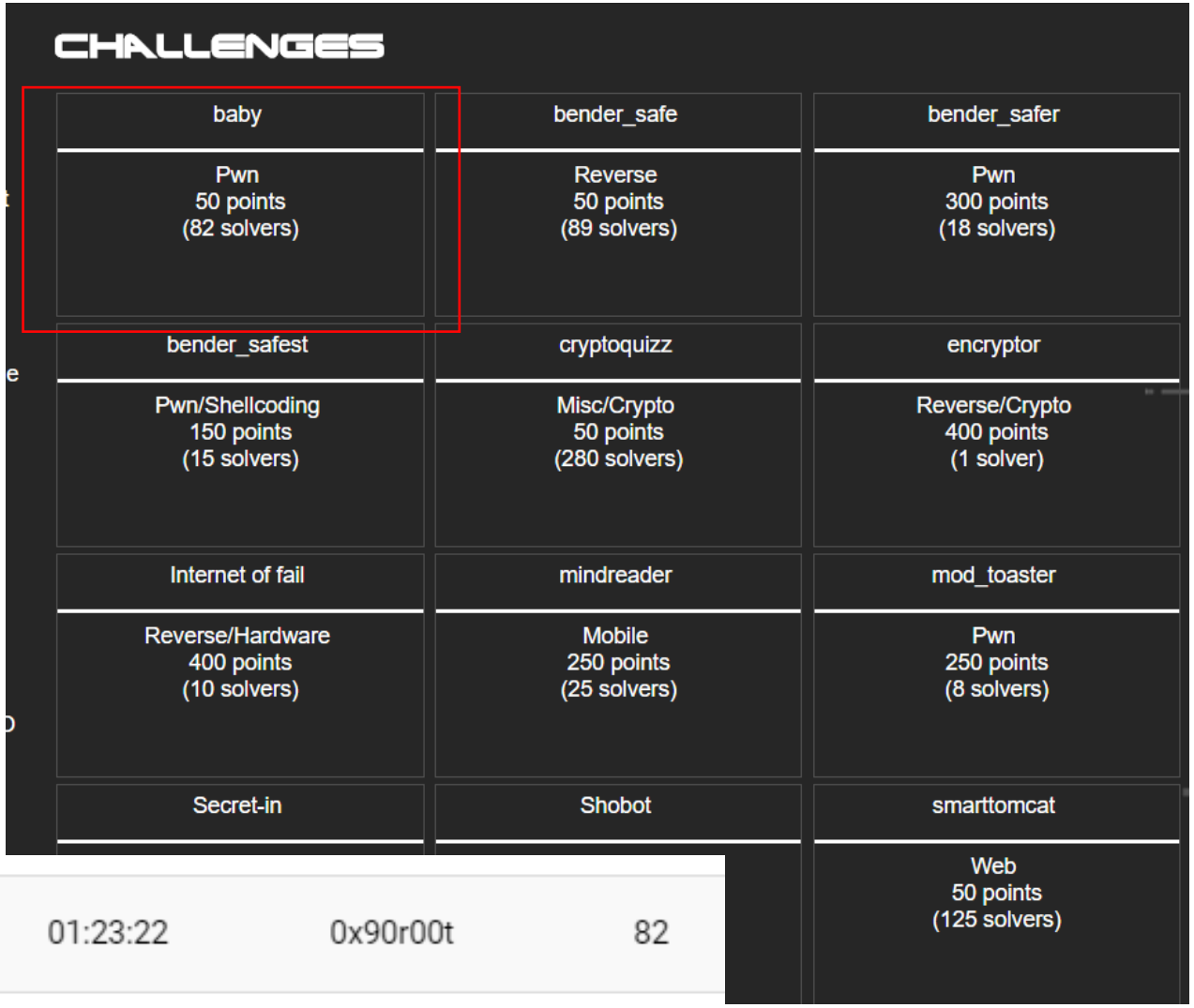
- Is “only” able to execute arbitrary library functions

ROP

- Can execute arbitrary code by re-using existing code from program or shared libraries
- Can defeat often ASLR + DEP
- Can defeat ASLR+DEP+PIE, with information disclosure

Insomnihack Teaser

- Insomnihack: Security Conference in Geneva
- Got a Teaser CTF (Capture the Flag)
- Baby challenge:
  - Forking Server
  - 64 bit
  - ASLR
  - PIE
  - Stack Canary



baby	Pwn	50	01:23:22	0x90r00t	82